The London School of Economics and Political Science

London Office Performance: Determinants and Measurement of Capital Returns

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Thesis submitted to the Department of Geography and Environment of the London School of Economics and Political Science for the degree of Doctor of Philosophy, London, May 2013.

Declaration

I certify that this thesis presented for examination for the PhD degree of the London School of Economics and Political Science is solely my own work other than where I have clearly indicated that it is the work of others. There is no joint work contained herein, nor work submitted for the attainment of a previous degree, nor has a third party been utilized for editorial purposes.

I declare that my thesis consists of 60,333 words in 233 pages; including footnotes but excluding appendices, bibliographies, and prefatory statements.

Acknowledgements

If a community is required to raise a child then no less than a small city is demanded by a thesis. Although I could not possibly name everyone who has contributed to this work anymore than I could affix a phonebook to this page, I shall try with some degree of failure to name those people and organisations which have had an especially large and predominately positive influence. Without a hint of irony the author would like to thank Paul Cheshire, Christian Hilber, Steve Gibbons, Elaine Gascoyne, Samuel Sebba, Gavin Murgatroyd, Gardiner & Theobald, Wenjie Wu, Landmark Information Group, Adam Ozimek, Transport for London, City of London Police, City of London Planning Department, Mayor of London, Google Maps, Derrick Reed, Hannah Lakey, Theresa Keogh, Joseph Kelly, Alessandra Scandura, Kerwin Datu, Rosa Sanchis-Guarner, Alejandra Castrodad-Rodriguez, Sejeong Ha, Prabhjot Babra, Phil Hammond, Steve Waterman, Christina Burbanks, Nick Price, Wai Sau Chan, Marc Espinet, Stephen Jenkins, Thomson-Reuters, Bloomberg, the FTSE Group, Investment Property Databank, Property Market Analysis UK Ltd, Real Capital Analytics, and Estates Gazette.

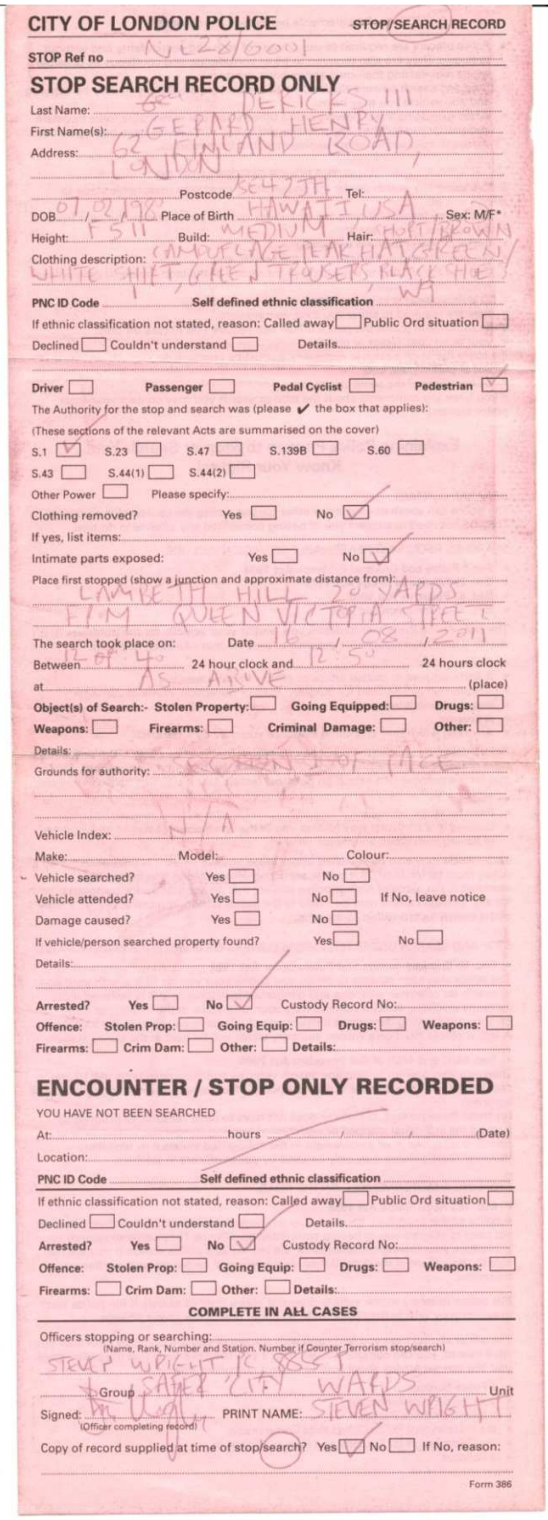
Friends and family come first, except in acknowledgement. Kun Lung Wu, Matt Baker, Shen Husain, ALW, Robert and Karen Allen, Anne, Beebe, Dash, Nunu, and of course Mom and Dad, without each of you none of this would have been possible and I dare say worth it. This thesis is dedicated you.

Preamble

While collecting office building data on foot on August 16th 2011, the author's activities were relayed to the City of London police by suspicious security at 99 Queen Victoria Street, at which point he was intercepted for search and questioning. In spite of the benign nature of his activities[1] he was informed by the police that he only very narrowly escaped arrest by fortune of possessing in person an old letter addressed to him from LSE which corroborated his status as a research student. It is the author's sincere wish that in future research students need not expose themselves to imprisonment and deportation in order to fulfil their degree requirements.

[1] Econometrics is mostly harmless (Angrist and Pischke, 2009) and occasionally even helpful.

Figure 1: Stop and Search Record



CITY OF LONDON POLICE — STOP/SEARCH RECORD

STOP Ref no: NL28/6001

STOP SEARCH RECORD ONLY

Last Name: DERICKS III

First Name(s): GERARD HENRY

Address: 62 FINLAND ROAD, LONDON

Postcode: SE4 2JH   Tel:

DOB: 07/02/1982   Place of Birth: HAWAII USA   Sex: M/F*

Height: 5'11   Build: MEDIUM   Hair:

Clothing description: CAMOUFLAGE PEAK HAT, GREEN/WHITE SHIRT, GREEN TROUSERS, BLACK SHOE

PNC ID Code   Self defined ethnic classification: W1

If ethnic classification not stated, reason: Called away ☐ Public Ord situation ☐

Declined ☐ Couldn't understand ☐ Details

Driver ☐ Passenger ☐ Pedal Cyclist ☐ Pedestrian ☑

The Authority for the stop and search was (please ✔ the box that applies):

(These sections of the relevant Acts are summarised on the cover)

S.1 ☑ S.23 ☐ S.47 ☐ S.139B ☐ S.60 ☐

S.43 ☐ S.44(1) ☐ S.44(2) ☐

Other Power ☐ Please specify:

Clothing removed? Yes ☐ No ☑

If yes, list items:

Intimate parts exposed: Yes ☐ No ☑

Place first stopped (show a junction and approximate distance from): LAMBETH HILL 20 YARDS FROM QUEEN VICTORIA STREET

The search took place on: Date 16/08/2011

Between 12:40 24 hour clock and 12:50 24 hours clock

at AS ABOVE (place)

Object(s) of Search:- Stolen Property: ☐ Going Equipped: ☐ Drugs: ☐

Weapons: ☐ Firearms: ☐ Criminal Damage: ☐ Other: ☐

Details:

Grounds for authority: SECTION 1 OF PACE

Vehicle Index: N/A

Make: Model: Colour:

Vehicle searched? Yes ☐ No ☐

Vehicle attended? Yes ☐ No ☐ If No, leave notice

Damage caused? Yes ☐ No ☐

If vehicle/person searched property found? Yes ☐ No ☐

Details:

Arrested? Yes ☐ No ☑ Custody Record No:

Offence: Stolen Prop: ☐ Going Equip: ☐ Drugs: ☐ Weapons: ☐

Firearms: ☐ Crim Dam: ☐ Other: ☐ Details:

ENCOUNTER / STOP ONLY RECORDED

YOU HAVE NOT BEEN SEARCHED

At: hours / / (Date)

Location:

PNC ID Code   Self defined ethnic classification

If ethnic classification not stated, reason: Called away ☐ Public Ord situation ☐

Declined ☐ Couldn't understand ☐ Details

Arrested? Yes ☐ No ☑ Custody Record No:

Offence: Stolen Prop: ☐ Going Equip: ☐ Drugs: ☐ Weapons: ☐

Firearms: ☐ Crim Dam: ☐ Other: ☐ Details:

COMPLETE IN ALL CASES

Officers stopping or searching: (Name, Rank, Number and Station. Number if Counter Terrorism stop/search)

STEVEN WRIGHT PC 855

Group SAFER CITY WARDS Unit

Signed: (Officer completing record)   PRINT NAME: STEVEN WRIGHT

Copy of record supplied at time of stop/search? Yes ☑ No ☐ If No, reason:

Form 386

Thesis Abstract

This thesis develops three chapters which extend our understanding of asset performance within the London office market by analysing the determinants and measurement of capital returns. The first chapter examines whether enlisting the services of a star-architect allows developers to persuade city planners to build bigger within the tightly regulated London property market, and therefore to engage in rent-seeking behaviour. We find that outside protected conservation areas famous architects can not only build taller, but that their designs have no effect on building sale prices holding the amount of space constant. For a given land plot however, the ability to build taller increases total floorspace and developer profits even when accounting for the increased costs of hiring a famous architect and building to their higher standards. The second chapter investigates potential sources of bias in commercial repeat-sales price indices by constructing such an index for the central London office market and examining the sources of index change relative to the underlying market. We find evidence that employment density changes and the restrictiveness of new development in the relevant local authority are key external drivers of bias on estimated price levels. This discrepancy arises because repeat-sales occur disproportionately in areas where changes in these attributes differ relative to the stock as a whole. The third chapter presents a comparison of seven competing real estate price index construction methodologies in the London office market. This exercise sheds light on the history of London office market returns from 1998-2010, and the relative pros and cons of the major index construction methods utilized by research and industry. This comparison also reveals substantial differences between indices in the timing of market turning points and various descriptive statistics, and demonstrates that the hedonic model outperforms the repeat-sales index due to the greater inclusivity of sale observations.

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Thesis Introduction

In contrast to many other areas of the economy, research into commercial property is frequently hindered by the scarcity of large high quality datasets. As a result of this deficit, many questions germane to effective policy and economic efficiency remain poorly understood or altogether unanswered. In an effort to in part address these deficiencies, this thesis utilizes a unique dataset which combines primary data collection from office sites in London with secondary sale-transaction and building stock information from some of the most prominent property-data providers in London.

Data on the London office market is of particular interest because London is one of the world's premier financial and business centres, and while liquid and attracting high-profile investors from around the world, its real estate market is surprisingly opaque. This lack of transparency has often been cited as a critical barrier to the wider acceptance of real estate assets within the institutional investment community. Moreover, London is one of the world's most highly regulated land markets; with undevelopable encircling green belts, zoning and height restrictions, expensive and uncertain planning controls, and ubiquitous historic preservation. Therefore questions of political economy can not only be analysed with some diversity, but the answers to these questions are liable to have a direct and material impact on the welfare of some 8 million citizens.

This thesis aims to further our understanding of commercial real estate by analysing the drivers of capital returns in the London office market and the measurement issues which surround them. Asset performance is a crucial indicator for industry and precise and timely measurement is necessary for; benchmarking competition, transparency, revealing risk-adjusted profit opportunities, and efficient risk-sharing in derivatives markets. In the public sector, accurate price indices are an important bellwether for both central bank monetary policy and the assessment of market regulation. Furthermore, developing our understanding of real estate return drivers may make it possible to formulate policy which can improve the operation of the market and better respond to unanticipated economic shocks.

With these goals in mind, the first chapter of this thesis examines whether star architects are exceptionally allowed to build bigger office buildings in London, and therefore earn supernumerary returns on their land plots. Given that the extant literature has identified substantial economic rents generated by the strict land market regulations in force across London, this chapter extends the previous theoretical work of Krueger (1974) to test empirically whether famous architects are able to successfully engage in an aesthetic form of rent-seeking. Even though London currently sports some of the world's most eccentric office building designs, the extent to which these designs and the famous architects who create them are able to influence the planning process has hitherto been unexplored. This research finds that outside protected conservation areas famous architects can not only build taller (by 20 floors), but that their designs have no net effect upon the ultimate sale price per m^2 of buildings. For a given land plot however, the ability to build tall increases developer profits (by approximately 100%) even when accounting for the increased design fees charged by famous architects and building to their generally higher standards.

As such, famous architects are able to quite literally engage in rent-seeking by design. However, unlike the analysis of Krueger, for architecture on prominent public display, the competition for regulatory exemptions through design may generate social benefits in addition to the standard deadweight losses associated with competitive rent-seeking. The data used in this study also corroborates the previous findings of Cheshire and Hilber (2008) that the regulatory environment in London imposes substantial costs on the economic efficiency of the office market. However, the estimated magnitudes of these costs are notably smaller than those reported by Cheshire and Hilber, but it is likely that this discrepancy is due to categorical differences in the definition of building grades between the two papers, rather than mismeasured values.

The second chapter investigates potential sources of bias in repeat-sales price indices of commercial property by constructing such an index for the central London office market and examining the sources of index change relative to the market as a whole. Repeat-sales indices are essentially a fixed-effects modelling specification and therefore implicitly control for all constant building and locational characteristics when estimating price-levels. Since commercial property is relatively heterogeneous and often difficult to model explicitly, in recent years the repeat-sales method has grown in popularity and practice. However, because the repeat-sales method does not model locational characteristics explicitly, its validity is sensitive to external changes in the environment of sampled buildings that are not representative of the market as a whole. Although the problem of sample selection bias in repeat-sales has been well explored in the context of residential property, the literature has yet to examine the existence of bias in repeat-sales of commercial property or to empirically investigate the potential sources of bias in these indices. This section finds evidence for bias in a commercial repeat-sales index of London caused by employment density changes and the restrictiveness of new development in the governing local authority. This discrepancy arises because repeat-sales occur disproportionately in areas where changes in these price determinants differ systemically from the office stock as a whole.

The third chapter analyses seven competing price index construction methodologies used by research and industry between 1998-2010 for office property in London. In so doing, the relative advantages and limitations of these different indices with respect to commercial real estate can be better understood, and greater light can be shed upon the actual price movements experienced by London office property over this turbulent period. The indices produced are; valuations, unsmoothed valuations, a sophisticated hedonic model, repeat-sales, transaction-linked indices, real estate securities, and stock market equities. A comparison of these indices finds substantial differences between the valuation and transaction-based indices primarily related to inertia and dampened price movements, especially during the pronounced market oscillations experienced in the latter half of the 2000s. In addition, we find that the production of a hedonic time-series of commercial offices in London is not only feasible but likely to be superior to the more common method adopted by industry of repeat-sales. This result holds due to the reduction in effective sample size and the concomitant decrease in representativeness that occurs as a result of the need to exclude all property sales which do not occur in multiples over the study period. We can be confident in this result due to the introduction of a novel methodology for verifying the validity of our hedonic model: comparing the hedonic price index with a repeat-sales index consisting of the same sample of sales. With specific regard to repeat-sales, this paper finds that the 3SLS procedure conventionally used to correct for heteroskedasticity in housing is indistinguishable in commercial offices from an uncorrected OLS series.

Other notable findings include the fact that, contrary to previous research, real estate securities in the UK follow the movements of London office property more closely than the stock market as a whole, the method of desmoothing valuations introduced by Geltner (1993b) produces a mixed analogue to actual transaction-based series which could perhaps be improved with better calibration of the desmoothing parameter, and that the relatively new transaction-linked index methodology is extremely similar to its underlying uncorrected valuation index. Finally, this paper introduces an original fractional-time weighting procedure for repeat-sales that allows for simpler calculation of transformation-bias while maintaining a minimum of temporal aggregation bias.

This thesis continues in paper-based format with the first chapter analysing rent-seeking in the London office market through architectural design, followed by chapters on the sources of repeat-sales index bias in commercial office property, and then a comparison of commercial real estate index construction methodologies. The thesis then concludes with an overview of the results of these three research projects and suggests direction for future inquiry.

Chapter 1: License to build: rent-seeking by design

Abstract

This paper examines the conjecture first put forward by Cheshire and Hilber (2008) that city planners in London are willing to make special exemptions for developers to build larger and more expensive office buildings outside of conservation areas if they possess world-class design. Building development regulations in London are perhaps the most restrictive in the developed world, and enlisting a star-architect to persuade city planners to build bigger may be a profitable form of rent-seeking. This study confirms that famous architects are able to build bigger outside conservation areas because they can build taller. However the concession to build taller comes at the expense to the developer of increased construction and design costs, and results in a sale price per m^2 no greater than a standard building of similar quality. On net however, the increase in lettable floorspace from building tall 'overshadows' the subsequent increase in costs, and star-architects are able to erect buildings on a given plot of land which are more profitable compared to buildings which lack an eminent designer.

Introduction

"If you want to build a tall building, as long as you've got a world-class design and it is in one of two locations we will go along with it"[2]

Ken Livingstone, Mayor of London 2000-08.

London office towers make headlines worldwide with eccentric designs ranging from gherkins and cheese-graters to walkie-talkies and cans-of-ham. Although London has strict planning controls in place to monitor new and existing building developments, these restrictions are to a certain extent flexible and based on the discretion of local planners and politicians. The British use of the 'development control' mechanism to implement its planning system on a case by case basis, rather than a Master Plan or Zoning system, makes it possible in principle to obtain specific exceptions to these otherwise tight and binding regulations. Furthermore, there is now substantial evidence to suggest that supply restrictions across office (Cheshire and Hilber, 2008), retail (Cheshire et al, 2011) and residential (Hall et al, 1973; Evans, 1991; and Hilber and Vermeulen, 2010) property sectors in the United Kingdom are responsible for the creation of extensive market distortions, and these market distortions create the potential for savvy and organised market-actors to earn economic rents (Pennington, 2000). In a similar vein to Krueger's (1974) seminal paper on the welfare implications of rent-seeking in the context of import licensing, the combination of semi-binding land-use controls and economic rents in London has meant that developers who can convince planning authorities to permit tall building designs can earn excess profits on their land investments. While the competition for such permits is by all accounts a deadweight social loss, unlike the case of Krueger, in the present context leveraging architectural design to exact special privileges may in fact lead to some ancillary social benefits in the form of better public architecture. This paper examines whether commercial office buildings in London designed and built by famous architects are able to exceptionally exploit the flexibility of the planning system in order to

[2] The Observer, October 1st 2006, "High Hopes: 'London will soon have 18-20 skyscrapers'". http://www.guardian.co.uk/business/2006/oct/01/politics.greaterlondonauthority1, accessed July 18th 2012. The two locations Ken Livingsone is likely referring to is the City of London and Canary Wharf.

build larger buildings on a given plot of land, and to sell buildings for more compared to offices which lack an accomplished designer.

The London office market

London is perhaps the world's premier financial centre attracting both international office occupiers and investors[3]. Its office market is frequently ranked as the world's most expensive and has one of the highest turnover rates in the world[4]: containing nearly 20 million m^2 of office space over 55 square kilometres. Although the geographic boundaries may differ slightly according to opinion, London is characterised by four main office submarkets. From West to East these are; the West-End, Mid-town, the City of London (City): centred around the Bank of England, and the modern business district of Canary Wharf (see Figure 2). The Canary Wharf and City office markets are predominantly tenanted by financial service firms, whereas the West End is distinguished by creative industries, hedge funds and private equity firms, and Mid-town is known for its legal, media and publishing tenants. Rents per m^2 are highest in the West End. Mid-town office rents are some 20-30% lower than the West End, while rents in the City are some 15-20% lower, and rents in Canary Wharf are lower still. The West End is primarily administered by the City of Westminster, Mid-Town is divided between the City of Westminster, Camden Islington, and the City of London, the City of London submarket is predominately run by its namesake, and Canary Wharf is governed by Tower Hamlets (see Figure 3 and Figure 4).

[3] By value, only 34% of investments between 2007-2011 in the City of London office market were undertaken by UK-based investors, and over 50% of the office stock in the City of London is held by international investors (Lizieri, Reinhart, and Baum, 2011).
[4] Total office turnover Q1 2007-Q2 2012; London US$163bn, Tokyo US$168bn, and New York US$180bn, source: Real Capital Analytics.

Figure 2: London Submarkets according to Estates Gazette

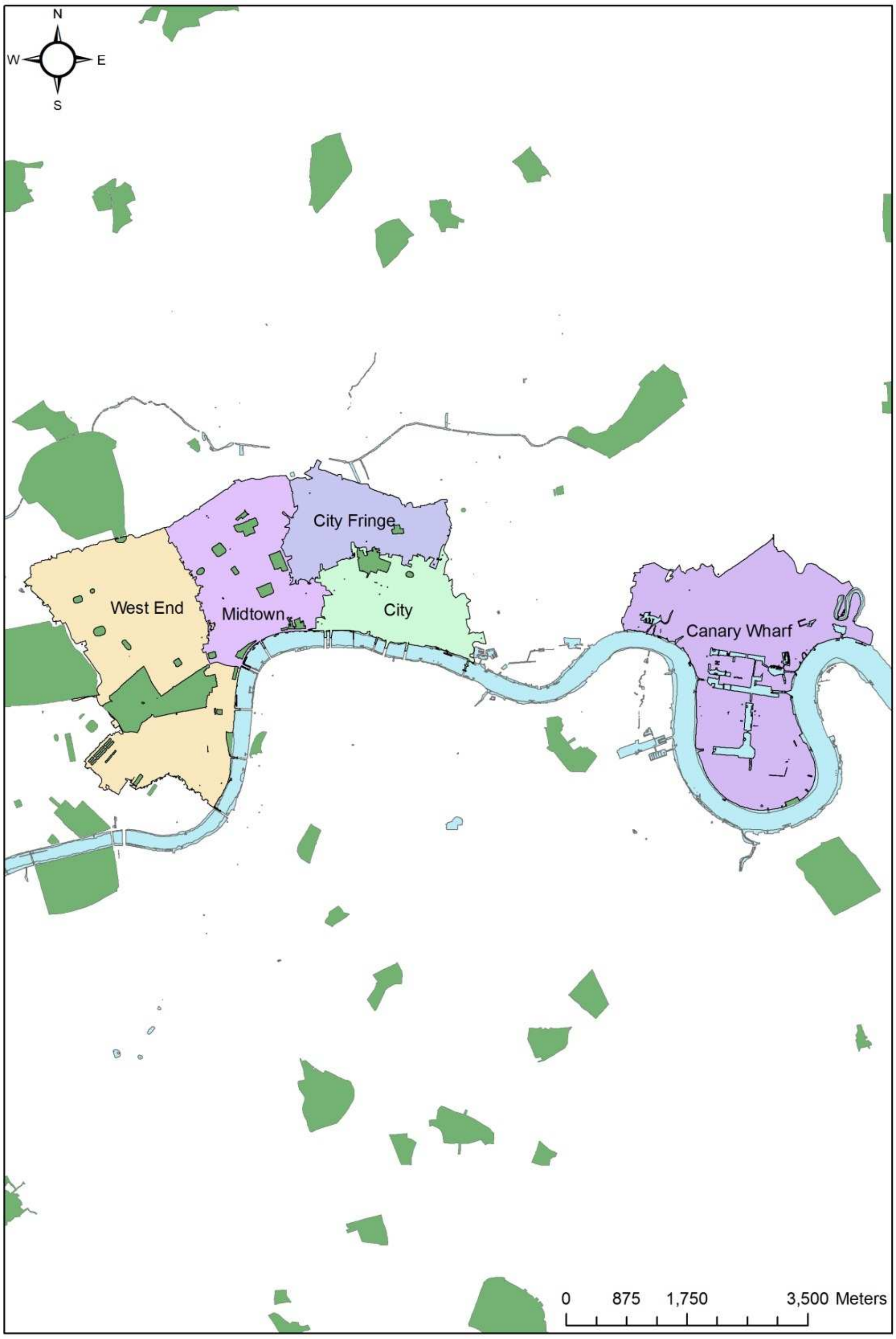
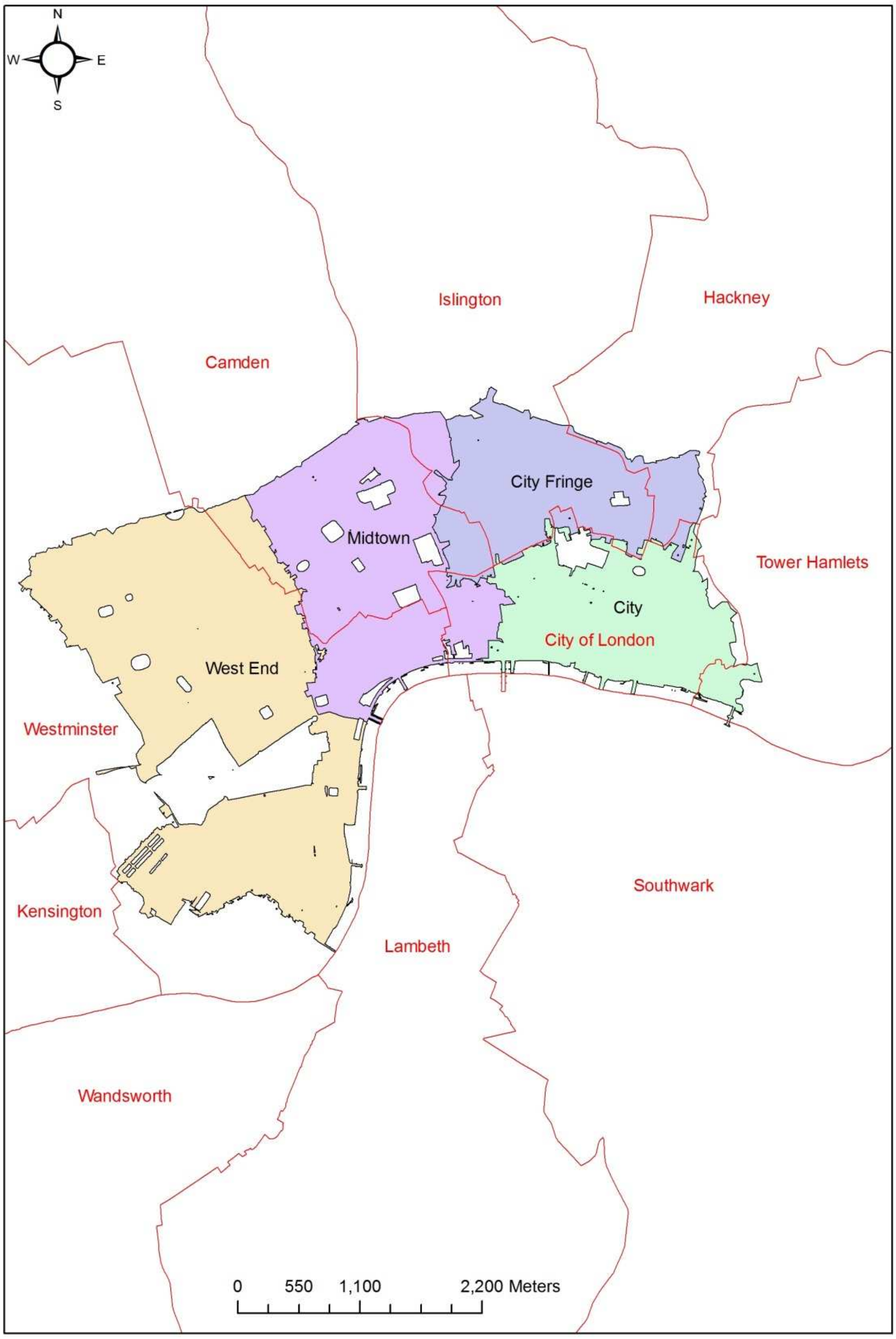


Figure 3: Central London submarket and Local Planning Authority boundaries



The history of building height regulation in London

There exists two layers of building size regulations in London, the first is building control which is statutory and fixed[5], the second is planning control which is a matter of policy and therefore more flexible. The modern history of building size regulation in London begins with the London Council Act of 1890, which set a statutory limit of 27m plus two-storeys in the roof (Inwood, 2005). This was shortly followed by the London Building Act of 1894, which restricted maximum building height to 24m to the roof cornice, with an additional 6m allowed for a recessed roof (Simon, 1996). These height limits were billed as a matter of safety, as the London fire brigade did not have ladders long enough to reach exceptionally tall buildings[6]. These restrictions came right at the time that building very tall became not only possible technologically due the introduction of steel skeletons in the 1880s, but also profitable because of the arrival of passenger lifts (Turvey, 1998). As a result of the statutory height restrictions London produced no buildings which could be termed ‘skyscrapers’ throughout the first half of the 20th century[7], though at that time many such structures were rising elsewhere across the industrialized world.

In addition to this statutory limit, further height restrictions were imposed in 1938 which specially protected views of St Paul’s Cathedral and the Monument from obstruction by new development in their vicinity. Although initially these protected sightlines were merely a ‘gentleman’s agreement’ among City developers, they were remarkably effective until such time as they were incorporated more formally into the City of London’s development plan. The current extent of the protected sightlines are broadly consist with their original 1938 manifestation, though they were extended in 1989 to include some Northern views of St Paul’s dome (City of London, 2007).

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[5] However special dispensations were exceptionally given to build in excess of statutory height limits, such as the 19-floor University of London Senate House built in 1937 and designed by Charles Holden: winner of the 1936 Royal Institute of British Architects (RIBA) Gold Medal.
[6] Although legend has it that Queen Victoria balked at the construction of tall buildings after the construction of the 12-storey Queen Anne’s Mansions in 1873 blocked her view of parliament from Buckingham Palace. At the time of construction this was the tallest residential building in Britain.
[7] Turvey (1998) notes however that even with the widespread use of lifts it took several decades for a significant proportion of new buildings in the City of London to begin approaching the statutory maximum height.

However outside of these protected sight-lines, the statutory limit was finally rescinded by the London County Council (LCC) in 1956 due to the advent of fire-lifts, at which point the London County Council Plan of 1951 was the next highest layer of binding building size regulation. Although the regulations contained therein did not control height per se, it did control building height indirectly through allowable plot-ratios[8] and minimum angles from the opposite pavement to the building's cornice (usually 56°)[9]. The plot-ratio restrictions varied according to location. For most areas in London the maximum allowable plot-ratio was 5:1, for central areas of the City close to the Bank of England the permitted ratio was 5½:1, for other areas deemed sensitive to increased density the restriction was set at 2:1 (City of London, 2010). Although originally intended to be maxima in theory, these plot-ratios came to be regarded as minima in practice. For instance, loopholes in planning law such as the notorious Schedule 3 of the Town & Country Planning Act of 1947 allowed existing buildings to be redeveloped with 10% greater *cubic* capacity than the building which preceded it. Since old buildings have higher ceilings, thicker and more numerous walls, larger passages and the like, the rentable floorspace of such redeveloped structures could be increased considerably[10]. The removal of the statutory height limit in 1956 ushered forth a boom in the construction of tall buildings in the late 1950s and early 1960s, which finally saw Christopher Wren's new St Paul's Cathedral dethroned as the tallest structure in London after a reign of over 250 years[11].

The LCC remained in charge of planning control until it was superseded by the Greater London Council (GLC) in 1965, at which point planning control was partly devolved to the local boroughs[12]. With the dissolution of the LCC, local boroughs initially maintained the old-LCC plot-ratio restrictions in force until such time as they produced new regulations of their own. In addition, in 1976 the GLC produced the Greater London Development Plan

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[8] The ratio of total building floorspace to total land-plot area: effectively a control on height.
[9] This restriction was enforced to ensure that a certain amount of daylight filtered onto workers' desks (Marriott, 1989, pp. 30).
[10] This regulation can explain for instance the disproportionate size of the 21-storey New Scotland Yard at 10 Broadway in the West End, built at an effective plot-ratio of 7:1 in spite of the fact that the maximum plot-ratio supposedly allowed by the LCC at that site was 3½:1 (Marriott 1989, pp. 171).
[11] The offending building was the BT Tower, see Table 4.
[12] However the GLC was still obliged to grant approval to all buildings in excess of 49m, until 1980.

which continued plot-ratio controls at the central-level. These planning controls existed concurrently with the plot-ratio restrictions set by the local boroughs until the GLC was finally abolished in 1986 and the Secretary of State for the Environment's Strategic Planning Guidance for London 1989 and the Planning and Compensation Act 1991 were published. These policy changes extended the power of local authorities to adopt their own development plans without direct permission from the Secretary of State (Pennington, 2000). In the case of the City of London, new development plans were implemented for local areas piecemeal, beginning with Smithfield in 1981 and continuing until 1989. Each local area plan contained distinct plot-ratios, and in the City of London these were used to guide new development until the publication of their Unitary Development Plan in 1994, at which point plot-ratios were removed in favour of the predominately discretionary system of planning controls seen across the City of London today (City of London, 2010).

At present London lacks a statutory height ceiling and local planning officials, "enjoy a considerable degree of discretion over the formulation of plans and the granting of individual planning permissions" (Pennington 2000, p.29). Though additionally, all buildings over 30m high must also receive central permission from the Mayor's Office[13] and buildings over 90m in height within the zone east of millennium bridge must be consulted with the London City Airport (City of London, 2010). Since the Greater London Authority Act 2007 the Mayor of London has also had executive power to overrule local councils and determine planning decisions unilaterally on any project which the mayor deems to be of strategic importance to London (Secretary of State for Communities and Local Government, 2008). A final layer of control rests with the Secretary of State for the Environment, who retains the right to overturn the decisions of local planning authorities through the national appeals system (Pennington, 2000).

[13]These restrictions do not apply to the City of London and areas adjacent to the Thames. In the City of London the mayor must approve buildings exceeding 150m, while buildings adjacent to the Thames must be approved by the mayor if they exceed 25m in height (City of London, 2010).

Historic designation

London has two regulatory designations for the protected status of buildings which apply to our sample; buildings located within a conservation area and listed buildings. Both buildings located within a conservation area and listed buildings cannot be altered externally without special planning consent that is rarely granted. Furthermore listed status buildings also cannot be altered internally without such consent. For failing to repair and maintain a listed building properly, owners may face criminal prosecution and the local council can compulsorily expropriate the building and recover repair costs from the owner. If a new building were to be built in a conservation area, it would automatically be given conservation status on account of the fact that it is located in such an area. On the other hand, listed status is given after a building is built, and therefore this designation cannot influence allowable building specifications at the development stage.

Conservation areas were first introduced to the United Kingdom with the Civic Amenities Act of 1967. This act made it the local planning authorities' duty to identify and preserve or enhance areas of special architectural and historic interest. Before this legislation, historic protection was based solely on individual buildings rather than areas as a whole. The provisions of the 1967 Act were incorporated into the Town and Country Planning Act 1971, which has now been superseded by the Town and Country Planning Act 1990 and the Planning (Listed Buildings and Conservation Areas) Act 1990. The consequence of these regulations is that buildings located in conservation areas are subject to additional restrictions and more extensive planning controls. The City of London, for instance, an area where building tall is possible, expressly forbids the development of tall buildings in conservation areas[14] (City of London, 2002). In central London roughly half of the total land area has been designated as a conservation area[15].

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[14] The most notable modern exception to this rule was the 16-storey New Court Building at 4-7 St Swithin's Lane completed in 2010, and designed by Pritzger-Prize and RIBA Royal Gold Medal-winning architect Rem Koolhas. Although located in the Bank conservation area and deemed detrimental to the area's architectural character, the City of London felt that the New Court building was an "exceptional piece of architecture" and that allowing Rothschild's Bank to consolidate its staff into this location was key to maintaining the City's position as a leading financial centre (City of London 2010, p. 35).

[15] See Table 6 below.

Although a limited number of historic structures were given protected status starting with the Ancient Monuments Protection Act of 1882, it wasn't until after the Second World War that buildings were protected under listing due to architectural merit alone. The reason for this change was to distinguish between which buildings would and would not be allowed to be rebuilt as a result of damage caused by German air-raid bombings. The current listing practice began with the Town and Country Planning Act 1947. Generally, buildings under 30 years old are not listed unless deemed to be of outstanding quality and under threat, and buildings under 10 years old are not listed (Creigh-Tyte, 1998). At present there are 19,198 listed buildings and structures in Greater London.

The planning process

In the City of London the process of development control for new buildings generally begins with pre-application meetings and proceeds by undertaking assessments of the various envisioned impacts of the new structure deemed important. These assessments may include but are not limited to; viewing corridors, historical designation, effects on surrounding local character, congestion, light-blocking, wind-corridor effects, the effect on commercial and political interests in promotion of the financial 'cluster' located in the City, and of course architectural design[16]. This process involves reciprocal negotiation between the interests of the developers and the preferences of the City planners, with concessions generally meted out from both sides. As a rule however, buildings within conservation areas and strategic viewing corridors are not allowed to build taller than surrounding structures. Outside of these areas there may be considerable room for compromise. The assessment and negotiation process usually lasts a couple of years before a formal application is submitted, at which point it may still be rejected.

[16]As a comparison, for the recent large-scale office known as Columbus Tower (see Table 5), the Tower Hamlets council called upon the developers to prepare an Environmental Impact Statement (EIA) covering the following issues; Demolition and construction, Alternatives and design evolution, Sustainability, Socio-economics, Traffic and transport, Air quality, Noise and vibration, Ground conditions, Water resources and flood risk, Wind, Daylight, sunlight, overshadowing, light-spillage and solar glare, Archaeology, Ecology, TV and radio interference, Aviation, and Conservation, townscape and visual impacts (Commercial Estates Group, 2008).

Central to determining the social value of a proposed building is its design quality and height[17]. While design quality presents an unambiguous benefit to the surrounding area, the net benefits of building height are ambiguous, on the one hand bringing economic efficiency, higher employment densities, and possible prestige, but on the other potentially adversely altering the skyline, casting large shadows, increasing local congestion, and creating wind-tunnel effects[18]. As a result of these potentially negative consequences tall buildings face greater scrutiny at all planning stages, and are usually required to make substantial section 106 contributions to the local community and infrastructure[19]. However, local city planners in London do have an official mandate to promote and preserve the built environment, and architectural quality and iconic design are often cited as the main contributors to the success of planning applications[20].

With these trade-offs in mind, it is plausible that a tall building which might otherwise be rejected by the planning commission could be approved if it additionally offered the surrounding areas views of world-class design. However assessment of the architectural merit of new development is by its very nature both subjective and speculative. For instance, in judging good design the City of Westminster calls its city planners to;

> *[H]ave regard to such matters as height, bulk, massing, relationship to existing building lines, and historic plot widths. The scale, proportions, vertical and horizontal emphases, solid-to-void ratios of the facades, the richness of detailing and modelling… and the light and shade this gives to the façade.* (City of Westminster, 2004, p.17).

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[17]See 'Appendix A: Policy on the location and design of tall and large buildings' for the Mayor's official policy regarding tall and large buildings.
[18] The wind-tunnel effect is more formally known as a 'rolling eddy' and is caused by tall 'slab' buildings. Notorious examples include the Merrion Centre in Leeds opened in 1963 and the Croydon Centre in Croydon, Greater London. The problem was dealt with in both cases by securing a roof above the affected area to protect pedestrians. In London this phenomenon can also be observed at Shell Tower on the Southbank, at the Elephant & Castle, and by the Stag Brewery development in Victoria (Marriott 1989, pp. 244-5).
[19] Usually amounting to around 2% of total building construction costs.
[20] The importance of good design in planning permission is explicitly recognised in Planning Policy Statement 1 from the Office of the Deputy Prime Minister (2005). This policy stance is additionally reinforced by the Commission for Architecture and the Built Environment (CABE) and English Heritage.

Clearly substantial architectural training and experience would be required in order to evaluate proposed developments along these aesthetic criteria with any competence. On the main, planners do not possess such training and/or cannot quantify all the relevant trade-offs inherent in a given development decision. Therefore, to a considerable degree planners must rely instead upon their own value judgments (Cheshire and Sheppard, 2004). Due to the inherent uncertainty, difficulty, and subjectivity involved with assessing the aesthetic impacts of a building, particularly in the case of new developments, architectural fame may provide one of the few 'concrete' signals of design quality available to planners. As such it is plausible that planners pay particular attention to the reputation of architects, and afford preferential treatment in the planning process to buildings designed by prominent architects regardless of actual design.

Political incentives

While it is clear that, as profit maximisers, developers will wish to keep building taller so long as each additional floor contributes more to final sale prices than it subtracts in costs, it is not necessarily obvious what incentives the planners and politicians on the other hand face for permitting exceptionally tall buildings. As mentioned in the previous section, there are direct benefits and positive externalities arising from the economic efficiencies and higher employment densities that tall buildings make possible. Although it might be seductive to imagine that politicians would strive to tap all potential founts of additional public welfare, as public choice theory instructs us, this need not be the case (Olson, 1965). For example, the report of a Committee of Inquiry into the Greater London Development Plan in 1973 commented that it did not accept the statement that, "the improvement of London depends on the Londoner's well-being" (Foster and Whitehead, 1973)[21]. Therefore, it cannot be naively assumed that the mere existence of potential social benefits is sufficient for political action. Rather the direction of policy is necessarily dictated by political incentives, which may or may not be aligned with economic ones.

[21] This point was taken from Evans (2004, p.9).

One potential source of these political incentives is increased government revenues. At the municipal level, local authorities and the mayor's office have limited scope for increasing revenue collection and lack fiscal independence due to heavy reliance on the national government for funding (Sweeting, 2003; Travers, 2004, Gordon, 2006). However, Section 106 of the Town and Country Planning Act 1990 allows local governments to extract substantial concessions from developers in exchange for granting planning permission[22]. Although used for all manner of social initiatives, these appeasements have been most notably used for the financing of large-scale infrastructure improvements. For instance, the mayor recently invoked his veto privilege to permit the construction of Columbus Tower in view of the contribution this project was slated to make to the London Crossrail project[23]. Uniquely, the City of London also has special permission from the central government to retain a small percentage of the revenues it generates from commercial property taxes. Therefore, the City of London in particular has a special interest in allowing developments which will increase the commercial rents charged under its purview.

A further political impetus for building tall in London may rest in the maintenance of a vibrant business community. It is certainly the case that many top financial firms prefer among other things; the consolidation of office functions in a single building, large floorplates, and fiber optic cabling. Buildings which cannot be so retrofitted are for all practical purposes indefinitely obsolete. Therefore the acceptance of new buildings and in particular tall buildings is a way for politicians to promote the continued vibrancy of their business community, and perhaps secure campaign contributions for re-election. Modern physical characteristics aside, tall buildings built by famous architects may also add an aura of prestige to cities which may attract businesses to London and business to London businesses. The London Docklands Development Corporation[24] and the City of London in particular see a large part of their remit as developing and maintaining the financial clusters within their borders, and recognise that investments in state-of-the-art office buildings are

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[22] Naturally, the very existence of 'planning gain' to begin with is a red flag that there are economic rents to be had from flexing these regulations.
[23] See Table 5.
[24] Now disbanded but originally responsible for the creation of the Canary Wharf business cluster.

crucial for London's international business reputation. For instance both Rothschild's Bank and the insurer Swiss RE considered vacating the City of London if their controversial New Court[25] and 30 St Mary Axe[26] buildings, respectively, were not granted planning permission in a timely fashion (Sudjic, 2001; City of London, 2010).

The goal of promoting financial clusters could also explain why tall modern buildings in London are almost exclusively designed as office space. Although there is nothing which overtly prohibits developers from enlisting famous architects to flex height regulations for a tall apartment building, acceptable locations to build high outside of conservation areas and protected sightlines in central London are relatively scarce. And since the economic spill-over benefits and added commercial caché of an office as opposed to a residential building are likely greater, business-conscious local authorities such as the City of London and the Docklands may discriminate in favour of tall building applications for offices.

Pecuniary interests aside, there is also a cogent argument to be made that iconic architecture becomes a tourist attraction in own right, providing direct benefits to the local hospitality industry. By way of example, there is no doubt that Frank Gehry's Guggenheim museum in Bilbao or the Sydney Opera House by Jorn Utzon have increased the appeal of these cities to tourists, to say nothing of the aesthetic value these structures may confer on their citizens (Plaza, 2000; Evans, 2003)[27]. Making grand architectural statements *per se* may also be a direct goal of politicians regardless of any attendant commercial effects. History is filled with examples of political leaders who are either directly or indirectly responsible for the erection of monumental architecture (often for personal glory), and London may be no exception. In addition to the structure itself, politicians may also appreciate the positive association they gain by dint of having collaborated with famous architects. Of course, championing new architectural landmarks in this way also carries significant political and reputational risk. Particularly for tall buildings, which, if critically

[25] At 20 St Swithin's Lane.
[26] See Table 2.
[27] The benefits of tourist attractions however suffer from the fallacy of composition, not all cities can increase tourism, or if they can they collectively also reduce their effective workforce.

received, are on view for the entire voting population for likely the remainder of their political career[28].

Perhaps the most cynical view is that politicians and planners are motivated to expedite the applications of famous architect buildings (tall and squat alike) merely in order to expand their regulatory empire. Buildings protected from refurbishment and demolition require additional staff to monitor status and approve changes. Thus, by increasing the number of buildings which are under their purview, politicians can both preserve favoured jobs and expand the number of subordinates in their employ. However, in London this causal chain would not be quite so direct, as any building built by a famous architect would, like other protected structures, take 30 or more years to attain listed status. If however additional staff are required to assess hopeful tall building applications or to monitor various aspects of these buildings prior to listing, then the empire expansion argument could still hold.

On this point of regulatory expansion, Glaeser (2011) suggests that due to the costs involved with protecting buildings and the concomitant productivity losses which arise due to the prohibition of all future redevelopment, the number of buildings granted protected status in any given city should be capped. Therefore, according to Glaeser's proposal, in order to put an additional building on the protected roster, a less significant structure would have to be likewise removed. Without such limits the implicit goal of historic conservation groups is evidently to create a city where all physical structures therein remain utterly sacrosanct and new development is impossible. Such a situation would of course be catastrophic for any such economy, and with more than half of all buildings in central London granted either listed or conservation status, we are currently not so far removed from this hypothetical world.

[28] It is perhaps ironic however how nearly every structure in the world which is critically condemned upon completion eventually becomes a treasured and protected centrepiece of the cityscape. In London, Christopher Wren's new St Paul's Cathedral and the now listed Centrepoint building by Richard Seifert at 103 Oxford Street (see Table 3) are prime examples. Perhaps familiarity is all that's really needed to turn the staunchest critics into doctrinaire acolytes.

Interest groups

Although developers can be expected to oppose size restrictions being enforced upon their own designs, it could also be argued that, on the whole, they may prefer the present semi-binding height restrictions to a world of laissez-faire. Entrenched developers with specialized (and costly) local and procedural knowledge will outcompete new entrants that lack resources to surmount these obstacles. These entry barriers serve to reduce competition and likely raise the return to development activity in London in general. Developers may therefore support political candidates who are favourably inclined to the current regulatory barriers.

Property investors as well have no less of a vested interest in the current regulatory regime. Naturally, any investor who currently holds property in London would be subject to a large capital loss should development regulations be relaxed in any meaningful way (Cheshire, 2005). It is also possible that new investors may prefer markets with potential for both real rental and capital growth, and since such growth is more likely to occur in heavily supply restricted markets, investors may support development regulations as well. A counterpoint however is that, at least in housing markets, supply restrictions may add to the volatility of returns, which deters investment (Glaeser, Gyourko and Saiz, 2008). Since stable supply in face of demand shocks means unstable (but possibly growing) prices, it is not immediately clear whether new investors to the London market prefer regulatory barriers or not. Incumbent investors on the other hand would almost universally prefer the maintenance and indeed the expansion of development restrictions.

Literature Review

Although this paper may be among the first formal investigations into the question of whether city-planners allow famous architects to build bigger, a body of related literature exists which examines the influence of good architecture and building taller on sale prices. While good architecture may provide benefits to both internal and external parties, only internal benefits should be reflected in sale-prices. Among the first studies into the effect of good architecture on office properties is the work of Hough and Kratz (1983). In their hedonic estimation of rental rates in Chicago they find that tenants pay premiums of 22%

for ‘good’ architecture, but only if the building is also ‘new’. Hough and Kratz attribute this discrepancy to the fact that the dummy variable they used to indicate ‘good’ architecture prior to 1930 was simply an indicator for those buildings which had also been marked for conservation, and were therefore subject to abridged property rights on top of the architectural benefits they were attempting to isolate.

Later work by Asabere and Huffman (1991) confirms the apparent tension evident in Hough and Kratz between the positive influence of good architecture on the one hand, and the ostensibly negative influence of historic designation on property rights on the other, by failing to find a net premium on landmarked commercial and industrial properties. Vandell and Lane (1989) on the other hand produce a measure of architectural quality independent of historic status and find similar rental premiums for good architecture as Hough and Kratz do for good and new architecture. A more recent study by Fuerst et al (2011) examined the effect of ‘signature’ architects; defined as winners of the Pritzger Prize or American Institute of Architects Gold Medal, on US offices and concluded that these buildings yielded a rental premium of 5-7% and a sale price gain of 17%. However their sale price gain disappeared when they reran the model with a sample of counterfactuals statistically chosen to be similar to their famous architect buildings, and their sample choice of signature architects was heavily weighted towards a single architectural firm whose inclusion was questionable. The rent results were also sensitive to this new comparison and to the definition of their treatment group (i.e. signature architect).

In addition to internal price effects, good architecture may also confer important externalities. Although the literature abounds with studies on the positive spill-over effects of good architecture on residential property[29], the author was unable to locate any such studies examining office buildings explicitly. It may therefore be the case that any such positive effects are small or simply too difficult to disentangle. Furthermore, for

[29] See for instance Ahlfeldt and Maennig (2010) and Noonan and Krupka (2011).

commercial property in particular, the putative benefits of good architecture are unlikely to be universally viewed as such[30].

Although the literature lacks studies on the positive externalities of good office architecture, Thibodeau (1990) documents the negative externality associated with high-rise office construction near residential properties. He estimates that these non-conforming structures exact as much as a 15% discount on neighbouring homes, whereas houses more than 1,000m away enjoyed a 5% price premium. Since the number of houses in a residential neighbourhood roughly increases as the square of distance[31], the net effect of the externalities observed by Thibodeau increased total housing values in the vicinity by 1%. In a similar vein, tall modern office buildings in London may represent a non-conforming use to the surrounding low-rise period structures in the same way that Thibodeau found for high-office buildings on residential property.

As opposed to the variable effect of good architecture on sale prices outlined above, building height exhibits an unambiguously positive influence on building price other things equal. Of course, building higher allows developers to build more total floorspace on a given land area. But even controlling for the amount of floorspace, higher floors also tend to be more valuable than those below[32]. The reasons given for the price advantages of building higher are often cited as greater prestige, productivity increases associated with greater intra-building face-to-face contact, and better views. To gain perspective on the magnitudes involved, one of the most recent studies by Koster, Ommeren, and Rietveld (2011) used the presence and height of pre-WWII buildings as an instrument to show that office rents increase by 4% for every 10m height increase in the building, and that prestige effects account for 17.5% of the total rents paid for buildings six-times the average height in Holland.

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[30] For instance the London Shard built by famed architect Renzo Piano has been criticized by English Heritage and UNESCO.
[31] πr^2, assuming uniform average residential plot areas.
[32] For instance see Colwell et al. (1998) for the effect of height on transaction prices, and for the effect on rents see Bollinger et al (1998) and Frew and Jud (1988).

Looking at the profit-maximising height of new office developments, Helsley and Strange (2008) argue that agglomeration economies and economies of scale are insufficient to explain the extreme stature of many of the world's tallest skyscrapers. They posit that there is a valuable reputation effect for being the tallest building, and that developers compete to attain this recognition. The consequence of their game theoretic model is a stock of office buildings that are taller than profit-maximisation would imply. Although Helsley and Strange only cite historical anecdotes to underpin their theoretical model, Barr (2012) empirically tests the incidence of office overbuilding historically in New York, and indeed finds that developers have engaged in profit-dissipating height competition. In contrast to offices however, other research by Chau et al (2007) did not find a significant disparity between the theoretical profit maximising height of residential high-rises in Hong Kong and their actual heights. It may therefore be the case that benefits outside the normal calculus of project-development profits accrue more readily to firms than individuals from being associated with an exceptionally tall building.

With regard to political incentives and disincentives to build taller in London, Cheshire and Hilber (2008) discuss some pertinent differences in the political forces at work in the administrative boroughs which divide London. In their paper on office supply restrictions in Britain they provide evidence that the peculiar tax structure of the City of London[33] and the fact that the it is run by the local business community and its interests, has incentivized the City to relax office space supply restrictions and encourage new development relative to other boroughs. Cheshire and Hilber also suggested that 'trophy' architects might help developers to bend these lax rules even further. Similarly, they argue that since political control of the Docklands is also held by the London Docklands Development Corporation and not the voting population, the Docklands has quelled 'NIMBY[34]' interests in favour of high-rise commercial space and economic growth. Conversely other areas of London, in particular the West End, have much stronger planning protection and height restrictions that

[33] Wherein the City of London is uniquely allowed to levy an additional business rates tax (tax on commercial property rents) and retain the revenues so generated, rather than have all revenues pooled at the central government level and reallocated to local authorities by formula grant.
[34] "Not In My BackYard", an acronym for political actors opposed to new development.

are practically impossible to breach, and as a result a less malleable office stock and higher building price to construction-cost ratios. Moreover, at a glance it is apparent that the West End of London has nearly no tall buildings[35], while both the City of London and Canary Wharf (Docklands) exhibit the only clusters of tall buildings in London.

This paper continues with an overview of the data collection methodology and how variables were constructed from this data. It then applies this data to test the hypotheses that; (i) famous architects are allowed to build bigger outside conservation areas, (ii) if this is indeed because they can build taller, and (iii) whether building bigger allows famous architects to erect buildings which sell for more on a given quantity of land. Finally the paper concludes with a discussion of these results.

Data

Building Sample

Data on office building characteristics and sale prices were acquired from Estates Gazette (EG) and Real Capital Analytics (RCA). Combined, the EG and RCA data sum to 2,932 unique sale instances in central and outer London between 1998 and 2011. This dataset was then culled with the following methodology.

1. Removed non-central[36] London buildings, as defined by EG and RCA. There were less than 100 such observations and this was done in order to make data collection more manageable and preserve the study focus.
2. Removed all portfolio sales, as there is no way to correctly allocate portions of the composite sale price to each sold building.
3. Removed all buildings whose primary use was not office space.
4. Removed all sales of buildings which had been rebuilt, refurbished, or otherwise altered since last transacted. This was done to ensure that each building when visited was essentially identical to the building which had been sold.

[35] Notable exceptions include the 37-storey BT Tower at 60 Cleveland Street commissioned by the Government General Post Office to support microwave aerial antennae for telecommunications and the 33-storey Centre Point at 103 New Oxford Street which was exceptionally granted planning permission in exchange for land concessions of the surrounding area to the LCC for road improvements (Marriott, 1989, pp.114).

[36] The EG and RCA ‘Central London’ boundaries actually correspond more closely to the standard definition for inner London which comprises the 11 central boroughs, than the standard definition for central London which only includes the West End, Midtown and City submarkets.

5. Removed sales which lacked any required data needed for the hedonic estimation.
6. Removed sales which occurred less than 12 months after the previous sale[37].

This data was then supplemented with information collected from on-site-visits to the remaining 575 properties in the sample between July and September 2011, and internet research between October 2011 and Jan 2012. Required hedonic data was successfully collected on all characteristics for 387 properties which covered a total of 513 sales (126 repeat-sales).

Famous Architect

Central to the question of this paper is the definition of what constitutes a famous architect. Although architectural excellence is necessarily a subjective judgment, there is considerable consensus within the architectural community that awards from the Royal Institute of British Architects (RIBA), the American Institute of Architects (AIA), and the Pritzker Prize are the most prestigious. Among the awards conferred by these bodies, the RIBA Royal Gold Medal, AIA Gold Medal, and the Pritzger Prize are the most esteemed as they are given annually for a lifetime body of work. Buildings which have been built by architects which have won an award from any of these three bodies are considered to be famous architects for the purposes of this study[38]. Given the exclusivity of these awards the number of potential candidates and buildings are limited. The architects who fall into this list and whose buildings were successfully surveyed consist of Cesar Pelli, Norman Foster, Terry Farrell, Aston Webb, Edward Lutyens, and Joseph Emberton consisting of ten buildings[39,40]. Four of these buildings are located outside of a conservation area, and each

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[37] These so called ‘flips’ may have a distorting effect on price indices (Clapp and Giacotto, 1999), and the hedonic model F-statistics tested here improved markedly with their exclusion.

[38] Cesar Pelli, Norman Foster, Terry Farrell, and Edward Lutyens built each of their buildings in the sample after winning one of these architectural awards. Sir Aston Webb’s 23 Austin Friars was constructed before the imposition of height controls, and Edward Lutyens Banking Hall and Lutyens House and Joseph Emberton’s Summit House were constructed during the period of statutory height controls.

[39]The architect Richard Seifert’s notoriously tall Centre Point building at 103 New Oxford Street is included in the sample of 387 buildings. But because Richard Seifert did not win any of the architectural awards recognized here, he is not considered a famous architect by this study. In fact it could be argued that he is famous in London precisely *because* of his ability to exploit loopholes in planning law to build tall, rather than through any particular design skill. Marriott (1989) even remarks that, “The trouble with Seifert…was that he knew some of the regulations far better than the LCC itself”, pp.32.

of these was either designed by Cesar Pelli, Norman Foster or Terry Farrell (see Table 2 below). We define 'modern' buildings as those buildings built after the retraction of statutory height restrictions in 1956, and 'pre-modern' as buildings built before. As we can see from Table 2 below there is in fact a 54 year gap between the completion dates of the closest modern and pre-modern famous architect buildings in our sample. Sales of the 6 modern famous architect buildings were observed a total of 10 times, and sales of the 4 pre-modern famous architect buildings were observed 6 times[41].

Table 1: Famous architect and awards

Architect	Awards Won	Year Awarded
Cesar Pelli	AIA Gold Medal	1995
Norman Foster	Pritzker Prize, RIBA Royal Gold Medal, AIA Gold Medal	1983-1999
Terry Farrell	RIBA Award, AIA Award	1978-2010
Edward Lutyens	RIBA Royal Gold Medal	1921
Aston Webb	RIBA Royal Gold Medal	1905
Joseph Emberton	RIBA Award	1930

The validity of using awards from these three bodies as indicators of architectural fame is potentially reinforced by noting that all of the four buildings in our sample built by pre-modern famous architects have been listed by the Historic Buildings and Monuments Commission for England for possessing special architectural or historical interest; assuming of course that these buildings are not listed ipso facto of being built by a prominent architect. All modern buildings in the sample, on the other hand, are not yet eligible for listing as buildings as they are under 30 years of age (see Historic designation above). All pre-modern buildings built by famous architects are also located in conservation areas. Although it can be noted from Table 2 that the two tallest buildings in the sample were built by architects that this paper regards as famous, the criterion used by this paper for being deemed a famous architect was chosen blind of the data.

A caveat to bear in mind with our famous architect metric is that it does not directly test for good architecture, but rather asks the simpler and more objective question of whether a

[40] The tallest building in Europe, the London Bridge 'Shard' designed by Pritzker-Prize, RIBA Royal Gold Medal, and AIA Gold Medal-winning architect Renzo Piano is not part of the sample, see Table 4.
[41] See 'Appendix C: Descriptive statistics' for a detailed breakdown.

building's architect has been recognized for excellence by the most prestigious architectural-bodies. This simplification comes at a cost however. Although plausible, it may not be a valid inference to say that the particular buildings built by famous architects in this sample are also examples of good architecture. To be sure that this is the case would require independent evaluation of each building's actual architectural merits, ideally by a panel of experts. However, for the purpose of assessing the impact of mere architectural fame on the willingness of planners and politicians to allow extra building height at the application stage, this metric is sufficient.

The following four Tables describe (i) the Famous architect office buildings in the sample. (ii) Tallest non-famous-architect office buildings in the sample, (iii) Tallest London office buildings not in the sample, and (iv) Tallest London office buildings not yet completed but with planning permission. Unsurprisingly, a notable feature of existing modern and permitted tall office buildings in London is the preponderance of buildings designed by famous architects. Furthermore, only one of these 'tall' office buildings in our sample (14-storey 12 Throgmorton Avenue) was built while in an active conservation area[42].

[42] The predecessor to the current Drapers Gardens building was actually 28-storeys tall and only allowed because the architect (Richard Seifert) invoked the much abused Third Schedule of the Town and Country Planning Act 1947 and amassed all the allowable floorspace of the considerable land-plot into a single narrow tower (Marriot 1989, pp.117).

Table 2: Famous architect buildings in sample

Building Name	Address	Architect	Floors†	Year Built	Borough	Conservation Area	Listed	Sales
-	25 Canada Square	Cesar Pelli	43	2002	Tower Hamlets	NO	NO	2
'The Gherkin'	30 St Mary Axe	Norman Foster	40	2003	City of London	NO	NO	1
Bishops Square	10 Bishop Square	Norman Foster	13	2005	Tower Hamlets	NO	NO	2
-	10 Gresham Street	Norman Foster	8	2004	City of London	YES	NO	1
Alban Gate	125 London Wall‡	Terry Farrell	19	1992	City of London	NO	NO	3
Sugar Quay[c]	Lower Thames Street	Terry Farrell	6	1979	City of London	YES	NO	1
Lutyens House	1-6 Finsbury Circus	Edward Lutyens	9	1923	City of London	YES	YES	1
Banking Hall	27-35 Poultry	Edward Lutyens	6	1925	City of London	YES	YES	3
-	23 Austin Friars	Aston Webb	6	1888	City of London	YES	YES	1
Summit House	12 Red Lion Square	Joseph Emberton	5	1925	Camden	YES	YES	1

†Floors refers to all above-ground levels including the ground floor but not including basements.
‡Alban Gate replaced the 18 floor Lee House designed in 1962 by Burnet, Tait and Partners.
[c]Norman Foster is currently slated to design a replacement development to Sugar Quay.

Table 3: Tallest non-famous-architect office buildings in sample

Building Name	Address	Architect	Floors	Year Built	Borough	Conservation Area	Listed	Sales
Centre Point	103 New Oxford Street	Richard Seifert	33†	1965	Camden	YES*	YES	1
Empress State Building	Empress Approach	Stone, Toms & Partners	30‡	1961	Hammersmith	NO	NO	1
Commercial Union Tower	1 Undershaft	Gollins, Melvin, Ward	26	1969	City of London	NO	NO	1
New Scotland Yard	10 Broadway	Chapman, Taylor and Partners	21	1962	Westminster	NO	NO	1
City Tower	40 Basinghall Street	Burnet, Tait and Partners	21	1957	City of London	NO	NO	0[a]
Angel Court	1 Angel Court	Fitzroy Robinson and Partners	19	1980	City of London	YES*	NO	1
Plantation Place	30 Fenchurch Street	Arup Group	15	2004	City of London	NO	NO	1
Landmark House	Hammersmith Bridge Road	Thomas Saunders Partnership	15	1973	Hammersmith	NO	NO	2
Drapers Gardens	12 Throgmorton Avenue[c]	Foggo Associates	14	2009	City of London	YES*	NO	1
-	280 Bishopsgate	Foggo Associates	13	2001	Tower Hamlets	NO	NO	2

*Centre Point, Angel Court, and the original Drapers Gardens building at 12 Throgmorton Avenue were granted planning permission before their surrounding areas were given conservation area designation.

†Centre point was permitted to be taller than would normally be allowed by the London County Council because the developer Harry Hyams consented to fund the creation of a needed road junction under and around the building.

‡This figure includes three floors added to the top of the building during a renovation in 2003 at a cost of £80m.

[c] 12 Throgmorton Avenue replaced the 29 floor building known as Drapers Gardens originally designed by Richard Seifert in 1962.

[a] One sale observation was obtained on this property but it was a ‘flipped’ sale and therefore this observation was removed from analyses concerning sales. This observation was retained however for analyses concerning building size.

Table 4: Tallest inner London office buildings not in sample

Building Name	Address	Architect	Floors	Year Built	Borough	Conservation Area	Listed
'The Shard'	32 London Bridge Street	Renzo Piano*	95	2012	Southwark	NO	NO
One Canada Square	1 Canada Square	Cesar Pelli*	50†	1991	Tower Hamlets	NO	NO
Tower 42	25 Old Broad Street	Richard Seifert	47	1980	City of London	NO	NO
Heron Tower	110 Bishopsgate	Kohn Pedersen Fox‡*	46	2011	City of London	NO	NO
HSBC Tower	8 Canada Square	Norman Foster*	45	2002	Tower Hamlets	NO	NO
Broadgate Tower	201 Bishopsgate	Skidmore, Owings, and Merrill	33	2009	City of London	NO	NO
-	25 Bank Street	Cesar Pelli*	33	2003	Tower Hamlets	NO	NO
-	40 Bank Street	Cesar Pelli*	33	2003	Tower Hamlets	NO	NO
One Churchill Place	1 Churchill Place	HOK International	32	2004	Tower Hamlets	NO	NO
-	10 Upper Bank Street	Kohn Pedersen Fox*	32	2003	Tower Hamlets	NO	NO

*Denotes famous architect according to this paper's definition.
†To comply with air-traffic safety regulations for London City Airport the architect removed 5 floors from the original design of One Canada Square.
‡Kohn Pedersen Fox was Winner of the AIA Architectural firm award in 1990, and William Pedersen has received 5 AIA Awards between 1984-2003.
ᵟBT Tower located at 60 Cleveland Street is 37 floors tall and contains some office space to let, but because it was designed primarily as a signal tower by the Government General Post Office to support microwave aerial antennae for telecommunication we do not consider it to be a comparable office building.

Table 5: Tallest proposed inner London office buildings with planning permission

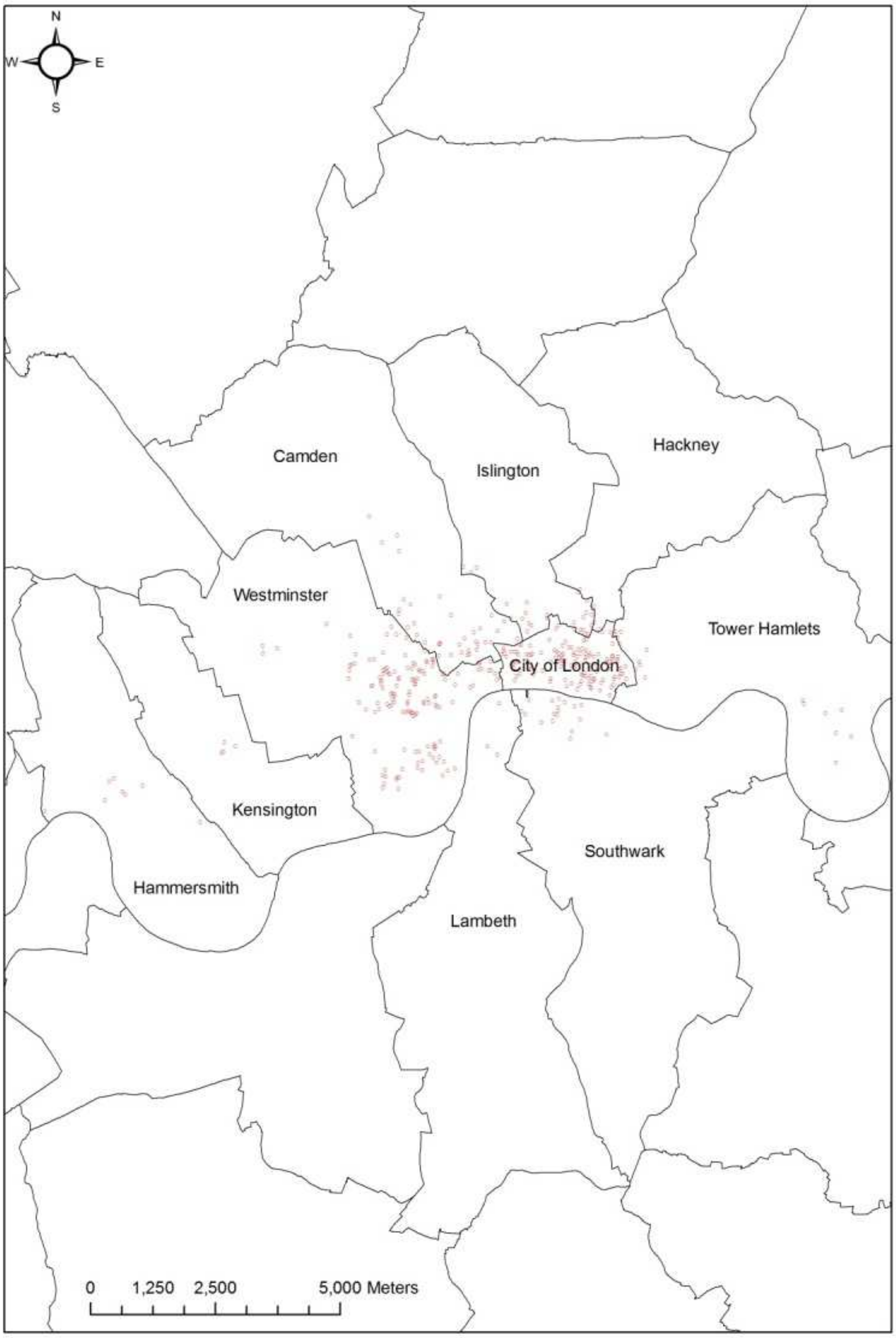
Building Name	Address	Architect	Floors	Comp Year	Borough	Conservation Area	Listed
The Pinnacle	24 Bishopsgate	Kohn, Pedersen Fox*	63	2014	City of London	NO	N/A
Columbus Tower	West India Quay	Mark Weintraub	61	N/D	Tower Hamlets	YES†	
One Nine Elms	1 Nine Elms Lane	Kohn, Pedersen Fox*	58	N/D	Wandsworth	NO	
'The Cheesegrater'	122 Leadenhall Street	Richard Rogers*	48	2014	City of London	NO	
Riverside South	Westferry Circus	Richard Rogers*	45	2016	Tower Hamlets	NO	
One Park Place	1 Park Place	Horden Cherry Lee	45	2012	Tower Hamlets	NO	
-	100 Bishopsgate	Allies and Morrison*	40	N/D	City of London	NO	
North Quay	Aspen Way	Cesar Pelli*	40	N/D	Tower Hamlets	NO	
Heron Quays West	Heron Quays	Richard Rogers*	40	N/D	Tower Hamlets	NO	
'The Walkie-Talkie'	20 Fenchurch Street	Rafael Vinoli*	36	2014	City of London	NO	

*Denotes famous architect according to this paper's definition.
†Tower Hamlets council initially rejected this proposal due to an anticipated detrimental effect on the local conservation area, but the Mayor of London exercised his veto power claiming this project was of strategic importance to London.
N/D means no definite completion date at present.
Listed column is N/A because buildings can only be given listed status post construction.

Administrative Regions

Boundaries for London boroughs were taken from the UK ordnance survey boundary-line maps and spatially referenced to each office property. The sample of 387 buildings falls in all ten boroughs which comprise inner London. These are; the City of London, the City of Westminster, Tower Hamlets (containing the Docklands), Southwark, Lambeth, Kensington and Chelsea, Hammersmith and Fulham, Islington, Hackney, and Camden. Although the sample of 387 buildings used in this study is spread across all 10 boroughs, 86% of these buildings are located in the City of Westminster, Camden, Islington, and the City of London.

Figure 4: Map of inner London boroughs and office locations (in red)



Conservation Areas and Listed Buildings

Data on conservation areas was acquired from the London Mayor's Office with maps produced by Landmark Information Group. Data on the listed status of buildings comes from English Heritage and Estates Gazette. Of the 387 buildings in the sample 209 or 54% are currently located within a conservation area, 90 or 23% were built while located within a conservation area, 46 or 12% are listed, and 35 or 9% are both currently located within a conservation area and listed. As the Table 6 below shows, a large percentage of the total land area in the four main boroughs which comprise our sample is contained within conservation areas.

Table 6: Conservation areas in primary central London boroughs

Local Planning Authority	Number of areas	Percent of total borough covered	First introduced
City of Westminster	55	75%	1967
Camden	39	50%	1968
Islington	40	50%	1968
City of London	26	33%	1971

The variable conservation density 300m was approximated by randomly adding one point for each 100sqm of conservation area within each conservation area's perimeter (excluding parks, gardens, and water features), with a minimum distance between points of 4m, and then calculating the number of points which fell into a 300m radius of each building. 100m and 500m radial distances were also tested and were not as statistically significant in the model. The variable listed building density 300m was calculated by spatially matching the point map of listed buildings from English Heritage with the Ordnance Survey containing a map of each building's curtilage[43]. Then a point was randomly placed within each listed building's curtilage for every 10sqm of curtilage area, with a minimum inter-point distance of 1m, and the number of points which fell within 300m of each office building was tallied. Again 100m and 500m radial distances were tested but were not as statistically significant as the 300m distance. A possible explanation for this distance being the most statistically significant for both conservation area and listed building density is that it may conform to

[43] Curtilage is defined as the land area attached to a structure and forming the enclosure around it.

the distance around the building which visually most contribute to the quality of the surrounding local environment. It may also proxy for micro-location supply restrictions which increase prices, though much of this effect would likely be captured by planning permission refusal rate at the local authority level (see below).

For the analyses into the effect of conservation area on building size (dependent variables; Sqm/Curtilage, Floors, Footprint/Curtilage), buildings are only identified to be located in a conservation area if the building was built *after* the corresponding conservation area had been put in force. For the Price/Sqm regression, conservation area is defined as such if the building was located within a conservation area at the time of sale. For the Price/Curtilage regression a separate dummy variable is used for conservation designation at the time of construction and within conservation area at the time of sale. These dummy variable adjustments are done so that when a building is included in a conservation area it measures the restriction to building size and/or the effect on building prices as appropriate for the analysis at hand. The most notable tall buildings in the sample which were first built and then subsequently designated a conservation area were 103 New Oxford Street (33-floors) and 1 Angel Court (19-floors).

Parks and Gardens

A digital map of London’s parks and gardens was acquired from English Heritage. Parks and gardens density was calculated by placing a random point within the perimeter of each park or garden for each 10sqm contained within, with a minimum distance between points of 1m. Then the total number of points within a 300m radius of each office property was counted.

Planning Permission Refusal Rate

In London, planning decisions are administered at the borough level of local government. Each borough has a different degree of regulatory strictness regarding new development. This study employs data on office planning refusal rates from 1990 to 2008 for the ten boroughs[44] which contain the 387 properties in the sample, provided from the research of Hilber and Vermeulen (2010). Of course, the planning permission refusal rate is somewhat endogenous in that applicants will likely adjust their planning requests according to the restrictiveness of the borough in question. However, it is infeasible for this study to collect and analyze data on each office planning request to ascertain the absolute restrictiveness of each borough. In lieu of this limitation, the office planning refusal rates produced by Hilber and Vermeulen (2010) from the Department for Communities and Local Government is used despite the potential endogeneity problems mentioned above. Since data post-2008 was unavailable, for years 2009-2011, 2008 data is used. For the regressions on building size the average 1990-2008 office planning refusal rate is used. This is done because, again, we do not have data on refusal rates prior to 1990, and it is thought that taking account of the entire dataset would make the most sense given that the majority of buildings in the sample were built prior to 1990[45]. The regressions considering sales prices use the 9-year moving average of office permission refusal rates based retroactively on the date of sale. This was done so as to accommodate as much prior information about the restrictiveness of the local planning authority in question as possible (given that the earliest sale date of buildings used in this analysis is 2000) without including irrelevant information on the restrictiveness of the local authority after the sale has occurred.

With regard to these planning statistics, the City of London is a bit of an anomaly in that, although the office planning permission refusal rate is effectively zero for this borough, planning in the City of London is in fact highly restrictive. Instead of flat-out refusal, the City of London tends to negotiate by rejecting certain aspects of a proposal and then return the application for modification and resubmission before final approval will be granted. Although other boroughs manage applications in this way to a greater or lesser degree (Ball, 2011) the City of London is exceptional in this regard. Therefore the City of London has a higher effective refusal rate than is evident from the DCLG statistics. To account for

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[44] City of London, City of Westminster, Kensington and Chelsea, Hammersmith and Fulham, Camden, Islington, Hackney, Lambeth, Southwark, Tower Hamlets.
[45] See 'Appendix C: Descriptive statistics'.

this disparity a dummy variable for the City of London is added in some regressions on building size.

It has also been argued by Cheshire and Hilber (2008) that because of business control of the planning process the City of London and the Docklands have especially permissive regulations with regard to building size compared to other areas of London. In order to account for this possible disparity a dummy variable for the Docklands is also included with the City of London dummy variable in regressions of building size.

Employment Density

Employment density is empirically one of the strongest drivers of office rents and sale prices. Accordingly, we would expect profit-maximizing developers to wish to build more space on a given parcel of land if they can sell, lease or rent office space on that land for more[46]. Therefore ceteris paribus, employment density is also likely to be an important driver of average office building height.

The most detailed publicly available statistics on the location of the workforce in London consist of postcode sector data from the NOMIS Annual Business Inquiry (ABI) Employee Analysis. This dataset begins in 2000 and the most recent data at the time of writing is for 2008. Furthermore, only employees from industries with a 2003 SIC section code designation of J or K, corresponding to the banking, finance, business services and insurance industries were included in this count. Unfortunately this dataset possesses a structural break in how the data was collected between 2005 and 2006. Therefore our 2006-08 postcode sector employment counts are rescaled pro rata using the scaling factor provided by the ONS for London SIC codes J and K using the pre-2005 methodology.

A map of employment density was constructed from the 11,773 postcode sectors in greater London by including all postcode sectors that have any part of their boundary within 2km

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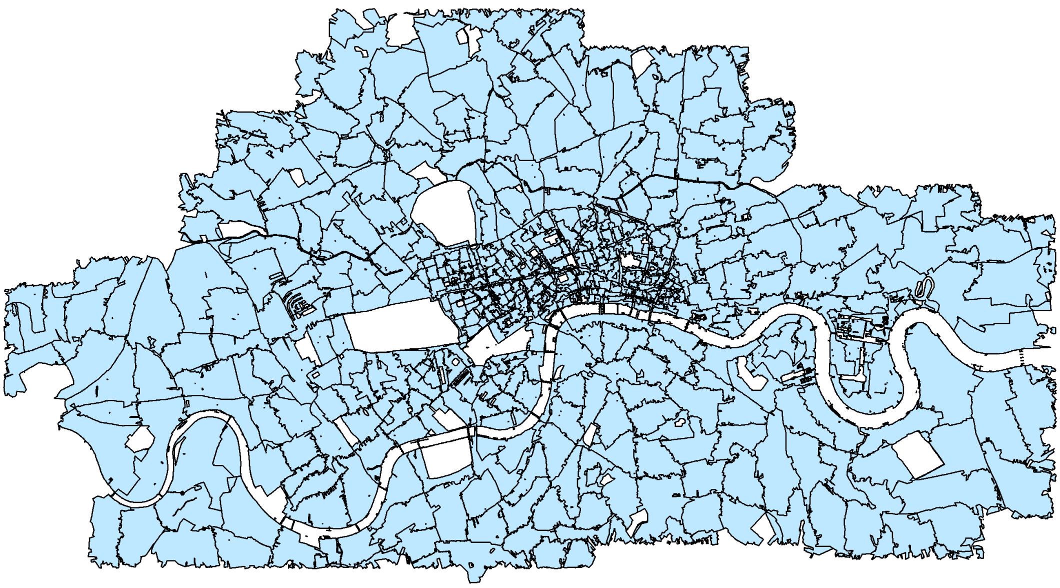
[46] Since the marginal cost of constructing another floor increases with each additional floor (Gat, 1995), we would only expect the tallest buildings to be located in the most favourable locations with the highest office rents.

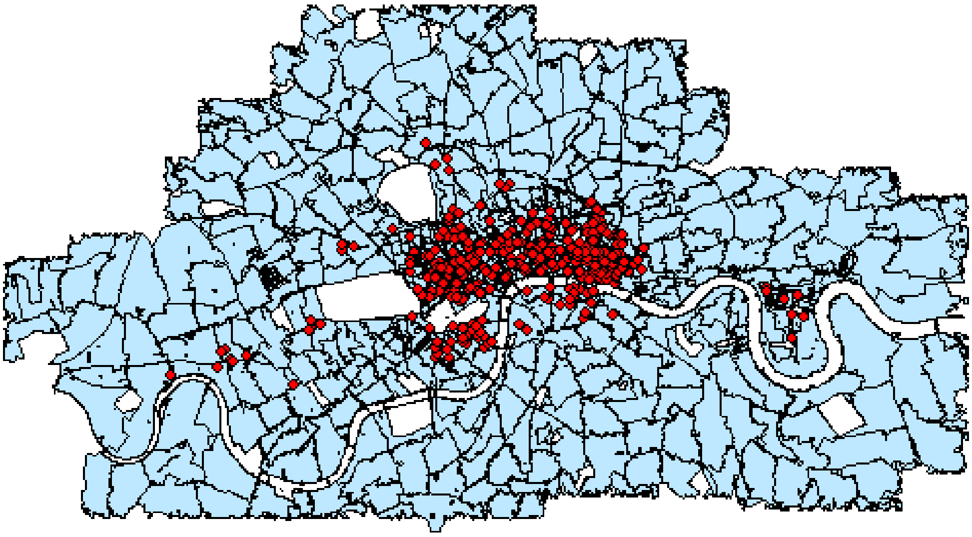
of any office property in the sample. This left a total of 546 postcode sectors. A feature of this dataset is that density/number of postcode sectors is substantially higher within central London, where the majority of properties are located (see Figure 5 and Figure 6)[47]. All water features from the Ordnance Survey Mastermap and Parks and Gardens from English Heritage were then removed so as to produce a map which better reflected the locations within the postcode sectors where employees could actually work. Then a number of points corresponding to the employment counts within the remaining boundaries of each of the 546 postcode sectors for each year between 2000 and 2008 were randomly placed within each boundary, and then the number of employees within a radial buffer of 500m from each property at the year of sale was calculated. 500m was chosen as this has been empirically observed in studies of other cities to correspond approximately to the distance after which the hedonic influence of employment density begins to attenuate, see Arzaghi and Henderson (2008) and Jennen and Brounen (2009).

Figure 5: The 546 postcode sectors



[47] This map was constructed by aggregating common postcode units up to the postcode sector-level from the Ordnance Survey.

Figure 6: The 546 postcode sectors and 387 office locations



However, it is important to note that the employment density measure used here is automatically somewhat endogenous with respect to large buildings when regressing on building size. The reason being that the employment counts taken from the ABI include employees working inside the very building for which the surrounding employment density is being calculated. Therefore when a big building is built at a given location, there is automatically a higher employment density at that location. So in effect, every building adds to its own density, and therefore big (occupied) buildings cause high density, even if the converse is not true. However, the average employment count per 500m radial distance from each property between 2000-08 is 35,000, whereas, the average building size is 9,400sqm. If we take an average of 185 sqft (17.1sqm) per worker[48], that leaves us with an average of 550 workers per building, which represents only 1.6% of the working population of the average postcode sector in our sample. The potential endogeneity of employment density on prices and building height might also arise from unobserved physical and environmental characteristics. However, it is not as crucial to address the potential endogeneity of employment density in this study looking at famous architecture as it would

[48] Taken from http://www.officefinder.com/officespacecalc.html on July 17th 2012 as the least amount of office space needed per typical worker.

be if the effect of employment density was the variable of interest. This is because the extent to which employment density is correlated with unobservables only improves its function as a control, and residual endogeneity (such as a big building increasing its own employment density) can only affect the famous architect coefficient to the extent that the two variables are correlated. However, as a result of this potential problem we do attempt to instrument for employment density levels at the time of sale with the density of financial service workers, the density of total workers, and the proportion of male workers from the 1981 census at the local authority level provided by NOMIS. The rationale behind using old measures of employment density is that, following the research of Ciccone and Hall (1996), places with high employment density in the past may also be areas in which employment density is high today. But if enough time has elapsed, these historic employment density levels may also no longer be correlated with the unobservables that can bias contemporaneous estimates of employment density. The 1981 estimates were used because these were the earliest employment numbers available which were associated with a definite geographic boundary.

A further problem with our employment density measure is that we do not have this data prior to 2000, while many of the buildings in our sample were built even before the 20th century. As accurate data on local employment densities in London for this period could not be obtained, the average employment density between 2000-08 is used for regressions which estimate building size, and instruments are used to predict this variable in the Instrumental Variable 2-Stage Least Squares (IV2SLS) specifications.

Access to Labour Force

Access to the labour force is estimated by taking the distance in metres to the nearest underground, overground, or rail station. Although simple, this statistic outperforms several more sophisticated estimates of access to the labour force; see ‘Appendix B: Separately tested but omitted controls’.

Submarket Area

The sample contained the following 15 postcode districts; EC1, EC2, EC3, EC4, E1, WC1, WC2, W1, SW1, SW6, W6, N1, NW1, SE1, and E14. Submarkets were defined according to Estates Gazette's market definition shown below.

City Core: EC1A, EC2M, EC2N, EC2R, EC2Y, EC2V, EC2A (only Finsbury Pavement, Finsbury Square, Appold Street and Chiswell Street), EC3, EC4 (excluding EC4A & EC4Y)

City Fringe: EC1M, EC1N (excluding postcode sector 2), EC1R, EC1V, EC1Y, EC2A (excluding Finsbury Pavement, Finsbury Square, Appold Street and Chiswell Street), E1

Southbank: SE1 postcode sectors, 0, 1, 2 & 9

Docklands: E14

Midtown: EC4A & EC4Y, EC1N (postcode sector 2), WC1, WC2 (excluding Leicester Square)

West End: W1, SW1, NW1 sectors 2 (Euston Road only), 3, 5 & 6, Leicester Square (WC2) and W2 sectors 1, 2 & 6

South Central: Remainder of SE1 and all of SE11

North Central: Remainder of NW1 and N1 and all of E8

West Central: Remainder of W2 and all of W6, W8, W14, SW3, SW5, SW6, SW7 & SW10

Building Characteristics

Data on building characteristics such as; the number of floors[49], the number of basements, number of parking spaces, single or multi-tenant, and air conditioning (A/C) was gathered from EG, RCA, internet research, and site visits to each building. The quality of the floorspace comes from Estates Gazette, which grades each floor of the building either A or B. Buildings with only grade A space are graded as an A, with A and B graded A/B, and only B space is the omitted dummy variable. Data on the area of building footprints and curtilages comes from the Ordnance Survey MasterMap.

Decade of Construction

Data on the decade in which the building was built comes from EG, RCA, and internet research. This is an important variable because it simultaneously accounts for technology improving cost reductions to building tall and general changes in planning regulation and sentiment through the years. Buildings built prior to the 1950s are contained under the omitted dummy variable. This is done because more precise data on the construction dates of pre-WWII buildings were not always forthcoming.

Whereas most hedonic studies include when the building was built and possibly a dummy variable indicating whether the building has ever been refurbished, this study uses a more sophisticated measure for obsolescence by utilizing the number of years at the time of sale since the building had been built or last refurbished; known here as "Depreciation Age".

Analysis

We first examine whether famous architects designing buildings outside conservation areas have been able to build more office space on a given plot of land. It is logical to assume that this has only been possible since 1956; the year that statutory height restrictions in London were lifted in exchange for the more flexible system of planning control in force

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[49] Like employment density the number of floors may also be endogenous with respect to prices (Koster, H., Ommeren, J., and P. Rietveld, 2011). Although suitable instruments for the number of floors were not found, as with employment density this should not be problematic as the focus of this study is not the estimation of the causal relation between floor height and sale price.

today[50]. To test this hypothesis we employ our data set of 387 buildings. As per Table 2, four of these buildings were built by famous architects post-1956 outside a conservation area, two by famous architects post-1956 within a conservation area, and four by famous architects pre-1956[51]. The dependent variable is total building floorspace (sqm) divided by the area of the plot of land encompassing the building (curtilage)[52]. The results of this analysis are reported in Table 7. Since we only expect famous architects to be able to build bigger outside a conservation area, we use an interaction term[53] to capture this expected effect. As independent controls we utilize; built by famous architect (not interacted), within conservation area, average office permission refusal rate for the corresponding local planning authority between 1990-2008, and the decade the building was built. For some specifications we also include a dummy variable for the City of London and Docklands, to take account of their relative regulatory leniency (Cheshire and Hilber 2008), and average employment numbers within 500m. Employment density is likely to be endogenous to the amount of floorspace at a given location, so for one specification of the model in Table 8 we attempt to instrument for employment density with the density of workers employed in financial services, total employment density, and the proportion of workers who are men by local authority from the 1981 census. With floorspace/curtilage as the dependent variable, White tests reject the null hypothesis of homoskedasticity, and so robust standard errors are reported.

[50] See the section ‘The history of building height regulation in London’ above.
[51] See Table 2.
[52] Also known as the Floor Area Ratio (FAR) or Plot-ratio.
[53] Namely; (Building designed by famous architect) x (Outside conservation area).

Table 7: Dependent variable is Floorspace/Curtilage

VARIABLES	(1) OLS Floorspace/ Curtilage	(2) OLS Floorspace/ Curtilage	(3) OLS Floorspace/ Curtilage	(4) OLS Floorspace/ Curtilage
Famous Architect Outside Conservation Area		4.889***	3.875***	3.338***
		(0.876)	(0.850)	(0.570)
Famous Architect	1.823**	-0.135	0.118	0.215
	(0.865)	(0.356)	(0.366)	(0.388)
Built in Conservation Area	-0.109	-0.0807	-0.503**	-0.454**
	(0.197)	(0.193)	(0.221)	(0.230)
Average Office Permission Refusal Rate	-11.18***	-11.31***	-10.29***	-15.76***
	(1.554)	(1.523)	(1.578)	(3.712)
Built 1950s			0.124	0.163
			(0.387)	(0.394)
Built 1960s			0.892	0.932
			(0.583)	(0.586)
Built 1970s			0.592*	0.655*
			(0.333)	(0.338)
Built 1980s			0.390	0.348
			(0.293)	(0.309)
Built 1990s			0.765***	0.750***
			(0.256)	(0.254)
Built 2000s			1.432***	1.384***
			(0.265)	(0.272)
Built 2010s			0.423	0.356
			(0.806)	(0.881)
City of London				-0.699
				(0.499)
Docklands				1.747***
				(0.674)
Constant	5.737***	5.742***	5.188***	5.846***
	(0.174)	(0.172)	(0.204)	(0.479)
Observations	387	387	387	387
R-squared	0.146	0.186	0.247	0.268

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

As we can see the coefficient on famous architect is significant in the first regression specification, and the average office refusal rate of the local planning authority has a strongly negative effect on the floorspace allowed on a given curtilage. When we interact famous architect with built in conservation area in specification 2 the effect on the interaction term is even stronger and the original significance on the famous architect term is lost. This result is consistent with the hypothesis that it is only the combination of a famous architect outside a conservation area that makes it possible to build taller. In the third specification we add controls for the age of the building, which has a significant effect for buildings built in the 1970s, 1990s and 2000s. There are only two buildings in the sample built in the 2010s[54], so the lack of significance on this variable should be considered a preliminary result only. With the addition of building age controls we also see that the 'built in conservation area' term now becomes negatively significant. In the fourth specification dummy variables for the City of London and the Docklands are added, and both have their expected signs though only the Docklands is significant. Table 8 below presents the full specification which includes average employment density between 2000-08 within 500m as an additional control.

[54]See Table 17.

Table 8: Dependent variable is Floorspace/Curtilage

VARIABLES	(1) OLS Floorspace/ Curtilage	(2) IV2SLS Floorspace/ Curtilage
Famous Architect outside Conservation Area	3.255***	2.926***
	(0.528)	(0.738)
Famous Architect	0.137	-0.169
	(0.320)	(0.391)
Built in Conservation Area	-0.488**	-0.622**
	(0.227)	(0.269)
Average Office Permission Refusal Rate	-14.89***	-11.45**
	(3.649)	(4.868)
Built 1950s	0.184	0.269
	(0.388)	(0.408)
Built 1960s	1.012*	1.327*
	(0.595)	(0.687)
Built 1970s	0.703**	0.889**
	(0.332)	(0.401)
Built 1980s	0.361	0.411
	(0.307)	(0.323)
Built 1990s	0.727***	0.635**
	(0.254)	(0.301)
Built 2000s	1.402***	1.471***
	(0.268)	(0.288)
Built 2010s	0.183	-0.499
	(1.074)	(1.882)
City of London	-1.190**	-3.133*
	(0.514)	(1.651)
Docklands	1.857***	2.293***
	(0.644)	(0.662)
Average Employment 500m	1.47e-05**	7.28e-05
	(6.42e-06)	(4.83e-05)
Constant	5.410***	3.688**
	(0.521)	(1.545)
Observations	387	387
R-squared	0.278	0.118

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Wald chi2(14) = 215.20

As we can see from Table 8 the additional control for average employment density tightens up the model, disentangling its effect with the City of London dummy which is now statistically significant. In Table 8 specification 2 we attempt to instrument for the potentially endogeneous control: average employment density. The 2SLS instrument has an acceptable Wald statistic of 215.20 confirming its relevance, and the first stage regression has an R-squared of 0.118. The Durbin-Wu-Hausman test for exogeneity of the instrumented variable is not rejected (p =.1932), and Sargan-Hansen tests do not reject the exogeneity of the instruments. Unfortunately however the instrumented employment density is not a significant predictor of floorspace/curtilage (t-stat =1.51). Regardless, the famous architect outside a conservation area interaction term remains significant in the 2SLS specification. Indeed, this result is robust with respect to adding each successive group of controls.

In addition to building taller, the increases in floorspace for a given lot-size observed in Table 7 and Table 8 above can also come about as a result of building 'wider' – in two dimensions. That is, increasing the proportion of the building's curtilage occupied by the building's footprint. In the next set of regressions we run the same group of independent control variables, only this time on the total above ground floors (including the ground floor) to confirm the results in Table 7 and Table 8. The results of this specification will test whether famous architects have indeed been able to build bigger because they can build taller. White tests reject homoskedasticity in all cases and robust standard errors are reported. The results of these regressions can be seen in Table 9.

Table 9: Dependent variable is Total above ground floors

VARIABLES	(1) OLS Floors	(2) OLS Floors	(3) OLS Floors	(4) IV2SLS Floors
Famous Architect outside Conservation Area	20.65***	20.17***	19.99***	20.19***
	(6.513)	(6.004)	(5.882)	(5.896)
Famous Architect	-0.351	-0.526	-0.697	-0.512
	(0.589)	(0.602)	(0.573)	(0.651)
Built in Conservation Area	-1.311***	-1.064***	-1.139***	-1.058***
	(0.246)	(0.274)	(0.271)	(0.307)
Average Office Permission Refusal Rate	-5.891*	1.724	3.654	1.572
	(3.126)	(10.48)	(10.44)	(9.917)
Built 1950s	1.385***	1.303***	1.350***	1.299***
	(0.389)	(0.381)	(0.363)	(0.386)
Built 1960s	5.219***	5.156***	5.333***	5.142***
	(1.519)	(1.475)	(1.472)	(1.497)
Built 1970s	2.502***	2.314***	2.419***	2.306***
	(0.656)	(0.662)	(0.674)	(0.673)
Built 1980s	0.561**	0.268	0.295	0.265
	(0.262)	(0.307)	(0.310)	(0.310)
Built 1990s	1.552***	1.237***	1.185***	1.241***
	(0.325)	(0.358)	(0.352)	(0.356)
Built 2000s	2.289***	1.996***	2.034***	1.993***
	(0.341)	(0.362)	(0.358)	(0.368)
Built 2010s	1.806	1.713	1.331	1.743
	(1.401)	(1.157)	(1.586)	(1.285)
City of London		1.075	-0.0139	1.160
		(1.206)	(1.290)	(2.401)
Docklands		3.914*	4.158**	3.894**
		(2.015)	(1.964)	(1.974)
Average Employment 500m			3.26e-05***	-2.57e-06
			(1.21e-05)	(5.40e-05)
Constant	6.634***	5.699***	4.734***	5.775***
	(0.339)	(1.234)	(1.257)	(1.729)
Observations	387	387	387	387
R-squared	0.441	0.457	0.468	0.455

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Wald chi2(14) = 117.14

In Table 9 we start with the famous architect and conservation area interaction and successively add controls as in the previous tables. As we can see, famous architect outside a conservation area is a significant predictor for the number of floors in the building, as well as 'built-in-conservation area' and all buildings built from the 1950s onwards. Similar to Table 7 and Table 8, the un-interacted famous architect dummy also has no effect upon the number of floors. In specification 4 we also attempt to instrument employment density. A Wald test yields 117.14, with a first stage R-squared of 0.455, and exogeneity of the instrumented variable is not rejected (Durbin-Wu-Hausman, p =.4639), and neither is the exogeneity of the instruments (Sargan-Hansen, p =.1044). However as in the floorspace per curtilage case, instrumented employment density loses its significance as an explanatory factor. Notice that the coefficients for famous architect outside conservation areas across the four regressions in Table 9 averages about 20 floors. If we assume 3m per floor, that would mean that office buildings built by a famous architect outside a conservation area are on average 60m taller than all other buildings. Recall that 24m was the maximum allowable height of buildings to the roof cornice built between 1894 and 1956.

Though perhaps not as obvious a characteristic as building taller, buildings on a given plot of land can also be bigger because their footprints take up more of the available land-plot. However there is a limit to this type of growth in that the ratio of the footprint/curtilage cannot exceed 1[55]. To test whether famous architects since 1956 outside conservation areas have also been allowed to build 'wider', for the dependent variable in the next set of regressions we use the ratio of the area of the building footprint over the total area of the building curtilage. White tests reject homoskedasticity and therefore robust standard errors are reported. The results of these regressions are displayed in Table 10.

[55] A possibly interesting exception to this rule is the 'walkie-talkie' building under-construction at 20 Fenchurch Street in the City of London. With a tapered base and bulging towards its roof, this office building may be an example of overcoming the floorspace limitations imposed by both height restrictions and plot size (see Table 5). Such design was also typical of Tudor era buildings of the 15th and 16th century which sported overhanging upper floors to increase the amount of total floorspace while simultaneously reducing their taxable building footprint.

Table 10: Dependent variable is building Footprint area / Curtilage area

VARIABLES	(1) OLS Footprint/ Curtilage	(2) OLS Footprint/ Curtilage	(3) OLS Footprint/ Curtilage	(4) IV2SLS Footprint/ Curtilage
Famous Architect outside Conservation Area	6.58e-05	-0.0354	-0.0441	-0.0667
	(0.127)	(0.125)	(0.128)	(0.143)
Famous Architect	-0.0933	-0.0798	-0.0878	-0.109**
	(0.0656)	(0.0678)	(0.0614)	(0.0500)
Built in Conservation Area	0.0690***	0.0666***	0.0631***	0.0539***
	(0.0159)	(0.0176)	(0.0173)	(0.0209)
Average Office Permission Refusal Rate	-0.603***	-1.306***	-1.216***	-0.979**
	(0.132)	(0.480)	(0.459)	(0.465)
Built 1950s	-0.0141	-0.00827	-0.00606	-0.000293
	(0.0252)	(0.0238)	(0.0261)	(0.0337)
Built 1960s	-0.147***	-0.141***	-0.133***	-0.111*
	(0.0491)	(0.0488)	(0.0509)	(0.0582)
Built 1970s	-0.161***	-0.150***	-0.145***	-0.132***
	(0.0451)	(0.0451)	(0.0434)	(0.0422)
Built 1980s	-0.0648***	-0.0605***	-0.0592***	-0.0557**
	(0.0205)	(0.0229)	(0.0224)	(0.0234)
Built 1990s	-0.0756***	-0.0682***	-0.0706***	-0.0769***
	(0.0215)	(0.0244)	(0.0240)	(0.0252)
Built 2000s	-0.0484**	-0.0447**	-0.0429*	-0.0381
	(0.0189)	(0.0220)	(0.0219)	(0.0240)
Built 2010s	-0.0895***	-0.0931***	-0.111***	-0.158*
	(0.0140)	(0.0173)	(0.0344)	(0.0938)
City of London		-0.0926*	-0.144**	-0.277*
		(0.0555)	(0.0601)	(0.142)
Docklands		0.0504	0.0619	0.0919*
		(0.0377)	(0.0392)	(0.0517)
Average Employment 500m			1.53e-06**	5.51e-06
			(6.09e-07)	(3.74e-06)
Constant	1.029***	1.115***	1.069***	0.951***
	(0.0130)	(0.0527)	(0.0516)	(0.114)
Observations	387	387	387	387
R-squared	0.182	0.198	0.217	0.088

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Wald chi2(14) = 64.71

As is evident from Table 10, buildings built by famous architects outside conservation areas do not have bigger footprints for a given curtilage in any of the four specifications. Interestingly, the footprint of buildings built inside a conservation area take up significantly more of the available land-plot. Perhaps in consequence of not being able to build as many floors (Table 9), in conservation areas developers maximize the dimensions upon which they do have greater discretion. In addition, since the 1950s buildings have reduced the ratio of footprint to curtilage. This may have come about due to developers building tall but also being constrained by plot-area ratios to simultaneously build narrow. In specification 4 the employment density instruments have a Wald statistic of 64.71, the first-stage regression has an R-squared of .0876, and exogeneity of the instrumented variable (p =.2406) and the instruments (p =.2257) are not rejected. However as in the previous tests when employment density is instrumented in specification 4, the instrumented employment density no longer has a significant impact on the dependent variable. In addition, in the 2SLS specification famous architect registers a significantly negative coefficient, which may appear perverse. However, a common requirement in order to build tall is that the ratio of the building's footprint to its curtilage[56] must be smaller, so as to allow extra light to shine at street level and to prevent buildings from intensifying high winds through funnel effects. This effect should be most pronounced for tall buildings, presumably those built by famous architects. So the significance of this term could possibly be accounted for by the fact that famous architects must build somewhat narrower in order to build much taller.

Now that we have confirmed that famous architects build bigger because they can build taller-but not wider, we now examine whether famous architects can also increase the sale price of buildings they design for a given curtilage. Although we know that famous architects can put more space on top of a given curtilage from Table 7 and Table 9, we do not know what the effect of the architect's design will have on the building's value *per* square metre. On the one hand, tenants may appreciate and pay more for good architecture. But on the other, famous architects may impart greater costs on building owners due to the maintenance costs involved with eccentric design or reduced flexibility with planning authorities to later alter or refurbish the building. Therefore, there may be a number of simultaneously confounding effects that bundle into the variable 'famous architect', making it difficult to predict ex-ante what the net effect of all of these influences will be. Although

[56] As opposed to maximum plot-ratios discussed earlier with regard to development planning.

we may presume there to be a positive effect given that developers do continue to solicit the services of famous architects in spite of their higher fees.

To test the net effect of famous architect on building price controlling for the amount of space already in the building, we regress office price per square meter on the hedonic controls. The results of these regressions are shown in Table 11. Note that whereas the previous regressions were analysing the physical characteristics of 387 buildings, the sample size now consists of the 513 sale-transactions of these 387 buildings completed between 2000-2011. White tests do not reject homoscedasticity and so normal standard errors are reported.

Table 11: Dependent variable is the natural log of (Price / Total floorspace sqm)

VARIABLES	(1) OLS Ln(Price/ Sqm)	(2) OLS Ln(Price/ Sqm)	(3) OLS Ln(Price/ Sqm)	(4) OLS Ln(Price/ Sqm)
Famous Architect	-0.281***	-0.332***	-0.177**	-0.223**
	(0.101)	(0.0978)	(0.0899)	(0.0865)
Within Conservation Area	0.0757*	0.0682*	0.0209	0.0280
	(0.0402)	(0.0394)	(0.0368)	(0.0360)
Listed Bldg	-0.00199	-0.0300	-0.0261	-0.0388
	(0.0536)	(0.0574)	(0.0475)	(0.0506)
Ln(Office Permission Refusal Rate 9yr Moving Average)	0.0418***	0.0435***	0.0278*	0.0301**
	(0.0141)	(0.0136)	(0.0156)	(0.0150)
Ln(Employment Density 500m)	0.109***	0.0894***	0.179***	0.157***
	(0.0281)	(0.0273)	(0.0344)	(0.0331)
Ln(Conservation Area Density 300m)	0.0209**	0.0245***	0.00634	0.00779
	(0.00813)	(0.00787)	(0.00902)	(0.00871)
Ln(Listed Bldg Density 300m)	0.0182	0.0218*	0.0203	0.0233
	(0.0128)	(0.0123)	(0.0152)	(0.0147)
Ln(Park and Garden Density 300m)	0.00897***	0.00845***	0.00938***	0.00937***
	(0.00290)	(0.00281)	(0.00270)	(0.00261)
Adjacent to Park or Garden	0.267***	0.211***	0.185***	0.147***
	(0.0526)	(0.0518)	(0.0469)	(0.0458)
Ln(Nearest Rail Station Distance)	0.0274	0.00493	0.0121	-0.00527
	(0.0306)	(0.0297)	(0.0278)	(0.0269)
Ln(Number of Above-Ground Floors)	0.275***	0.343***	0.153***	0.206***
	(0.0583)	(0.0593)	(0.0528)	(0.0539)
Ln(Depreciation Age)	-0.0135*	-0.00796	-0.0161**	-0.00759
	(0.00747)	(0.00763)	(0.00661)	(0.00673)
Ln(Basements/Total Floors)	-0.00965	-0.0211**	-0.00905	-0.0205**

	(0.00949)	(0.00936)	(0.00841)	(0.00830)
A/C	0.339***	0.243***	0.263***	0.202**
	(0.0897)	(0.0882)	(0.0804)	(0.0787)
EG Office Grade A/B	0.0728	0.0466	0.0640	0.0352
	(0.0494)	(0.0493)	(0.0438)	(0.0434)
EG Office Grade A	0.154***	0.0786*	0.159***	0.0830**
	(0.0436)	(0.0447)	(0.0388)	(0.0395)
Ln(Percent Occupied)	0.0364***	0.0295***	0.0364***	0.0299***
	(0.00933)	(0.00909)	(0.00821)	(0.00796)
Multiple Tenant Bldg	-0.0536	-0.0895**	-0.0659*	-0.106***
	(0.0389)	(0.0384)	(0.0344)	(0.0337)
Ln(Parking Spaces)	-0.00119	0.00137	0.00239	0.00412
	(0.00408)	(0.00401)	(0.00359)	(0.00352)
Built 1950s		-0.144		-0.200**
		(0.0889)		(0.0780)
Built 1960s		-0.372***		-0.252***
		(0.0783)		(0.0694)
Built 1970s		-0.253***		-0.214***
		(0.0780)		(0.0688)
Built 1980s		-0.0883		-0.0656
		(0.0571)		(0.0502)
Built 1990s		-0.000658		0.0278
		(0.0552)		(0.0489)
Built 2000s		0.115**		0.142***
		(0.0567)		(0.0500)
Built 2010s		0.0317		0.319
		(0.258)		(0.229)
City Fringe			-0.307***	-0.318***
			(0.0781)	(0.0764)
Docklands			0.256	0.184
			(0.228)	(0.218)
Midtown			-0.0187	-0.0309
			(0.0585)	(0.0575)
North Central			0.104	0.0148
			(0.147)	(0.142)
South Central			-0.0741	-0.0730
			(0.122)	(0.118)
Southern Fringe			-0.00216	0.0278
			(0.110)	(0.106)
West Central			0.213	0.232*
			(0.133)	(0.128)
West End			0.333***	0.314***
			(0.0686)	(0.0667)
Quarter Sold	YES	YES	YES	YES
Constant	5.917***	6.254***	5.548***	5.867***
	(0.352)	(0.344)	(0.410)	(0.396)
Observations	513	513	513	513
R-squared	0.439	0.493	0.578	0.621

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The four regressions alternately add controls for decade built and submarket location. Notice that now the conservation area control is now testing whether a building is currently located within a conservation area, and not whether the building was built while a surrounding conservation area was in force as in the previous regressions. We see that there is some evidence for the value imparted by being within a conservation area in the first two specifications with the 'Within Conservation Area' and 'Conservation Area Density 300m' variables. But when submarket location dummies are added to the regression we see that this relationship gets subsumed into them. Since we simultaneously test the effect of being located within a conservation area, it may be the case that the 'Conservation Area Density 300m' variable is separately picking up the positive effect on price of reduced local supply rather than an additional measure of the positive externality resulting from the aesthetics of the surrounding area. We also see from Table 11 that office planning permission refusal rate, parks and gardens, the number of above ground floors, A/C. building grade, employment density, and the occupancy rate of the building have significantly positive effects, while the ratio of basement to above ground floors and multiple tenanted (as opposed to single occupier) buildings sell for a significant discount. Perhaps unsurprisingly, the depreciation age variable loses its negative effect when decade built dummies are included in the regression.

However, the main result from these regressions is to note that famous architects have a demonstrably negative effect on the sale price of office buildings. This result is not contrary to our previous findings that famous architects increase building size because the above regressions control for the amount of total space in the building in the construction of the dependent variable (Price/Sqm). Given this negatively-signed relationship it would appear that famous architect-built buildings may have supernumerary costs of upkeep per sqm and/or additional (implicit) regulatory restrictions due to their celebrated-status that outweigh the benefits captured internally by good design. To examine this effect further, Table 12 specification 1 below splits the famous architect coefficient into pre-and post-modern architects, to see whether older or newer design has a different effect on sale prices. Specifications 2 and 3 also instrument for employment density.

Table 12: Dependent variable is the natural log of (Price / Total floorspace sqm)

VARIABLES	(1) OLS Ln(Price/ Sqm)	(2) IV2SLS Ln(Price/ Sqm)	(3) IV2SLS Ln(Price/ Sqm)
Famous Architect		-0.202**	
		(0.0856)	
Modern Famous Architect	0.00924		0.0385
	(0.111)		(0.111)
Pre-Modern Famous Architect	-0.560***		-0.542***
	(0.133)		(0.132)
Within Conservation Area	0.0317	0.0577	0.0668
	(0.0356)	(0.0434)	(0.0437)
Listed Bldg	-0.0138	-0.0336	-0.00720
	(0.0506)	(0.0492)	(0.0501)
Ln(Office Permission Refusal Rate 9yr Moving Average)	0.0307**	0.00107	-0.00358
	(0.0149)	(0.0292)	(0.0295)
Ln(Employment Density 500m)	0.157***	-0.0621	-0.102
	(0.0327)	(0.194)	(0.196)
Ln(Conservation Area Density 300m)	0.00673	0.0138	0.0138
	(0.00862)	(0.00993)	(0.00999)
Ln(Listed Bldg Density 300m)	0.0278*	0.0389**	0.0462**
	(0.0146)	(0.0196)	(0.0199)
Ln(Park and Garden Density 300m)	0.00952***	0.00761**	0.00745**
	(0.00258)	(0.00296)	(0.00298)
Adjacent to Park or Garden	0.149***	0.158***	0.161***
	(0.0453)	(0.0452)	(0.0455)
Ln(Nearest Rail Station Distance)	-0.0111	0.00991	0.00670
	(0.0267)	(0.0292)	(0.0294)
Ln(Number of Above-Ground Floors)	0.168***	0.255***	0.225***
	(0.0545)	(0.0675)	(0.0685)
Ln(Depreciation Age)	-0.00885	-0.00734	-0.00857
	(0.00666)	(0.00651)	(0.00657)
Ln(Basements/Total Floors)	-0.0207**	-0.0195**	-0.0195**
	(0.00820)	(0.00807)	(0.00813)
A/C	0.225***	0.206***	0.230***
	(0.0781)	(0.0762)	(0.0771)
EG Office Grade A/B	0.0319	0.0304	0.0261
	(0.0429)	(0.0422)	(0.0425)
EG Office Grade A	0.0884**	0.0605	0.0619
	(0.0391)	(0.0430)	(0.0433)
Ln(Percent Occupied)	0.0267***	0.0328***	0.0300***
	(0.00793)	(0.00810)	(0.00819)
Multiple Tenant Bldg	-0.0998***	-0.0989***	-0.0915***
	(0.0334)	(0.0332)	(0.0335)
Ln(Parking Spaces)	0.00433	0.000337	-0.000119
	(0.00348)	(0.00474)	(0.00477)
Built 1950s	-0.197**	-0.218***	-0.218***
	(0.0772)	(0.0771)	(0.0777)
Built 1960s	-0.239***	-0.269***	-0.258***
	(0.0688)	(0.0687)	(0.0693)

Built 1970s	-0.215***	-0.214***	-0.215***
	(0.0680)	(0.0665)	(0.0670)
Built 1980s	-0.0668	-0.0512	-0.0498
	(0.0496)	(0.0501)	(0.0505)
Built 1990s	0.0245	0.0479	0.0482
	(0.0484)	(0.0505)	(0.0508)
Built 2000s	0.130***	0.164***	0.156***
	(0.0495)	(0.0521)	(0.0525)
Built 2010s	0.323	0.402*	0.420*
	(0.227)	(0.233)	(0.235)
City Fringe	-0.339***	-0.416***	-0.455***
	(0.0758)	(0.113)	(0.114)
Docklands	0.180	0.196	0.195
	(0.216)	(0.212)	(0.213)
Midtown	-0.0366	-0.110	-0.130
	(0.0569)	(0.0887)	(0.0894)
North Central	0.00830	-0.439	-0.527
	(0.140)	(0.419)	(0.422)
South Central	-0.0761	-0.313	-0.359
	(0.116)	(0.238)	(0.240)
Southern Fringe	0.0239	-0.145	-0.180
	(0.105)	(0.182)	(0.184)
West Central	0.230*	-0.314	-0.414
	(0.127)	(0.492)	(0.496)
West End	0.306***	0.136	0.0958
	(0.0660)	(0.168)	(0.170)
Quarter Sold	YES	YES	YES
Constant	5.897***	7.678***	8.034***
	(0.391)	(1.626)	(1.640)
Observations	513	513	513
R-squared	0.630	0.583	0.577

Standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

With regard to the instrumental variable estimations in specifications 2 and 3, in both cases the Wald Statistic exceeds 700 and the Durbin-Wu-Hausman tests do not reject exogeneity. But unfortunately Sargan-Hansen tests reject exogeneity of the instrument, and again the coefficient on instrumented employment density is insignificant in the second-stage. As we can see from Table 12 most of the results from Table 11 are robust to the IV specifications, including the effects of famous architects. Moreover, there is now an interesting split observed between modern and pre-modern architects. Whereas modern architects apparently have no net effect on the price per sqm of their buildings, pre-modern architects have a strongly negative influence[57]. This difference could be explained if we consider that buildings built by pre-modern famous architects may have exceptionally restrictive regulatory monitoring in practice, perhaps in order to ensure the preservation of their work in perpetuity. These additional restrictions and the concomitant attenuation in property rights could explain the differential effect between modern and pre-modern architects. Since the modern architect dummy variable is not significantly positive, we can infer that either the positive effects of famous architecture on sale prices are small or that the additional restrictions on property rights are material enough to cancel out these positive benefits. Another possibility for the negative effect of famous architect design is that the prestige surrounding buildings built by famous architects may help to secure higher occupancy rates and that simultaneous inclusion of this variable with famous architect in the model strips famous architect of this positive effect. Although this explanation is plausible, a restricted regression run with the occupancy rate excluded refutes this interpretation as the coefficients on pre and post-modern famous architect are nearly unchanged in this specification[58].

Although the price/sqm is negatively affected or unaffected by being designed by a famous architect (Table 11), modern architects have also been able to build more space outside a conservation area on a given plot of land (Table 7). To see what the net effect of more (but perhaps cheaper) space has on the value of office properties, Table 13 regresses sales price/curtilage on relevant hedonic controls. Note that unlike the regressions in Table 11 and Table 12, the variable for the number of above-ground floors is omitted in the first four regressions of Table 13 because this would steal the very effect on price/curtilage we wish to capture in a building designed by a famous architect outside a conservation area. In addition, variables for whether the building is currently in a conservation area, and whether the building was built while inside a conservation area are added. The reason both are needed is that while the first may affect the sale price per sqm of the building, the second may affect the size of the building, and both are relevant when determining the price per

[57] A test for the equality of the coefficients on modern and pre-modern architects is rejected at the 1% level (p=0.0027).
[58] See ‘Appendix E: Occupancy rate excluded comparison’.

curtilage. White tests on the regression errors reject homoskedasticity, and so robust standard errors are reported for all specifications. The results of these regressions are displayed below in Table 13.

Table 13: Dependent variable is the natural log of (Price / Curtilage sqm)

VARIABLES	(1) OLS Ln(Price/ Curtilage	(2) OLS Ln(Price/ Curtilage	(3) OLS Ln(Price/ Curtilage	(4) OLS Ln(Price/ Curtilage	(5) OLS Ln(Price/ Curtilage
Famous Architect outside Conservation Area	1.185***	1.092***	1.187***	1.117***	1.156***
	(0.249)	(0.234)	(0.189)	(0.175)	(0.319)
Famous Architect	-0.484***	-0.484***	-0.391***	-0.398***	
	(0.127)	(0.109)	(0.139)	(0.129)	
Modern Famous Architect					-0.438
					(0.296)
Pre-Modern Famous Architect					-0.384***
					(0.142)
Within Conservation Area	0.0304	0.0537	-0.0671	-0.0525	-0.0528
	(0.0673)	(0.0848)	(0.0630)	(0.0818)	(0.0819)
Built in Conservation Area	-0.0978	-0.157	-0.000906	-0.0344	-0.0333
	(0.0718)	(0.103)	(0.0620)	(0.0953)	(0.0958)
Listed Bldg	-0.0916	-0.119	-0.0951	-0.139*	-0.140*
	(0.0726)	(0.0769)	(0.0707)	(0.0775)	(0.0779)
Ln(Office Permission Refusal Rate 9yr Moving Average)	0.0213	0.0209	0.0116	0.0131	0.0131
	(0.0210)	(0.0206)	(0.0211)	(0.0202)	(0.0202)
Ln(Employment Density 500m)	0.282***	0.272***	0.218***	0.206***	0.205***
	(0.0442)	(0.0428)	(0.0533)	(0.0510)	(0.0513)
Ln(Conservation Area Density 300m)	-0.00433	-0.00330	-0.0163	-0.0166	-0.0166
	(0.0118)	(0.0125)	(0.0142)	(0.0145)	(0.0145)
Ln(Listed Bldg Density 300m)	0.0209	0.0249	0.0292	0.0327*	0.0327*
	(0.0201)	(0.0195)	(0.0194)	(0.0194)	(0.0194)
Ln(Park and Garden Density 300m)	0.0197***	0.0192***	0.0166***	0.0169***	0.0169***
	(0.00402)	(0.00408)	(0.00382)	(0.00381)	(0.00381)
Adjacent to Park or Garden	0.297***	0.240***	0.189***	0.157**	0.156**
	(0.0755)	(0.0771)	(0.0689)	(0.0693)	(0.0696)
Ln(Nearest Rail Station Distance)	-0.00618	-0.0280	0.00149	-0.0105	-0.0102
	(0.0514)	(0.0547)	(0.0475)	(0.0500)	(0.0502)
Ln(Depreciation Age)	-0.0198*	-0.0136	-0.0226**	-0.0133	-0.0133
	(0.0102)	(0.0100)	(0.00889)	(0.00927)	(0.00931)
Ln(Basements/Total Floors)	-0.00714	-0.0183	-0.00557	-0.0180	-0.0181
	(0.0147)	(0.0141)	(0.0144)	(0.0135)	(0.0135)
A/C	0.602***	0.545***	0.475***	0.449***	0.449***
	(0.118)	(0.125)	(0.128)	(0.130)	(0.130)
EG Office Grade A/B	0.324***	0.319***	0.275***	0.265***	0.265***
	(0.0703)	(0.0704)	(0.0654)	(0.0655)	(0.0658)

EG Office Grade A	0.458***	0.404***	0.412***	0.362***	0.361***
	(0.0650)	(0.0658)	(0.0579)	(0.0587)	(0.0589)
Ln(Percent Occupied)	0.0306*	0.0249	0.0321**	0.0260*	0.0261*
	(0.0156)	(0.0152)	(0.0140)	(0.0139)	(0.0140)
Multiple Tenant Bldg	0.0543	0.00977	0.0358	-0.00828	-0.00848
	(0.0552)	(0.0550)	(0.0502)	(0.0505)	(0.0506)
Ln(Parking Spaces)	0.00554	0.00753	0.00576	0.00794	0.00795
	(0.00545)	(0.00570)	(0.00486)	(0.00510)	(0.00511)
Built 1950s		-0.131		-0.269**	-0.269**
		(0.140)		(0.123)	(0.124)
Built 1960s		-0.232*		-0.191	-0.191
		(0.129)		(0.124)	(0.124)
Built 1970s		-0.0991		-0.118	-0.118
		(0.119)		(0.113)	(0.114)
Built 1980s		-0.0905		-0.120	-0.121
		(0.104)		(0.0997)	(0.100)
Built 1990s		-0.00719		-0.0477	-0.0483
		(0.101)		(0.0981)	(0.0984)
Built 2000s		0.214**		0.153	0.154
		(0.0984)		(0.0941)	(0.0942)
Built 2010s		-0.235		0.104	0.104
		(0.611)		(0.439)	(0.440)
City Fringe			-0.517***	-0.541***	-0.542***
			(0.102)	(0.0999)	(0.100)
Docklands			0.253	0.194	0.193
			(0.330)	(0.322)	(0.323)
Midtown			-0.0812	-0.106	-0.107
			(0.0726)	(0.0710)	(0.0713)
North Central			-0.532***	-0.627***	-0.628***
			(0.204)	(0.203)	(0.204)
South Central			-0.427**	-0.445**	-0.446**
			(0.202)	(0.199)	(0.200)
Southern Fringe			-0.263	-0.261	-0.261
			(0.177)	(0.185)	(0.186)
West Central			-0.368*	-0.369*	-0.371*
			(0.197)	(0.196)	(0.198)
West End			0.216**	0.185**	0.185**
			(0.0921)	(0.0919)	(0.0924)
Quarter Sold	YES	YES	YES	YES	YES
Constant	6.020***	6.336***	6.692***	6.994***	6.999***
	(0.514)	(0.528)	(0.552)	(0.560)	(0.561)
Observations	513	513	513	513	513
R-squared	0.483	0.508	0.591	0.611	0.611

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Notice that in specifications 1-4 the famous architect outside conservation area and famous architect coefficients are both significant, but in different directions. With famous architects outside of conservation areas able to produce higher priced buildings on a given curtilage, but famous architects overall producing lower priced buildings. The net effect of being a building built by a famous architect outside a conservation area is the additive combination of the famous architect and famous architect outside conservation area coefficients. We see that in specifications 1-4 the interactive benefit of a famous architect building built in a conservation area outweighs the negative costs associated with its design. In specification 5 the famous architect coefficient is split between modern and pre-modern architects. In this case a test for the equality of these coefficients cannot reject the null hypothesis that they are in fact equal (p =.8505). In the most preferred specifications 4 and 5, the net effect of these two factors is approximately 0.7, or roughly a 100% increase in building price for a given curtilage[59]. Of course, this result is only the gross sale price increase and does not account for additional costs which accrue to building taller and hiring a trophy architect. Buildings inside a conservation area however which cannot build appreciably taller may struggle to derive sufficient compensation from the drawbacks of famous architect design, as their coefficients are either negative or statistically indistinguishable from zero.

Table 14 utilizes a 2SLS instrument for employment density in specification 1, and specification 2 is the same as the preferred specification 4 in Table 13 with a control added for the number of floors. The intention of adding the number of floors to the estimation is to see whether it will steal the positive significant effect on famous architect outside conservation area, since this is how we suppose famous architects are able to increase the price of buildings on a given curtilage.

[59] See Kennedy (1981) for the exact calculation of the effect of dummy variables in a log-log regression, which differs from a continuous variable.

Table 14: Dependent variable is the natural log of (Price / Curtilage sqm).

VARIABLES	(1) IV2SLS Ln(Price/ Curtilage)	(2) OLS Ln(Price/ Curtilage)
Famous Architect outside Conservation Area	1.187***	0.347*
	(0.275)	(0.178)
Famous Architect	-0.410**	-0.351***
	(0.159)	(0.116)
Within Conservation Area	-0.0302	-0.00726
	(0.0924)	(0.0775)
Built in Conservation Area	-0.0455	0.0203
	(0.0907)	(0.0886)
Listed Bldg	-0.136*	-0.0949
	(0.0700)	(0.0690)
Ln(Office Permission Refusal Rate 9yr Moving Average)	-0.00250	0.00234
	(0.0408)	(0.0170)
Ln(Employment Density 500m)	0.0869	0.163***
	(0.272)	(0.0448)
Ln(Conservation Area Density 300m)	-0.0139	-0.00196
	(0.0133)	(0.0149)
Ln(Listed Bldg Density 300m)	0.0414	0.0396**
	(0.0281)	(0.0178)
Ln(Park and Garden Density 300m)	0.0160***	0.0156***
	(0.00415)	(0.00346)
Adjacent to Park or Garden	0.162**	0.156***
	(0.0635)	(0.0574)
Ln(Nearest Rail Station Distance)	-0.00371	0.0191
	(0.0398)	(0.0442)
Ln(Depreciation Age)	-0.0134	-0.0102
	(0.00917)	(0.00888)
Ln(Basements/Total Floors)	-0.0178	-0.00842
	(0.0113)	(0.0126)
A/C	0.458***	0.312**
	(0.108)	(0.130)
EG Office Grade A/B	0.267***	0.123**
	(0.0580)	(0.0606)
EG Office Grade A	0.354***	0.239***
	(0.0553)	(0.0543)
Ln(Percent Occupied)	0.0272**	0.0286**
	(0.0113)	(0.0135)
Multiple Tenant Bldg	-0.00408	-0.0164
	(0.0470)	(0.0462)
Ln(Parking Spaces)	0.00621	0.000397
	(0.00616)	(0.00476)
Ln(Number of Above-Ground Floors)		0.742***
		(0.0804)
Built 1950s	-0.274**	-0.334**
	(0.108)	(0.130)
Built 1960s	-0.188**	-0.450***
	(0.0947)	(0.118)

Built 1970s	-0.108	-0.229**
	(0.110)	(0.107)
Built 1980s	-0.108	-0.0665
	(0.0920)	(0.0912)
Built 1990s	-0.0301	-0.0677
	(0.0970)	(0.0917)
Built 2000s	0.173*	0.104
	(0.101)	(0.0895)
Built 2010s	0.158	0.0206
	(0.340)	(0.370)
City Fringe	-0.603***	-0.323***
	(0.174)	(0.0872)
Docklands	0.194	0.324
	(0.298)	(0.308)
Midtown	-0.151	-0.0830
	(0.128)	(0.0580)
North Central	-0.883	-0.389**
	(0.609)	(0.182)
South Central	-0.580*	-0.258
	(0.345)	(0.160)
Southern Fringe	-0.359	-0.0981
	(0.265)	(0.163)
West Central	-0.673	-0.228
	(0.708)	(0.174)
West End	0.0858	0.220***
	(0.242)	(0.0792)
Quarter Sold	YES	YES
Constant	8.017***	5.921***
	(2.368)	(0.521)
Observations	513	513
R-squared	0.606	0.680

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Wald chi2(14) = 773.95

As in the price per sqm regressions, although employment density is well explained by the instruments in the first-stage (Wald=773.95), and Durbin-Wu-Hausman tests do not reject exogeneity of the instrumented variable, Sargan-Hansen tests reject exogeneity of the instruments and as we can see from Table 14 specification 1, the coefficient is insignificant in the second stage. In any event, the coefficients on famous architect outside of a conservation area and famous architect are of similar magnitudes in the IV2SLS specification to the OLS specifications in Table 13. With the number of floors added in Table 14 OLS specification 2, we see that famous architects outside a conservation area lose most of their statistical significance in increasing the price of the building, and the negative effect of famous architect is largely unchanged. In spite of the fact that the 'Famous Architect outside Conservation Area' variable is significantly positive at the 10% level, the net effect of this with 'Famous Architect' is now almost exactly equal to zero. It therefore appears that, consistent with the results of Table 13 and Table 9, the ability of famous architects outside a conservation area to increase the price of a building on a given curtilage is indeed due to the fact that they can build taller.

The robustness checks in 'Appendix F: Robustness checks' which sequentially exclude the tallest famous architect buildings outside conservation areas from the preferred specification of floorspace/curtilage in Table 8, the number of above ground floors in Table 9, and the price/curtilage in Table 13 are all consistent with the full sample results presented above. Taken together, it appears that although famous architects negatively influence or have no influence on the price per unit of floorspace (Table 11 and Table 12), because of the fact that they can stack more units of floorspace up on a given amount of land (Table 7 and Table 9), on net famous architects appear to be able to increase the price of buildings built on a given land area (Table 13), so long as they have the freedom to build tall outside of a conservation area.

Discussion

Economic Rents

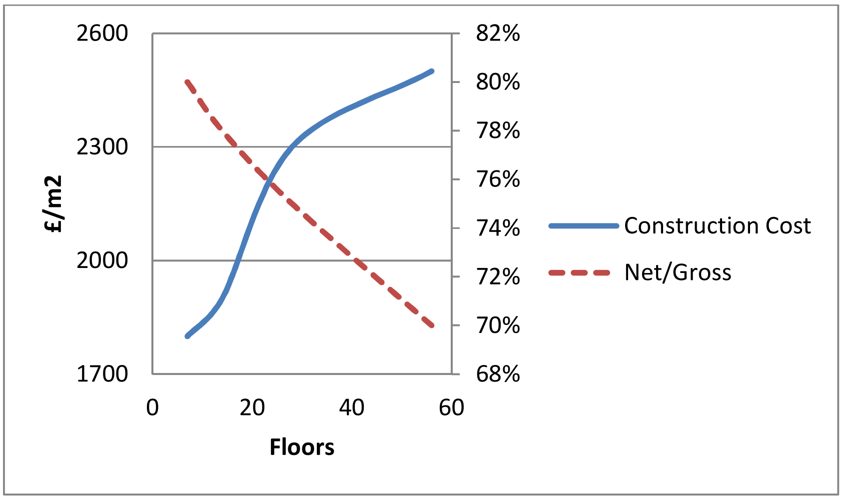
From Table 9 we know that famous architects outside a conservation area can increase the number of floors in their buildings by approximately 20, with a standard deviation of about 6. This would mean that utilizing a famous architect would allow a developer to go from an original allowable building height of 8 (our sample mean[60]) to 28 floors. Just how valuable is this increase in floorspace to a developer? In order to answer this question we utilize; (i) permissible development area land cost, (ii) gross internal area construction costs for standard and trophy architect designed office buildings by height, (iii) design costs for standard and trophy architects, and (iv) net-to-gross floorplate ratios by building height[61]. The hypothetical building in question is supposed to have a 1,600m^2 footprint (i.e. 40m a

[60] See 'Appendix C: Descriptive statistics'.
[61] The ratio of lettable space to gross internal area, see 'Appendix D: Net-to-gross internal area ratio'.

side squared, our sample mean) and to be located in the City of London. All office construction cost data was provided by the construction consultants Gardiner & Theobald.

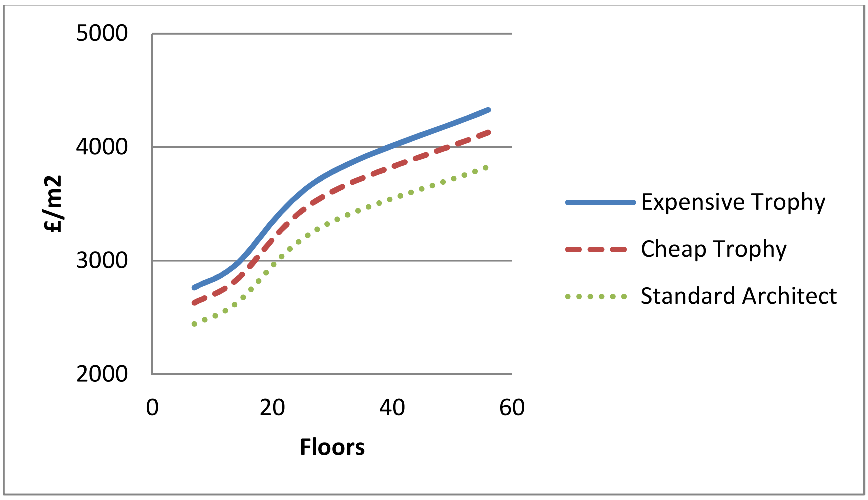
The data from Gardiner & Theobald shows that construction cost per sqm rises most steeply between floors 20 to 30, but is comparatively flat for buildings both below and above this height. This relationship is graphed in Figure 7 below with the net-to-gross ratio as a function of the number of floors.

Figure 7: Construction costs only (per sqm) and net to gross ratios as a function of building height



Adding land and design costs to construction costs we arrive at an estimate for the total building cost. However, trophy architects charge a fee premium compared to standard architects, and the buildings they design will generally incur additional construction costs over-and-above that of a standard building. Estimates for these cost differences were also provided by Gardiner & Theobald. Figure 8 below maps out the standard total construction cost for a standard office building, and an expensive and 'cheap' trophy architect office building. The expensive and cheap trophy architect buildings assume upper and lower bound estimates for land and trophy construction costs, respectively.

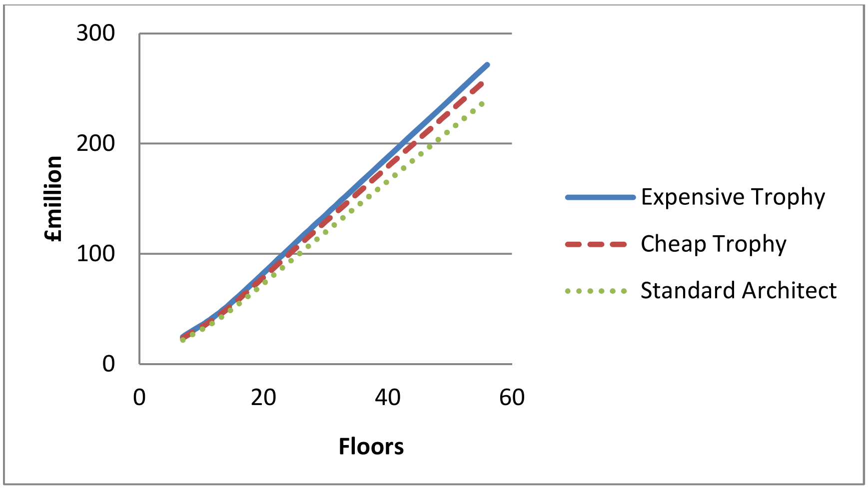
Figure 8: Total land, construction and design costs per sqm as a function of building height



Costs are for each lettable sqm, ie net of the net-to-gross ratio.

Figure 9 below shows how *total* (rather than per sqm) building costs increase with the number of floors.

Figure 9: Total land, construction and design costs as a function of building height



The next step is to derive estimates for the sale-price that can be achieved once the building is built and let. In order to construct these estimates we utilize the coefficients in Table 12 specification 1, and apply these to the sample means of the 167 buildings sold in City of

London throughout the study period, or to the particular values assumed[62]. These values are displayed below in Table 15.

Table 15: City of London means and assumed values

Variable	Actual Value Assumed
Modern Famous Architect	e†
Within Conservation Area	1‡
Listed	1
Office Permission Refusal Rate	0.28%
Employment Density 500m	67,217
Conservation Area (m^2) within 300m	123,207
Listed Buildings (m^2) within 300m	34,279
Parks & Gardens (m^2) within 300m	530
Adjacent to a Park	0.07
Distance to Nearest Station (m)	212
Floors	8.25
Depreciation Age	1
Basements per Floor	0.12
A/C	e
Office Space Grade A	e
Percent Occupied	0.89
Multiple Tenants	0.28
Parking Spaces	15

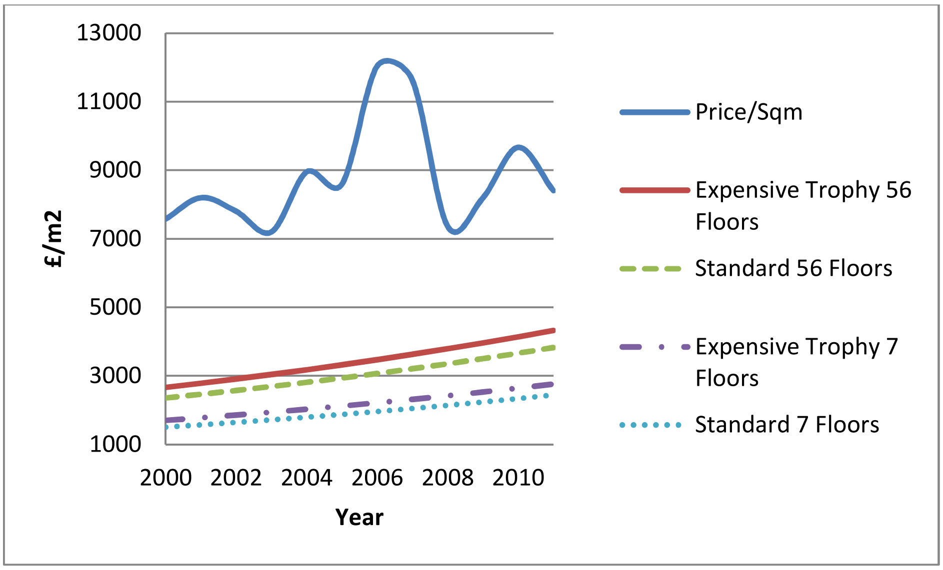
†ln(e)=1, i.e. the dummy variable is indicated in log form.
‡ln(1)=0, i.e. the dummy variable is not indicated in log form.

Using these assumed values combined with the fractionally time-weighted[63] time-dummy coefficients estimated from Table 12, we calculate an estimated sale-price/m^2 time-series for this hypothetical building across the study period. The results are displayed in Figure 10

[62] We assume that the building to be constructed is designed by a famous architect, outside a conservation area, is not listed, is brand new (no depreciation age), has A/C, and is Grade A (highest grade measured) office space. Other independent variables are assumed to be the sample mean of those properties exclusively located in the City of London.
[63] See chapter 3.

along with estimates for the cost/m^2 of expensive trophy architect and standard architect buildings by number of floors from 2000-2012 provided by Gardiner & Theobald.

Figure 10: Price per m^2 for 'average' office in City of London compared with building costs.



As we can see from the gap between prices and costs in Figure 10, there appears to be considerable profits to be earned from securing planning permission to build 'tall'. This has been true regardless of market conditions over the last decade and even assuming the additional costs involved with employing a trophy architect. Conservatively assuming a £7,000/m^2 price achieved at the time of sale[64], the 8-floor standard architect building will earn profits of £46m with a capital return[65] of 186%, and the 28-floor expensive trophy architect building will earn profits of £89m with a capital return of 71%. Notice that the trophy architect building earns 93% higher profits, which compares well with the 100% increase in revenues estimated earlier from Table 13 specifications 4 and 5. Since the two projects are mutually exclusive, if sufficient capital can be raised, ceteris paribus the 28-floor trophy architect building will yield greater profits and is the superior investment[66].

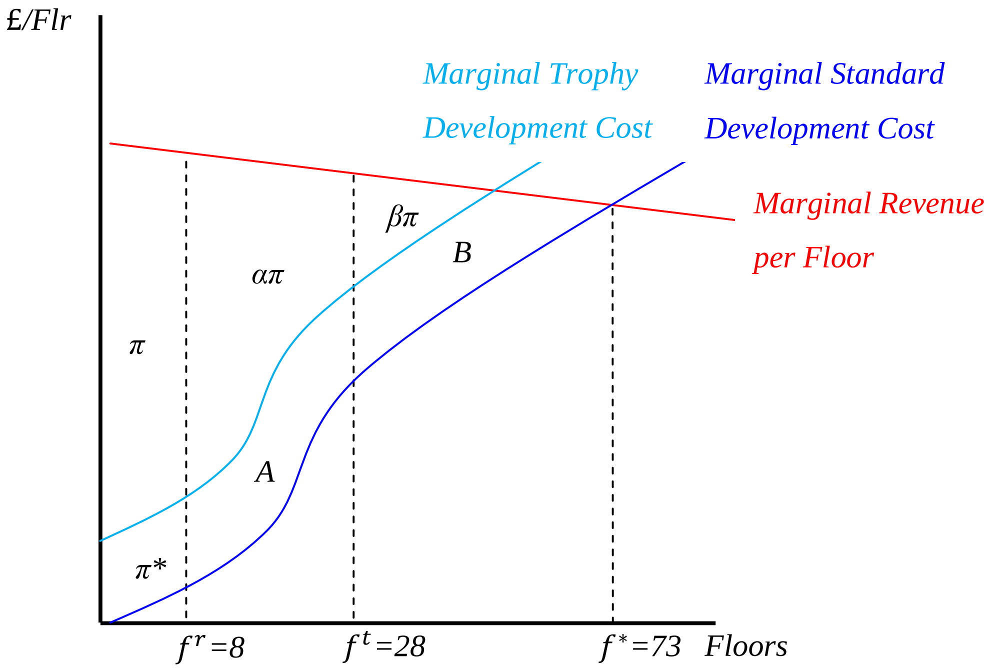
[64] At current 'prime' and 'grade A' rent levels this would suggest very plausible yields of 7.7% and 6.9%, repectively. Source: Gardiner & Theobald.
[65] Although an IRR would be ideal, we define capital return here as simply Profit/Cost.
[66] The cost of capital is subsumed in construction costs.

These results are formalized in Figure 11 below. On the vertical axis we have marginal revenues accruing from the sale of a building with an additional floor[67]. On the horizontal axis we have the number of floors in the building, which is a close approximation to supply. f^r represents the normal height restriction imposed on buildings by local councils, which in the City of London is approximately 8 floors. f^t is the average floor height achievable with a trophy architect outside a conservation area, which according to our estimates is 28 floors. And f^* represents the number of floors required to equate the marginal cost of an additional floor with the marginal revenue of an additional floor, that is, the number of floors at which profits are maximised. Using our cost data we find that standard buildings will achieve maximum profits at about 73 floors and trophy architects at about 65 floors[68]. Profit from building f^r floors is $\pi + \pi^*$ (presumably with a standard architect), and profit from building f^t floors with a trophy architect is $\pi + \alpha\pi$. The dead-weight loss on the famous architect project arising as a result of the increased cost of the trophy architect needed to build f^t floors relative to the standard architect is A. The fact that trophy architects are not allowed to build as tall as they wish leads to the dead-weight loss $\beta\pi$. And the total dead-weight loss to using a famous architect compared to a world with no height restrictions where developers of tall buildings can use the most efficient construction methods is $A + B + \beta\pi$.

[67] Note that marginal revenue per floor is downward sloping because the net to gross ratio decreases with building height, not because of assuming a downward sloping demand curve with respect to additional floors. Recent research by Koster, Ommeren, and Rietveld (2012) show in fact that each additional 10m in height adds 4% to the value of the building, in which case this demand curve would be upward sloping given the comparatively slow rate at which net-to-gross ratios decrease with the number of floors. As such the downward sloping revenue curve with respect to additional floors can be viewed as a conservative assumption.

[68] Standard architect and famous architect buildings would 'breakeven' under these assumptions with 140 and 135 floors respectively. Currently only one office building in the world, the 163 floor Burj Khalifa in Dubai has more floors than this, and the office building with the second greatest number of floors is the 118 floor International Commerce Centre in Hong Kong

Figure 11: Profitability of trophy architects



Taking our office price and cost information we can estimate these additional profits and dead-weight losses in Figure 11. Taking our above example we find that; $\pi^* = £3m, \pi = £43m, \alpha\pi = £46m, A = £32m$, and $\beta\pi + B = £45m$. This suggests that for a new office building in the City of London, height restrictions are preventing the developer and therefore society from realising gross gains of $A + \alpha\pi + B + \beta\pi = £123m$ for buildings by standard architects. To get an idea of the magnitude of these losses, this £123m represents a gross social welfare loss equivalent to 100% of the total cost of the 28-floor famous architect building, and 500% of the total cost of the 7-floor standard architect building.

Given the substantial extra profits to be earned from hiring a trophy architect to build tall the natural question to ask is why developers in London do not all hire famous architects to flex the planning controls. One potential rejoinder to this critique is that the actual costs to attempting to build tall are actually greater than those reported here or that the additional returns may be less certain. For instance in order to build exceptionally tall more extensive and detailed environmental impact statements may be required, legal assistance may be protracted, the architect may be asked to successively alter the building at various stages of the planning negotiation, the planning commission may take additional time to deliberate[69], and permission may still be ultimately refused at the local or municipal level (Kufner, 2011). Mayo and Sheppard (2001) refer to this type of costly, time-consuming, and uncertain process and outcome as 'stochastic development control'. These authors found that the regulatory variance (riskiness) of the development process was more important in reducing current supply than the actual length of planning delay. In order to assess the actual profit incentives facing developers to hire famous architects one must also account for the additional costs of proposing a large scale development to a local authority and rescale expected returns by a discount rate which appropriately takes account of the additional planning risks. Therefore the estimate above that profits can be nearly doubled from £46m to £89m merely by hiring a famous architect will be somewhat inflated as it does not take account of further planning and legal costs and assumes that successfully flexing planning controls with a famous architect is automatic. A further complication may be the fact that the additional returns estimated here from contracting a famous architect assume that upon sale the building will have the same occupancy rate as the sample average (89%). Of course in reality new developments may be speculative, and it is far from certain that the building will have filled with tenants upon completion. Indeed, major projects with planning permission are routinely paused or abandoned in London due to a failure to secure a sufficient number of pre-lets on the proposed new space. Unfortunately for this study, a more formal assessment of these additional costs and uncertainties will remain the domain of future research.

Regulatory tax

It may also be instructive to compare the 'regulatory tax[70]' produced by this dataset with the results originally reported in Cheshire and Hilber (2008). Following Cheshire and Hilber we define the regulatory tax R at time t in location j to be;

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[69] Kufner (2011) suggests that these additional regulatory demands increase the duration of the planning approval process for tall buildings by 1-2 years.

[70] The concept of 'regulatory tax' on new development was originally introduced by Glaeser et al (2005).

$$R_{tj} = \frac{V_{tj} - MCC_{tj}}{MCC_{tj}} = \frac{V_{tj}}{MCC_{tj}} - 1 \quad \textbf{(1)}$$

Where;

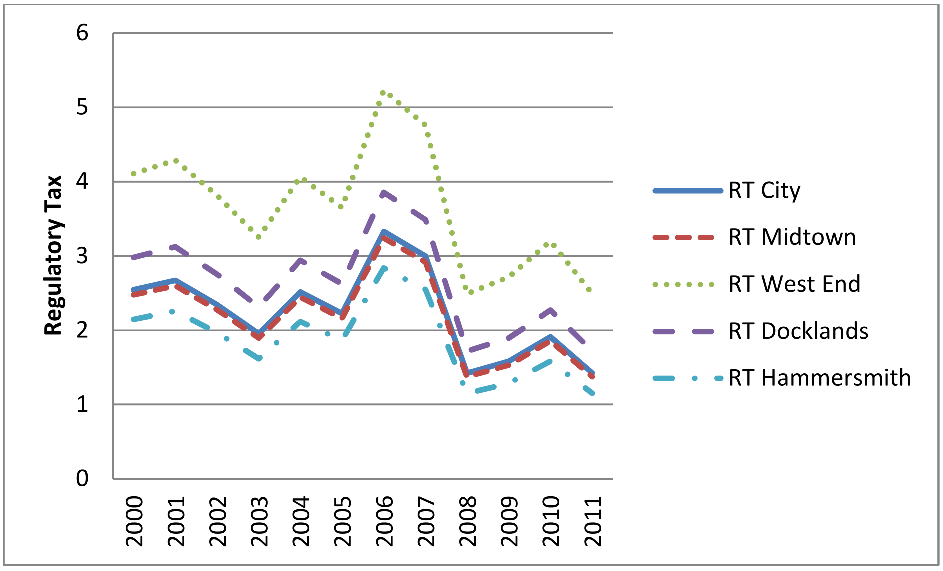
V_{tj} = The market price of an additional square metre of office space at time t in location j

MCC_{tj} = The corresponding marginal construction cost of adding a square metre of an additional floor

The regulatory tax is then the ratio of the profit to be earned on an additional floor in an average building to the cost of adding an additional floor to this average building. As is clear from equation (1), the regulatory tax represents the magnitude of economic rents which arise artificially from the state's intervention in the land market, since without this intervention the long-run trajectory of equation (1) would equal zero. In effect, the state could 'tax' rents in an unregulated market at the same rate of the regulatory tax, and total rents plus tax would rise to the current regulated level of rents alone, at least in partial equilibrium.

Using our dataset, capital values are constructed by submarket location by calibrating the estimated coefficients of Table 12 specification 1 with the average values of only the buildings located in their respective submarkets. The results are displayed in Figure 12 below.

Figure 12: Estimated regulatory tax (RT) by submarket



Note that unlike the estimates of the regulatory tax in Cheshire and Hilber, in this paper the regulatory tax differences between submarkets estimated is constant between years. This constant difference is an artefact of our hedonic estimation procedure which pools sales among submarkets and years without an interaction term. Therefore, the truest comparison we can make with the Cheshire and Hilber paper is the 2000-05 average shown in Table 16 below[71].

Table 16: 2000-05 Average regulatory tax comparisons

	2000-05 Average	
	Cheshire & Hilber (2008)	Current Study
City	4.63	2.38
West End	7.91	3.86
Docklands	3.24	2.79
Hammersmith	2.10	1.99

As we can see, our estimates of the regulatory tax are roughly half the magnitude of those calculated by Cheshire and Hilber for the City and the West End, and close to parity for the Docklands and Hammersmith submarkets. In all cases however, the averages in Table 16

[71] Cheshire and Hilber's (2008) regulatory tax data only go up to 2005, and our data only goes back to 2000.

are below those estimated by Cheshire and Hilber. There are a number of potential causes of this difference. To begin with, unlike this study, Cheshire and Hilber do not have access to capital values directly, but rather imputed them with data on effective rents and capital yields. Furthermore the source of our respective cost data is different, with Cheshire and Hilber applying data from Davis Langdon whilst this study employs the construction consultants Gardiner & Theobald. But perhaps the most likely source of this discrepancy lies in the difference between how the quality of space in each study is graded. While Cheshire and Hilber calculate their measure of the regulatory tax from only 'prime' space, this study was limited in the fact that it could only use an independent grading of the office floors in the building (whether A, B, or some of both) in order to assess its overall quality. Therefore the highest building-grade category in our study is almost certainly less accurate than Cheshire and Hilber, and potentially biased downward. Of course, it could also be the case that actual levels of the regulatory tax are indeed less than those measured by Cheshire and Hilber. At this juncture only future research will tell. Regardless of the regulatory tax differences seen in Table 16, in both cases our estimated regulatory taxes for all London submarkets are above unity for all time periods and averages between 2 and 3. These findings corroborate the severity of the gross social costs to building regulation in London and underscore potential problems with the restrictiveness of the current planning regime.

Of course the above analyses only examine the gross costs of a single hypothetical building and omit the aesthetic and other benefits which may also arise from building height controls. Therefore if welfare maximisation is the desired economic goal, one cannot directly draw normative conclusions about the appropriateness of current policy from these results. To estimate the net social welfare loss/benefit associated with building height controls would require estimation of the value of these ancillary benefits and estimation of a general equilibrium model of the entire office market. Although these further extensions are beyond the possibilities of the data, there is considerable anecdotal evidence that suggests that the quality of the architecture produced in London in the 20th century was low following the repeal of statutory height restrictions in 1956, but increased after problematic codes in planning law were removed[72] and local planning authorities were given greater independence and discretion. For instance, we can see from the hedonic estimation in Table 12 specification 1 that the decade built dummy variables reduce sales prices the most for buildings built in the 1960s and 1970s, but gradually increase towards positive values starting from about the 1990s. Indeed, it was a common view among real estate practitioners that post-WWII buildings looked as though they had been designed by 'chartered accountants', and that the rebuilding of damaged buildings during the war was unfavourably reminiscent of the notoriously haphazard reconstitution of London following the Great Fire of 1666 (Marriott 1989, pp. 28,66). Perhaps an even more objective metric for the low quality of office space characterising this period was the marked divide at the time between the costs of speculative office developments with those commissioned for the client's own occupation; with the former costing £4 10s to £7 per square foot and the latter £8-£10 in the years 1957-1967 (Marriott 1989, pp.29). As such it appears that the current planning regime is at the very least an aesthetic improvement upon its immediate post-war predecessor.

It is interesting to speculate as to whether the developers' predilection for low quality office space in great quantity following the removal of height restrictions in the 1950s was in fact exacerbated by the earlier imposition of these very restrictions. It may be the case for instance that this artificial supply constraint had driven prices to such high levels that budget constraints on the part of most tenants had an *income effect* which led to greater demand for an inferior good: low quality office space. This is plausible since, after labour, one the most significant costs to business service industries is office rent. If this were true, the original restrictions on building size enacted in the 1890s would have provoked aesthetic impacts in the marketplace that ran contrary to the statute's putative intention (Mises, 1929). Furthermore, once this state of affairs existed, further regulation at the

[72] For instance, under labour's Town and Country Planning Act 1947 a local authority which refused or revoked planning permission could be obliged to compensate the developer for their total abortive expenditure up to the time of revocation. Furthermore, in 1954 the Conservatives appended the law so that compensation must also include the development value lost, profit and all. While these laws stood, these requirements made it prohibitively expensive for the LCC, or any other planning authority, to refuse an application of any size (Marriott 1989, pp.172). Naturally this had the effect of handcuffing councils to prevent developments that it felt were in the interests of the developer but not the community.

planning level would have been required to ensure that uninspired developments did not pollute the existing building stock for the foreseeable future[73]. This is of course just one possible scenario. Equally plausible explanations for the change in the desired quality of office buildings in the 1950s, 1960s and 1970s include pure changes to social preferences or construction technology[74]. At the present the data does not permit us to discriminate among these competing claims.

Conclusion

Tall buildings are controversial additions to modern cities. Although they may block out light, obscure views, funnel winds, and change the aesthetics of the skyline, tall buildings can also bring benefits such as higher densities, economic efficiency, and attractive design. In recent decades a political process has been at work in London selecting for tall buildings which are deemed by city planners to provide the greatest of these benefits. In making this assessment planners may use architectural fame as a credible signal for architectural quality, which by its very nature is subjective and speculative. In accord with official statements, this research has demonstrated that politicians allow famous architects to build taller and to sell their projects for more. Outside of conservation areas the effect of a famous architect was found to yield 20 additional floors to an average building and 100% greater sales revenues for the developer. Using construction cost data from Gardiner & Theobald this paper was also able to demonstrate that these additional revenues were able to increase the development profits of a *high quality* office building in the City of London from £46m to £89m. In sum, there are significant economic rents to be earned from successfully commissioning a famous architect to build tall.

Although efficient levels of good architecture are no doubt desirable, when viewed through the lens of public choice, using famous architects to build taller may lead to additional social losses in the form of competitive rent-seeking. Krueger (1974) showed how import licensing in a hypothetical economy led to both inefficiencies in the composition of output

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[73] Since office stock is durable and considerable development would be required to bring prices back in line with market fundamentals.
[74] Although these explanations appear to sound more like 'just-so stories'.

and welfare losses as a result of competition for these licenses. In her model, competitive rent-seeking with selective supply restrictions produced greater social losses than the case where legal prohibitions were absolute. The situation of developers in London may be roughly analogous. Hiring famous architects, building to their higher standard, and navigating the additional planning scrutiny imposed on building tall is expensive. However unlike the stylized case of Krueger, in the present context not all of this activity may necessarily be considered wasteful. Again, to the extent that this competitive process leads to buildings which better mitigate negative impacts and accentuate potential benefits of building tall, the resulting building stock may prove socially superior to the non-competitive case (for example allocation of tall building permission by lottery).

The result that famous architects do not increase the sale-price per sqm of office buildings is an important contribution to the literature. Although previous studies identified here found a positive effect on both officially recognized and subjectively ‘good’ office architecture[75], all these studies save one employed rents and not transaction prices as their dependent variable. As a result these studies may not capture the additional costs associated with the ownership of an architecturally significant building. If landlords can pass on some but not all of these additional costs to tenants, the result will be lower profits and sale prices for owners in spite of abnormally high rents for tenants. If indeed this situation is true, it would reconcile the apparent paradox between this paper and previous research. Moreover, the single study which utilised transaction prices to identify the premium imparted by famous architects (Fuerst et al, 2011) found that their results collapsed when they regressed their famous architect buildings with only a sample of similar comparables, suggesting the presence of deleterious omitted variable bias in their full sample. Although we do not test the for sample selection bias with propensity score matching as do Fuerst et al (2011), the hedonic model employed here has almost twice their number of controls, includes the crucial variable employment density, and our sales instances are correctly time-weighted. A further potential problem with their original analysis is that 63% of their sample of famous architect buildings originates from a single architectural firm (Skidmore, Owings, and

[75] Hough and Kratz (1983), and Vandell and Lane (1989).

Merrill), and it is not clear whether many of this firm's buildings were in fact designed by architects who the authors would have considered famous by their own criteria[76]. Again when they restrict their sample through propensity matching, the significant effect of top-500 architectural firms, including Skidmore, Owings, and Merrill, disappears from the data. Assuming that, consistent with our findings, famous architects do not in fact increase the per area-unit sale price of office buildings in the current regulatory environment (Table 11), the probable existence of external benefits to good architecture implies that the divide between the sale price (internal benefits) of buildings with good architecture and the total benefits such buildings provide to the public may be large. It could be inferred from this situation that good architecture would be considerably underprovided by the private market. In which case, developers would require external incentives to enlist the services of good architects and thereby maximize the public good. The concession to developers who hire famous architects to build tall may be one such subsidy offered by the planning system which can overcome this price gap and deliver more efficient quantities of good architecture. However, the ability for planning system to deliver these superior outcomes in practice is a question of public choice[77].

Given the degree to which land markets in London are regulated it is not surprising that there are rents to be earned from obtaining special exemptions to them. What is of greater concern however is the magnitude of these rents, as this is indicative of the degree to which these regulations generate market distortions. Although not the primary aim of this paper, the data corroborates the controversial conclusion of Cheshire and Hilber (2008) that the regulatory restrictiveness of the London office market may impose non-trivial economic costs, though the estimated magnitudes of these effects were not found to be as large as in

[76] Fuerst et al (2011) does not indicate which buildings in their sample were actually designed by the founding 'signature' architects at Skidmore, Owings, and Merrill; who won relevant architectural awards, and which buildings were designed latterly by other architects under the firm's name. Presumably these are regarded by Fuerst et al (2011) as one and the same. This is a problem because the youngest founding architect at Skidmore, Owings, and Merrill that we identified which could be considered a 'signature' architect had been dead for 27 years at the time of Fuerst et al's publication.

[77] That is to say, do planners in London have both the necessary information and correct incentives to efficiently realize a beautiful built environment?

their earlier paper. Nevertheless the size of the regulatory distortions estimated here are still substantial and cause for concern.

A further implication of this study arises from the literature on agglomeration economies. Building taller affords greater density, which increases opportunities to network and exchange ideas which drive economic innovation. Greater density also allows for more efficient use of capital and resources, and as a natural consequence the potential for reductions in carbon emissions. However in spite of these potential benefits regulations across the world threaten the ability of developers to exploit these efficiencies and further drive economic progress through greater densities. Soliciting the services of famous architects may allow developers to partially circumvent regulations which would otherwise stymie the concentration of people and ideas which would naturally arise, and therefore for the economy as a whole to exploit otherwise suppressed opportunities for growth. Since we do not have estimates of the value created by good architecture it cannot be determined based on our data whether or not the planning regime in London is an institutional success or failure. However, if the current regulatory framework in London is too restrictive from a social welfare perspective, then the existence of this planning loop-hole is a state of affairs to be commended (Colombatto, 2003). If on the other hand the current building regulations are not in fact excessive, then concessions to skilled architects to build tall may still be a commensurate trade-off for better design and greater international recognition. Alas, as to answering which state of affairs characterises London's current planning regime is regrettably a question for subsequent analysis.

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Appendix A: Policy on the location and design of tall and large buildings

Excerpted from the *London Plan 2011* p.217.

Policy 7.7 Location and design of tall and large buildings

Strategic

A Tall and large buildings should be part of a plan-led approach to changing or developing an area by the identification of appropriate, sensitive and inappropriate locations. Tall and large buildings should not have an unacceptably harmful impact on their surroundings.

Planning decisions

B Applications for tall or large buildings should include an urban design analysis that demonstrates the proposal is part of a strategy that will meet the criteria below. This is particularly important if the site is not identified as a location for tall or large buildings in the borough's LDF.

C Tall and large buildings should:

a generally be limited to sites in the Central Activity Zone, opportunity areas, areas of intensification or town centres that have good access to public transport

b only be considered in areas whose character would not be affected adversely by the scale, mass or bulk of a tall or large building

c relate well to the form, proportion, composition, scale and character of surrounding buildings, urban grain and public realm (including landscape features), particularly at street level;

d individually or as a group, improve the legibility of an area, by emphasizing a point of civic or visual significance where appropriate, and enhance the skyline and image of London

e incorporate the highest standards of architecture and materials, including sustainable design and construction practices

f have ground floor activities that provide a positive relationship to the surrounding streets

g contribute to improving the permeability of the site and wider area, where possible

h incorporate publicly accessible areas on the upper floors, where appropriate

i make a significant contribution to local regeneration.

Appendix B: Separately tested but omitted controls

Employment Connectivity: Travel-time Gravity

In addition to employment density, a measure of employment connectivity was also tested. This measure was constructed by randomly plotting the number of points corresponding to the employment counts within each of the 546 postcode sectors described above for each year between 2000 and 2008. This plot was then partitioned with thiessen polygons surrounding each underground, overground, and rail station, and the number of workers working in each polygons was counted. Then for each station the public transportation travel-time in minutes from that station to a particular office was calculated with Google maps. This travel time was then back-scaled to reflect changes in public travel time speeds according to information provided by Transport for London. This yearly travel-time served as a divisor for the employment population surrounding each station, and was raised to powers of 1 ,1.5 and 2. Then for each office these travel times for all stations according to the date the office was sold were summed, and a measure of employment gravity for each office was calculated. This measure is omitted from the hedonic analysis below as it does not have an influence independent of employment density on sale-prices, and when employment density is omitted its significance and coefficient values are much less, with t-stats around 2 as opposed to 6 for employment density.

Labour-Force Connectivity: Travel-time Gravity

An additional measure for the connectivity of each office to the surrounding labour force was calculated by; (i) taking the population aged 20-64 in each of the 983 Census Middle Super Output Areas (MSOA) in London[78], (ii) dividing it by the public transportation travel-time in minutes as calculated from Google Maps[79] from the population-weighted centroid of each that MSOAs to a particular office[80], and (iii) summing up this number across all of the 983 MSOAs that office. Effectively this is a measure of labour force public

[78] For 2001, population data from the 2001 census was used. For years 2002-2010 official government population estimates were used. For years 1998-2000, the 2001 census counts were scaled back in time geometrically according to London population estimates from Key Population and Vital Statistics for each year.

[79] Travel-times were calculated between March and April 2012, and applied to previous years by using historic public and car transportation travel-time data provided by Transport for London.

[80] Separately raised to the power of 1, 1.5, or 2.

transportation travel-time gravity to each office. A separate measure was calculated for car travel-time and the minimum of car/public travel time in the denominator, also raised to powers of 1, 1.5, or 2. Although all nine[81] of these measures were tested in the hedonic model, the coefficients were often converse to expectations, and never close to significance for any iterations of the specification unless employment density was removed. If employment density is removed, the co-location of many workers close to transportation hubs apparently made the labour force gravity variables significant, with a t-stat of approximately 2. Since employment density has a t-stat of 6, and nearest station distance at least had the correct sign (negative) on its coefficient, it was chosen to run the preferred model with employment density and distance to nearest station as proxy for both employment and labour connectivity.

Congestion Charging Zone

From February 17th 2003 a congestion charging zone was imposed for vehicles entering central London. From 19th February 2007 to Dececmber 24th 2010 a Western Extension to this boundary was also enforced along London's West End. As a Pigouvian tax on congestion externalities, and with demonstrably positive and large effects on average vehicle speeds[82], the congestion charge should theoretically have had an effect on land prices within the charging zone. Although this paper tested controls for the congestion charge including dummy variables, distance of the property to congestion charging boundary if within the zone, interactions with the amount of retail space in the building[83], interactions with the number of office building parking spaces, double interactions with the Labour Force Connectivity by car (see above), and differences between the Central Charging Zone and the Western Extension, no statistically significant effects on the sale-price of office space were indicated.

[81] Public, car, and min(public,car) travel times raised to powers of 1, 1.5, or 2.
[82] Vehicles speeds increased 30% on average with the charging zone during peak hours (Transport for London, 2004).
[83] Previous studies have indicated reductions in retail sales as a consequence of congestion charging. For studies involving the London Congestion Charge see Quddus, Bell, Schmoker, Fonzone (2007), and for an international perspective see Daunfeldt, Rudholm, Ramme (2011).

Appendix C: Descriptive statistics

Table 17: Descriptive statistics of data used on building size regressions

	N	Mean	Standard Deviation	Minimum	Maximum
Modern Famous Architect	6	-	-	-	-
Pre-Modern Famous Architect	4	-	-	-	-
Floorspace (sqm)	387	8,757	10,993	181	113,666
Levels	387	8.37	4.17	4	46
Footprint (sqm)	387	1,528	1,491	66	10,806
Curtilage (sqm)	387	1,744	1,841	66	13,571
Floorspace/Curtilage	387	4.829	1.933	0.348	17.296
Footprint/Curtilage	387	0.939	0.147	0.093	1.0
Average Employment 500m	387	35,783	23,584	1,105	95,121
Built Pre-1950s	122	-	-	-	-
Built 1950s	13	-	-	-	-
Built 1960s	27	-	-	-	-
Built 1970s	25	-	-	-	-
Built 1980s	58	-	-	-	-
Built 1990s	67	-	-	-	-
Built 2000s	73	-	-	-	-
Built 2010s	2	-	-	-	-
Within Conservation Area	209	-	-	-	-
Built in Conservation Area	90	-	-	-	-
Listed	46	-	-	-	-

Table 18: Descriptive Statistics of data used on hedonic regressions

	N/Freq.	Mean	Standard Deviation	Minimum	Maximum
Modern Famous Architect	10	-	-	-	-
Pre-Modern Famous Architect	6	-	-	-	-
Price (£m)	513	65.89	101.05	1.45	1,111.9
Floorspace (sqm)	513	9,231	11,596	181	113,666
Levels	513	8.45	4.17	4	46
Footprint (sqm)	513	1,613	1,531	66	10,806
Curtilage (sqm)	513	1,819	1,831	66	13,571
Price (£)/ Floorspace (sqm)	513	7,025	3,097	1,492	25,477
Price (£)/ Curtilage (sqm)	513	34,594	20,705	1,584	141,427
Floorspace/Curtilage	513	4.853	1.891	0.348	17.296
Footprint/Curtilage	513	0.938	0.147	0.093	1.0
2008 Employment 500m	513	38,134	25,044	1,508	104,476
Built Pre-1950s	162	-	-	-	-
Built 1950s	20	-	-	-	-
Built 1960s	32	-	-	-	-
Built 1970s	30	-	-	-	-
Built 1980s	80	-	-	-	-
Built 1990s	93	-	-	-	-
Built 2000s	94	-	-	-	-
Built 2010s	2	-	-	-	-
Within Conservation Area	276	-	-	-	-
Built in Conservation Area	121	-	-	-	-
Listed	63	-	-	-	-
City Core	167	-	-	-	-
City Fringe	45	-	-	-	-
Docklands	8	-	-	-	-
Mid-Town	72	-	-	-	-
North Central	14	-	-	-	-
South Central	12	-	-	-	-
Southern Fringe	17	-	-	-	-

West Central	17	-	-	-	-
West End	161	-	-	-	-
Sold 2000 Q4	6	-	-	-	-
Sold 2001 Q1	6	-	-	-	-
Sold 2001 Q2	4	-	-	-	-
Sold 2001 Q3	6	-	-	-	-
Sold 2001 Q4	8	-	-	-	-
Sold 2002 Q1	5	-	-	-	-
Sold 2002 Q2	8	-	-	-	-
Sold 2002 Q3	5	-	-	-	-
Sold 2002 Q4	4	-	-	-	-
Sold 2003 Q1	5	-	-	-	-
Sold 2003 Q2	9	-	-	-	-
Sold 2003 Q3	5	-	-	-	-
Sold 2003 Q4	11	-	-	-	-
Sold 2004 Q1	13	-	-	-	-
Sold 2004 Q2	11	-	-	-	-
Sold 2004 Q3	11	-	-	-	-
Sold 2004 Q4	12	-	-	-	-
Sold 2005 Q1	9	-	-	-	-
Sold 2005 Q2	8	-	-	-	-
Sold 2005 Q3	14	-	-	-	-
Sold 2005 Q4	20	-	-	-	-
Sold 2006 Q1	13	-	-	-	-
Sold 2006 Q2	20	-	-	-	-
Sold 2006 Q3	19	-	-	-	-
Sold 2006 Q4	20	-	-	-	-
Sold 2007 Q1	15	-	-	-	-
Sold 2007 Q2	27	-	-	-	-
Sold 2007 Q3	19	-	-	-	-
Sold 2007 Q4	15	-	-	-	-
Sold 2008 Q1	10	-	-	-	-
Sold 2008 Q2	12	-	-	-	-

Sold 2008 Q3	7	-	-	-	-
Sold 2008 Q4	5	-	-	-	-
Sold 2009 Q1	13	-	-	-	-
Sold 2009 Q2	17	-	-	-	-
Sold 2009 Q3	13	-	-	-	-
Sold 2009 Q4	14	-	-	-	-
Sold 2010 Q1	12	-	-	-	-
Sold 2010 Q2	21	-	-	-	-
Sold 2010 Q3	19	-	-	-	-
Sold 2010 Q4	19	-	-	-	-
Sold 2011 Q1	13	-	-	-	-
Sold 2011 Q2	10	-	-	-	-

Appendix D: Net-to-gross internal area ratio

As buildings increase in height each floor must devote a greater percentage of space to structural support, plant operations, and passenger lifts. This requirement reduces the ratio of lettable floorspace to gross internal area as the building increases in height. For instance, using our sample of 387 buildings, a regression of the number of lifts on the number of floors, holding footprint constant, shows that on average for every 5-floor increase in height, buildings are allocated with 2 additional lifts. It is easy to see how, as a building of a given footprint is designed taller, its lettable office space would gradually be 'hollowed out' by these structural requirements.

Table 19: Lifts per floor

VARIABLES	(1) OLS Number of Lifts
Footprint	0.00143***
	(0.000171)
Floors	0.395***
	(0.0863)
Constant	-1.580**
	(0.691)
Observations	387
R-squared	0.757

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
$Floors^2$ was tested simultaneously but found insignificant

Appendix E: Occupancy rate excluded comparison

Table 20 below compares regressions which include and omit building occupancy rate in order to see whether a positive effect of famous architect on sale price is being subsumed by the occupancy rate variable. As the modern and pre-modern famous architect coefficients do not change by more than 1 standard error with the exclusion of occupancy rate, we can see that the inclusion of the occupancy rate variable does not significantly alter the result that modern and pre-modern famous architects have no effect and a negative effect, respectively on office building prices per unit of floorspace.

Table 20: Testing whether a positive effect of famous architect on sale-price is 'stolen' by the occupancy rate

VARIABLES	(1) OLS Ln(Price/ Sqm)	(2) OLS Ln(Price/ Sqm)
Modern Famous Architect	-0.0309	-0.0242
	(0.115)	(0.116)
Pre-Modern Famous Architect	-0.562***	-0.628***
	(0.133)	(0.133)
Within Conservation Area	0.0360	0.0309
	(0.0355)	(0.0359)
Listed Building	-0.0129	-0.0125
	(0.0506)	(0.0512)
Ln(Average Office Permission Refusal Rate 9 yr Moving Average)	0.0303**	0.0350**
	(0.0148)	(0.0150)
Ln(Employment Density 500m)	0.156***	0.162***
	(0.0327)	(0.0330)
Ln(Conservation Area Density 300m)	0.00655	0.00608
	(0.00860)	(0.00870)
Ln(Listed Building Density 300m)	0.0278*	0.0253*
	(0.0143)	(0.0145)
Ln(Park and Gardens Density 300m)	0.00954***	0.00957***
	(0.00258)	(0.00261)
Adjacent to Park or Garden	0.149***	0.134***
	(0.0451)	(0.0455)
Ln(Nearest Rail Station)	-0.0102	-0.0135
	(0.0267)	(0.0270)
Ln(Number of Above Ground Floors)	0.174***	0.170***
	(0.0531)	(0.0537)
Ln(Depreciation Age)	-0.00869	-0.00803
	(0.00665)	(0.00673)
Ln(Basements/Total Floors)	-0.0205**	-0.0217***
	(0.00819)	(0.00828)

A/C	0.223***	0.216***
	(0.0781)	(0.0790)
EG Office Grade A/B	0.0306	0.0458
	(0.0429)	(0.0431)
EG Office Grade A	0.0881**	0.110***
	(0.0390)	(0.0389)
Ln(Percent Occupied)	0.0268***	
	(0.00793)	
Multiple Tenant Building	-0.0996***	-0.0881***
	(0.0334)	(0.0336)
Ln(Parking Spaces)	0.00433	0.00609*
	(0.00347)	(0.00348)
Decade Built	YES	YES
Quarter Sold	YES	YES
Submarket Dummies	YES	YES
Constant	5.888***	5.874***
	(0.391)	(0.396)
Observations	513	513
R-squared	0.630	0.621

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Appendix F: Robustness checks

As shown in Table 2, there are four buildings in the sample built by famous architects outside a conservation area. All of these buildings were built post-1956 after the statutory height regulations were abolished. As a robustness check for Table 8, Table 9, and Table 14, in the following tables we sequentially remove these building observations from the sample according to their height from tallest to shortest.

Table 21: Floorspace/Curtilage robustness check

VARIABLES	(1) OLS Floorspace/ Curtilage Full Sample	(2) OLS Floorspace/ Curtilage Omit Tallest	(3) OLS Floorspace/ Curtilage Omit 2 Tallest	(4) OLS Floorspace/ Curtilage Omit 3 Tallest
Famous Architect outside Conservation Area	3.255***	2.909***	2.842***	2.150***
	(0.528)	(0.476)	(0.609)	(0.465)
Famous Architect	0.137	0.136	0.137	0.140
	(0.320)	(0.321)	(0.322)	(0.321)
Built in Conservation Area	-0.488**	-0.492**	-0.492**	-0.494**
	(0.227)	(0.226)	(0.226)	(0.227)
Average Office Permission Refusal Rate	-14.89***	-14.90***	-14.92***	-15.03***
	(3.649)	(3.638)	(3.646)	(3.655)
Built 1950s	0.184	0.182	0.183	0.186
	(0.388)	(0.388)	(0.388)	(0.388)
Built 1960s	1.012*	1.010*	1.010*	1.012*
	(0.595)	(0.595)	(0.595)	(0.595)
Built 1970s	0.703**	0.702**	0.702**	0.706**
	(0.332)	(0.331)	(0.331)	(0.331)
Built 1980s	0.361	0.359	0.359	0.362
	(0.307)	(0.304)	(0.304)	(0.304)
Built 1990s	0.727***	0.739***	0.740***	0.733***
	(0.254)	(0.255)	(0.256)	(0.256)
Built 2000s	1.402***	1.402***	1.402***	1.414***
	(0.268)	(0.267)	(0.267)	(0.269)
Built 2010s	0.183	0.188	0.189	0.187
	(1.074)	(1.070)	(1.070)	(1.079)
City of London	-1.190**	-1.172**	-1.173**	-1.206**
	(0.514)	(0.510)	(0.510)	(0.516)
Docklands	1.857***	1.680**	1.679**	1.673**
	(0.644)	(0.702)	(0.702)	(0.703)
Average Employment 500m	1.47e-05**	1.44e-05**	1.43e-05**	1.46e-05**
	(6.42e-06)	(6.44e-06)	(6.47e-06)	(6.50e-06)
Constant	5.410***	5.418***	5.421***	5.429***
	(0.521)	(0.520)	(0.522)	(0.523)
Observations	387	386	385	384
R-squared	0.278	0.250	0.236	0.225

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 22: Total above ground floors robustness check

VARIABLES	(1) OLS Floors Full Sample	(2) OLS Floors Omit Tallest	(3) OLS Floors Omit 2 Tallest	(4) OLS Floors Omit 3 Tallest
Famous Architect outside Conservation Area	19.99***	16.11**	8.436***	5.142***
	(5.882)	(6.478)	(2.374)	(0.741)
Famous Architect	-0.697	-0.697	-0.579	-0.564
	(0.573)	(0.570)	(0.566)	(0.566)
Built in Conservation Area	-1.139***	-1.205***	-1.225***	-1.235***
	(0.271)	(0.255)	(0.253)	(0.253)
Average Office Permission Refusal Rate	3.654	2.725	0.643	0.131
	(10.44)	(10.32)	(10.16)	(10.18)
Built 1950s	1.350***	1.341***	1.369***	1.384***
	(0.363)	(0.362)	(0.364)	(0.365)
Built 1960s	5.333***	5.324***	5.319***	5.333***
	(1.472)	(1.475)	(1.480)	(1.480)
Built 1970s	2.419***	2.439***	2.466***	2.485***
	(0.674)	(0.670)	(0.669)	(0.670)
Built 1980s	0.295	0.364	0.403	0.418
	(0.310)	(0.290)	(0.284)	(0.284)
Built 1990s	1.185***	1.335***	1.510***	1.477***
	(0.352)	(0.337)	(0.314)	(0.312)
Built 2000s	2.034***	2.061***	1.994***	2.056***
	(0.358)	(0.331)	(0.315)	(0.313)
Built 2010s	1.331	1.369	1.449	1.443
	(1.586)	(1.583)	(1.591)	(1.633)
City of London	-0.0139	-0.00486	-0.160	-0.313
	(1.290)	(1.248)	(1.211)	(1.216)
Docklands	4.158**	2.141**	1.982**	1.954**
	(1.964)	(0.965)	(0.950)	(0.953)
Average Employment 500m	3.26e-05***	3.05e-05**	2.59e-05**	2.73e-05**
	(1.21e-05)	(1.21e-05)	(1.17e-05)	(1.17e-05)
Constant	4.734***	4.883***	5.251***	5.289***
	(1.257)	(1.250)	(1.219)	(1.220)
Observations	387	386	385	384
R-squared	0.468	0.369	0.282	0.260

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 23: Price/Curtilage robustness check

VARIABLES	(1) OLS Ln(Price/ Curtilage) Full Sample	(2) OLS Ln(Price/ Curtilage) Omit Tallest	(3) OLS Ln(Price/ Curtilage) Omit 2 Tallest	(4) OLS Ln(Price/ Curtilage) Omit 3 Tallest
Famous Architect outside Conservation Area	1.156***	1.031***	0.956***	0.932***
	(0.319)	(0.320)	(0.322)	(0.330)
Modern Famous Architect	-0.438	-0.428	-0.424	-0.422
	(0.296)	(0.296)	(0.297)	(0.296)
Pre-Modern Famous Architect	-0.384***	-0.378***	-0.381***	-0.382***
	(0.142)	(0.142)	(0.142)	(0.142)
Within Conservation Area	-0.0528	-0.0536	-0.0548	-0.0550
	(0.0819)	(0.0822)	(0.0823)	(0.0825)
Built in Conservation Area	-0.0333	-0.0405	-0.0391	-0.0404
	(0.0958)	(0.0961)	(0.0962)	(0.0965)
Listed Bldg	-0.140*	-0.139*	-0.138*	-0.138*
	(0.0779)	(0.0777)	(0.0776)	(0.0777)
Ln(Office Permission Refusal Rate 9yr Moving Average)	0.0131	0.0135	0.0134	0.0140
	(0.0202)	(0.0202)	(0.0202)	(0.0202)
Ln(Employment Density 500m)	0.205***	0.193***	0.192***	0.193***
	(0.0513)	(0.0523)	(0.0523)	(0.0525)
Ln(Conservation Area Density 300m)	-0.0166	-0.0173	-0.0172	-0.0172
	(0.0145)	(0.0144)	(0.0144)	(0.0145)
Ln(Listed Bldg Density 300m)	0.0327*	0.0504**	0.0506**	0.0527**
	(0.0194)	(0.0211)	(0.0209)	(0.0208)
Ln(Park and Garden Density 300m)	0.0169***	0.0169***	0.0170***	0.0170***
	(0.00381)	(0.00378)	(0.00378)	(0.00383)
Adjacent to Park or Garden	0.156**	0.146**	0.149**	0.148**
	(0.0696)	(0.0700)	(0.0703)	(0.0720)
Ln(Nearest Rail Station Distance)	-0.0102	-0.000209	1.12e-05	-0.000338
	(0.0502)	(0.0507)	(0.0507)	(0.0510)
Ln(Depreciation Age)	-0.0133	-0.0133	-0.0133	-0.0135
	(0.00931)	(0.00931)	(0.00931)	(0.00929)
Ln(Basements/Total Floors)	-0.0181	-0.0181	-0.0176	-0.0172
	(0.0135)	(0.0135)	(0.0135)	(0.0136)
A/C	0.449***	0.443***	0.444***	0.444***
	(0.130)	(0.127)	(0.127)	(0.127)
EG Office Grade A/B	0.265***	0.263***	0.261***	0.262***
	(0.0658)	(0.0657)	(0.0656)	(0.0658)
EG Office Grade A	0.361***	0.368***	0.370***	0.371***
	(0.0589)	(0.0587)	(0.0589)	(0.0590)
Ln(Percent Occupied)	0.0261*	0.0264*	0.0263*	0.0261*
	(0.0140)	(0.0140)	(0.0140)	(0.0139)
Multiple Tenant Bldg	-0.00848	-0.00210	-0.00193	-0.00334
	(0.0506)	(0.0509)	(0.0509)	(0.0511)

Ln(Parking Spaces)	0.00795	0.00824	0.00811	0.00822
	(0.00511)	(0.00508)	(0.00508)	(0.00510)
Decade Built	YES	YES	YES	YES
Submarket Dummies	YES	YES	YES	YES
Quarter Sold	YES	YES	YES	YES
Constant	6.999***	6.991***	7.006***	7.049***
	(0.561)	(0.569)	(0.569)	(0.578)
Observations	513	511	510	507
R-squared	0.611	0.607	0.602	0.600

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Chapter 2 Transition

The previous chapter presented research on the ability of famous architects to relax building size restrictions in the tightly regulated London office market. The substantial gap between the sale price and cost of additional space (or regulatory tax) shows that these restrictions appear to be highly distortionary, and as a result sizeable economic rents can be earned from successfully flexing the planning system with famous design. Naturally, this knowledge has direct relevance to developers wishing to generate superior capital returns on their investments via building as tall as possible. However, the existence of these sizable economic rents should also be recognised as important evidence for local and national governments regarding the economic costs imposed by the current regulatory regime. Unless it can be shown that the added aesthetic benefits derived from these strict policies recoup these substantial losses, a more permissive development framework for London should be considered.

Consistent with the work of Cheshire and Hilber (2008), this paper also found that the estimated regulatory taxes varied considerably across London submarkets due to local differences in the price of space. As will be shown in the following chapter, this intra-city price variation appears to be at least partially due to differences in the restrictiveness of development control across local administrative boundaries, which roughly correspond to the recognised extent of these submarkets. It will subsequently be shown that this submarket price variability has important implications for the construction of an accurate repeat-sales price index for London in practice. In particular, we will demonstrate that submarket price effects bias estimated price levels in a city-wide index due to the unrepresentativeness of the observed sale-multiples required for repeat-sales indices. Thus the very factors which drive economic rents and potentially superior development profits in London on the one hand, may lead directly to measurement problems in price index construction on the other.

Chapter 2: Spatial heterogeneity in commercial repeat-sales indices

Abstract

This study investigates sources of bias in commercial repeat-sales price indices (RSPI) by constructing an RSPI for the central London office market, and examining sources of index change relative to the market as a whole. We find that very local employment density changes and the restrictiveness of new development in the relevant local authority impose substantial biases on estimated price levels because repeat-sales occur disproportionately in areas where changes in these attributes differ compared to the stock as a whole. Furthermore, when employment density changes and planning restrictiveness are controlled for, submarket dummies and a Heckman's correction for unobserved sample heterogeneity lose their ability to explain index levels. These findings are consistent with the conjecture that employment density changes and development restrictiveness are the key external drivers of RSPI bias in the central London office market.

Introduction

Accurate estimation of price-levels in real estate is as difficult as it is important. As an asset class real estate accounts for over £5 trillion or 20% of gross wealth in the UK (Office for National Statistics, 2012). Clearly the price indices that measure this wealth are important performance benchmarks for industry, and can help market participants identify when price changes are at odds with market fundamentals. However, since real estate – particularly commercial real estate – is in general highly heterogeneous and infrequently traded, the estimation of accurate and timely price indices is fraught with difficulty. Among the competing strands of price index construction methodologies, repeat-sales indices have become increasingly popular as a tool for measuring residential and commercial real estate prices and movements in them[84].

The repeat-sales method of index construction is essentially a fixed effects approach. By differencing sales occurring at separate points in time it is possible to implicitly control for property characteristics. This contrasts with hedonic price indices where the universe of relevant controls for property characteristics must be identified and obtained. Furthermore, if one assumes temporal and spatial parameter constancy, knowledge of the correct functional form of the model in repeat-sales is irrelevant, whereas in the hedonic case this decision is crucial (Cropper, Deck, and McConnell, 1988). Of course, any *internal* building attributes which change during the holding period (due to say, capital improvements or depreciation[85]) will naturally bias the index. Although one could attempt to model capital improvements hedonically within a repeat-sales regression, researchers generally deal with deliberate building changes by removing these observations from the sample. *External* changes to the building's environment on the other hand, will not necessarily bias repeat-sales. It is hoped in fact that the inter-period price movements which arise from changes external to the building will be reflected in the index. It is only when external changes are unrepresentative of the market as whole that such factors become problematic in a repeat-

[84] See Case and Shiller (1989), and Geltner and Pollakowski (2007).
[85] Until recently depreciation was not modelled, as a linear specification of this variable would be multi-collinear with the holding period. In recent years however research has circumvented this problem by modelling the depreciation rate non-linearly (Chau, Wong, and Yiu, 2005).

sales regression. For instance, it is correct for local transportation improvements to register in the price levels of a repeat-sales index. However, if the second-sales in a repeat-sales index consisted of only the houses sold within 2km say, of new stations following the 1999 jubilee line extension in London, this particular sample of properties would not be representative of price movements accruing to the entire housing stock across all of inner London (Gibbons and Machin, 2005). In a similar vein, real estate price indices based solely on samples of sold properties may not accurately represent the population of properties due to the potential for sample-selection bias. Note that by contrast a hedonic index which consisted solely of Gibbons and Machin’s sample could still produce unbiased price levels so long as transportation connectivity differences were correctly controlled. This sample sensitivity is a fundamental difference between hedonic and repeat-sales indices. Of course, like repeat-sales indices, hedonic indices can also be subject to sample selection bias. However, the scope for these problems in hedonic indices is relatively less.

The repeat-sales method, as introduced in the seminal article by Bailey, Muth, and Nourse (1963), can be derived from the hedonic method. If we assign the logged first and second sale price of property i as P_i^1 and P_i^2, respectively, in logs we have;

$$P_i^1 = \sum_{j=1}^{J} \beta_j X_{ij}^1 + \sum_{t=1}^{T} I_t D_t^1 + \epsilon_i^1 \tag{2}$$

$$P_i^2 = \sum_{j=1}^{J} \beta_j X_{ij}^2 + \sum_{t=1}^{T} I_t D_t^2 + \epsilon_i^2 \tag{3}$$

Where;

P_i^s = Log sale price for sale number $s = 1,2$

β_j = Coefficient on X_j

X_{ij}^{s} = Log characteristic *j* of property *i* for sale $s = 1,2$

I_t = Price-level at time *t*

D_t^s = Dummy variable indicating sale $s = 1,2$ at time *t*

ϵ_i^s = *i.i.d.* error term for property *i* and sale $s = 1,2$.

Assuming property characteristics are constant between sales, $\forall i \forall j (X_{ij}^1 = X_{ij}^2)$, differencing equation (3) with equation (2) yields;

$$P_i^2 - P_i^1 = \sum_{t=1}^{T} I_t (D_t^2 - D_t^1) + \mu_i^{1,2} \qquad (4)$$

Where $\mu_i^{1,2} = \epsilon_i^2 - \epsilon_i^1$. If we assume that sales 1 and 2 occur at time t and $t + \tau$, respectively, the estimation equation becomes;

$$P_i^{t+\tau} - P_i^t = I_{t+\tau} - I_t + \mu_i^{t,t+\tau} \qquad (5)$$

Index estimates I_t represent the cumulative price index for time t, and can then be anti-logged and corrected for transformation bias[86] to produce the unbiased nominal estimates of the price index.

This study investigates the existence of bias in a repeat-sales index of commercial office property in London, and identifies potential sources of this bias. It is found that exceptional local employment density changes (long thought to be a significant determinant of office demand and prices) not only cause properties to sell with greater probability, but that these density changes bias commercial repeat-sales price indices upward. In addition, the repeat-

[86] See Kennedy (1981) and Giles (1982) for the calculation of the transformation-bias correction.

sales in our sample tend to be located in places that are spatially unrepresentative of the distribution of actual offices across central London (relatively clustered around the City of London)., and since price movements across London submarkets vary to a considerable degree, this unrepresentativeness is expressed in repeat-sales index price levels. Furthermore, we find that the different price movements across submarkets can be linked to the restrictiveness of supply in the corresponding local authority area[87]. Because these effects are not constant over time, the bias they impart is more damaging to the usefulness of repeat-sales indices because index corrections cannot be generalised (Steele and Goy, 1997).

Literature Review

A fundamental question with regard to all transaction-based indices, whether derived from hedonic or repeat-sales methodologies, is the extent to which sold properties are actually representative of the property stock. That is to say, whether the prices of the properties that have sold are reflective of the unrealized return that would have been achieved had all the unsold properties also in fact sold[88]. A natural target for price indices is the central tendency of the distribution of price levels in a market (Wang and Zorn 1999). In a regression context, this estimated central tendency or *mean* will be biased when one or more of the independent variables are correlated with the error term. This can happen in the case of omitted variables or measurement errors which end up in the error term. When this happens, any regressors that are correlated with the mismeasured or unspecified factors will end up proxying for them, and one cannot interpret estimated price coefficients as an accurate gauge of their true effect. In a price index regression this leads to inaccurate estimates of price-levels and changes. Although repeat-sales regressions do not in general suffer from this type of problem, they do possess characteristics that particularly expose themselves to sample selection bias. Among these is the fact that because the index is based on repeat-sales rather than all sales, only a fraction (usually around a third) of any given

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[87] Although central London submarket definitions and local planning authority (LPA) boundaries are not perfectly coincident, the submarket and LPA boundaries for the uniquely permissive City of London are approximately equal (see Figure 25).
[88] An analogous problem in appraisal-based indices is the representativeness of the portfolio of properties comprising the index.

sample of sales will be able to be matched with a sale-pair. Of course, the remaining observations must be discarded and this is an incomplete use of transaction information. In addition, even when sale-pairs can be matched the resulting sample of repeat-sales has been found to be often (but not always) unrepresentative of the population of properties. This may come about because, by construction, a repeat-sales index is composed primarily of those properties which transact relatively frequently. One of the ways in which repeat-sales have been shown to vary is that residential properties which are resold 'rapidly' often appreciate at different rates (generally higher) than properties which take more time to sell between sales (Case, Pollakowski, and Wachter 1997; and Clapp and Giacotto, 1999). In their research these authors attribute this effect to the possibility that these rapidly resold properties have been improved structurally or cosmetically between sales, but that this information is not available to the researcher so that they could exclude these observations from their analysis. Other research by Steele and Goy (1997) found that the first-sale of repeat-house-sales in their sample sold for a relative discount, which imparted a positive bias to their price index. They explained this phenomenon by hypothesizing that repeat-sales properties were being held by an opportune buyer with exceptional ability to time the market. On the same token other research by Meese and Wallace (1997), and Clapp, Giacotto, and Tirtiroglu (1991) failed to find a systemic difference between properties sold once and repeat-sales, and research by Clapp and Giacotto (1992), while finding selection bias in repeat-sales, saw no effect on their price index for time periods greater than 3 years.

Dombrow, Knight and Sirmans (1997) examine sources of bias in repeat-sales regressions related to changes in unobserved property characteristics and the temporal instability of estimated parameters. When adding controls in a repeat-sales regression for whether a house was vacant at the time of sale and whether below market financing was achieved, they found that estimated price indices became smoother and exhibited less volatility. In addition, they found that the effect of house floorspace on sale-prices was not constant. The evidence that parameters are time-variable is of course problematic for both repeat-sales and hedonic regressions. The most common way to deal with this problem is to divide the sample by smaller time periods and re-estimate parameter values each period as in hedonic imputation. However, usually sample size limitations prevent this practice. Regardless, the lack of parameter stability is an insurmountable source of bias in mechanical methods of index estimation[89], and one can only hope that the bias in any particular case remains mild.

In contrast to explicitly examining sources of bias that can be *observed* (and if observed explicitly controlled) Gatzlaff and Haurin (1997) extend the analysis of unrepresentative repeat-sales by analysing the extent to which residential repeat-sales indices in Florida may be biased by *unobserved* sample selection. To do this they retain the standard repeat-sales regression method of Bailey, Muth, and Nourse (1963), but augment it with a bivariate sequential Heckman (1979) correction. As in the standard Heckman procedure, Gatzlaff and Haurin treat the censored repeat-sales equation as a specification error in which a variable is incorrectly omitted. As shown by Heckman, the expected value of the error term in this equation is not zero and therefore naïve OLS estimates are biased. However by estimating a probit model relating the probability of sale to a set of selection 'instruments', then using estimates produced from this equation to construct the inverse Mills-ratio[90], and finally including this variable as a control in the original estimation equation this bias can be remedied. The unique characteristic of the Heckman procedure is that one need not observe the potential sources of bias in one's sample in order to control for them. Using macroeconomic variables and house characteristics as instruments, Gatzlaff and Haurin find significant upward unobserved sample selection bias in their sample as a result of changing economic conditions and the variable composition of sold homes.

One limitation of these previous studies is none of them examine the existence of sample selection bias in commercial repeat-sales indices. Neither do the papers which focus on sample selection bias attempt to corroborate their hypotheses of the proximate causes of observed bias with evidence derived from their actual data. In fact, altogether the author was only able to source a single previous paper which examined a commercial repeat-sales index; the purpose of the paper was to compare it with an appraisal index (Gatzlaff and Geltner, 1998), and another paper which investigated sample selection bias in commercial property, but in the context of a hedonic regression (Munneke and Slade, 2000). This study

[89] Appraisals may, in principle at least, be better able to capture the effects of changing parameters.
[90] See chapter 3 for an exposition of the calculation of this quantity.

fills this gap in the literature by investigating the existence of sample selection bias in a repeat-sales index of commercial office property in London, and examining potential sources of this bias. We also extend the analysis of Gatzlaff and Haurin (1997) by showing that a standard Heckman's correction may be sufficient to account for unobserved sample selection bias in our sample, and that this bias disappears when controls for local employment density changes and supply restrictiveness are included.

Data

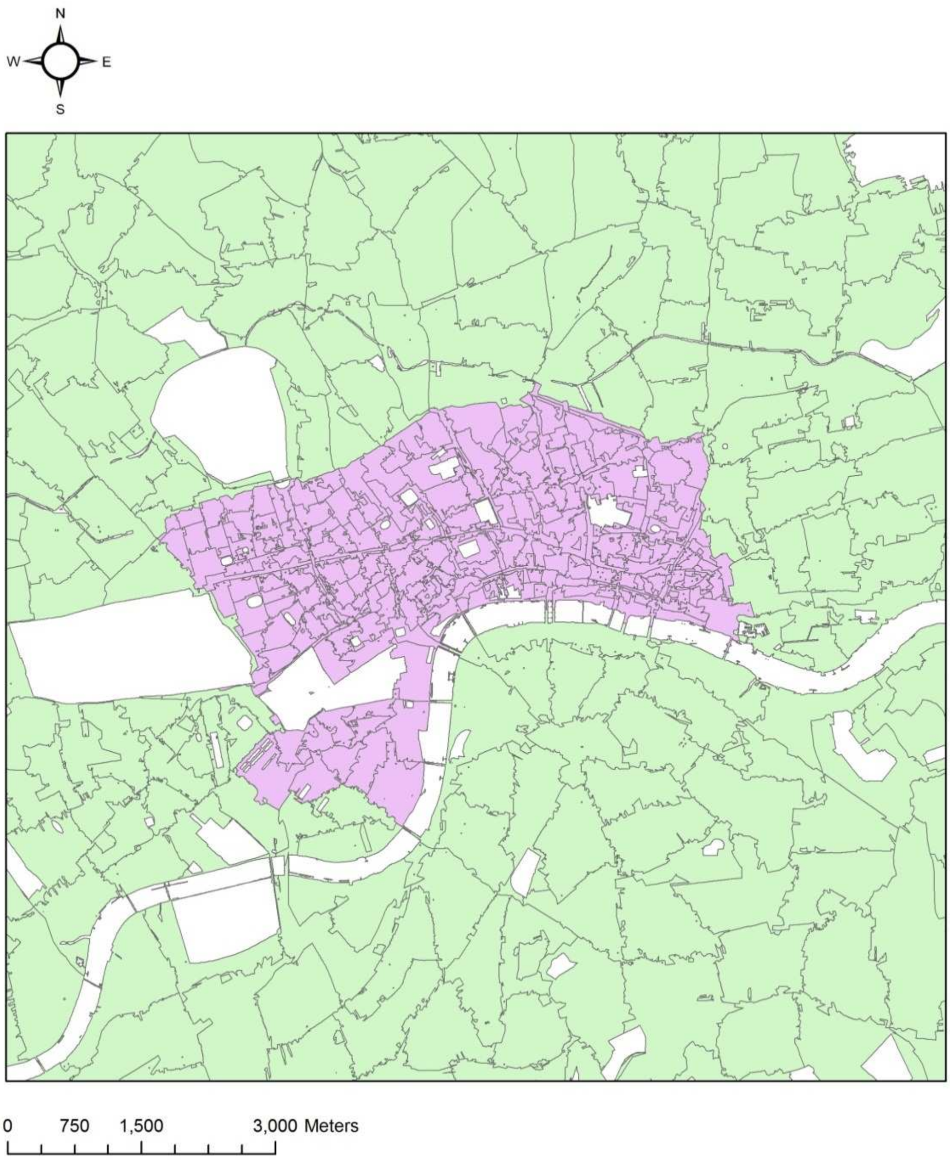
The data on commercial office transactions in central London from 2000-08 was provided by Estates Gazette and Real Capital Analytics. We restrict ourselves to the geographic boundary of central London as postcode sectors are considerably smaller in these areas than the rest of London allowing for finer-grained analysis. Only sales occurring between 2000 and 2008 are used as these correspond with the years for which we have data on employment density by postcode sector (see below). Paired sales were removed from the sample if a second sale occurred less than 12 months from the first. This was done in attempt to reduce the potentially biasing effect of these so-called 'flips' on price index estimation (Clapp and Giacotto, 1999). In addition, sales that were part of a portfolio were removed[91], as were those properties which had price movements exceeding 50% per annum, or which were refurbished or otherwise redeveloped between sales. This filtering process represents the current best practice with regard to repeat-sales, and is nearly identical to that used by Real Capital Analytics to compute indices of US markets for research and industry (Geltner and Pollakowski, 2007). The two alterations being that in order to allow for differences between London and the US markets, the second sale of the repeat-sales pair is deemed to be a 'flip' if it occurs in less than 12 months after the first rather than 18, and annual price movements cannot exceed 50% per annum for all years rather than using a rate of return which scales downward according to the holding period[92]. From an original dataset of 3,351 observations, this filter yielded 409 office properties sold

[91] For properties which sell as a portfolio it is not possible to separate individual property contributions to the combined sale price, and therefore these transactions cannot be used to infer information about market price-levels (unless an identical grouping of properties is sold in multiples).
[92] We do not adopt the more complex extreme returns filter of Geltner and Pollakowski (2007) because of the relatively short period under analysis and the unusual volatility endemic for the period (2000-08).

in central London sold between 2000-08 which did not have a repeat sale-transaction for any years between 1990-2011, and 173 repeat-sales occurring in central London between 2000-08. The original pool of observations differs slightly from the dataset adopted in chapter 1 of this thesis because additional sales observations for use in the repeat-sales index were latterly collected from Estates Gazette.

Data on the entire office stock in central London in 2002 was provided by Property Market Analysis LLP (PMA). As of 2002, the population of central London buildings whose primary function is office use amounted to 6,848 buildings, comprising 20.3 million m^2 of office floorspace. Although detailed data on the characteristics of each of these properties could not be obtained, the number of buildings in each postcode sector and total floorspace at the postcode sector-level was made available. Since we do not have data on the exact address of each of these 6,848 buildings, the number of office buildings in each central London postcode sector was used to construct a hypothetical office stock consisting of an identical number of office buildings dropped at random locations in each of the 244 postcode sectors that comprise our definition of central London. For instance, if we know that a certain postcode sector has 100 buildings in it, then a digital representation of this postcode area is created and the 100 office locations are plotted at random within this area for analysis. For the 16.4 million m^2 of land area in the 244 postcode sectors in this analysis, the average level of spatial detail (area) for each postcode sector is 67,200sqm or a 260m sided-square (see Figure 13). Water features from the Ordnance Survey Mastermap and Parks and Gardens from English Heritage were also removed from these postcode sectors so as to better reflect the locations within them where office buildings could actually be located, and where employees could work. In addition, PMA supplied data on the gross floorspace built in central London from 2002-2011 at the postcode sector level.

Figure 13: Postcode sectors of central (pink) and inner London (green)



The sale price and office location data is also supplemented with data on the number of employees within the 244 postcode sectors under study from NOMIS. In order to construct local employment density, a spatial point for each worker was placed at random within their corresponding postcode sector, and then the surrounding number of points within a 600m radius for each of the 6,848 simulated office locations was calculated for each year 2000-08. The number of workers was taken from the Annual Business Inquiry employee analysis with 2003 SIC J and K, standing for the banking, finance, and business services industries. SIC J and K were chosen as these are the measures of employment used in the real estate industry to model and forecast prices. Although other kinds of office employment, such as perhaps government (L), may also be important particularly in the West End, it was decided to use the more conventional measures of office employment in this analysis. Between 2005-2006 the employment dataset possesses a structural break in the collection methodology, and therefore our 2006-08 postcode sector employment counts are rescaled pro rata using the scaling factor provided by the ONS for London SIC codes J and K. The employment radius of 600m was chosen as it exhibited the highest level of statistical significance in a well specified hedonic analysis comparing all radial distances between 100 and 1000 meters in 100m increments, and 1,500 and 2,000 meters[93]. The number of employees working within 600m of each building each year was then used to calculate the employment density for each property for each year between 2000-08.

An important caveat to bear in mind with the following analysis with respect to postcode sectors is the concern over the modifiable area unit problem (MAUP), wherein the conclusions drawn from spatially aggregated data may depend upon the particular demarcation of the spatial aggregation[94]. However, the potential to encounter this problem declines with the level of spatial disaggregation. As noted above, the average area of the 244 postcode sectors is roughly equivalent to a 260 meter-sided square. Given that this is less than half of the radius used to measure employment density (600m), we believe that the potential for MAUP problems to jeopardize the validity of our findings to be small.

[93] Interestingly, the statistical significance of employment numbers exhibited a perfect inverted U-shape with respect to different radial distances with a maximum at 600m.

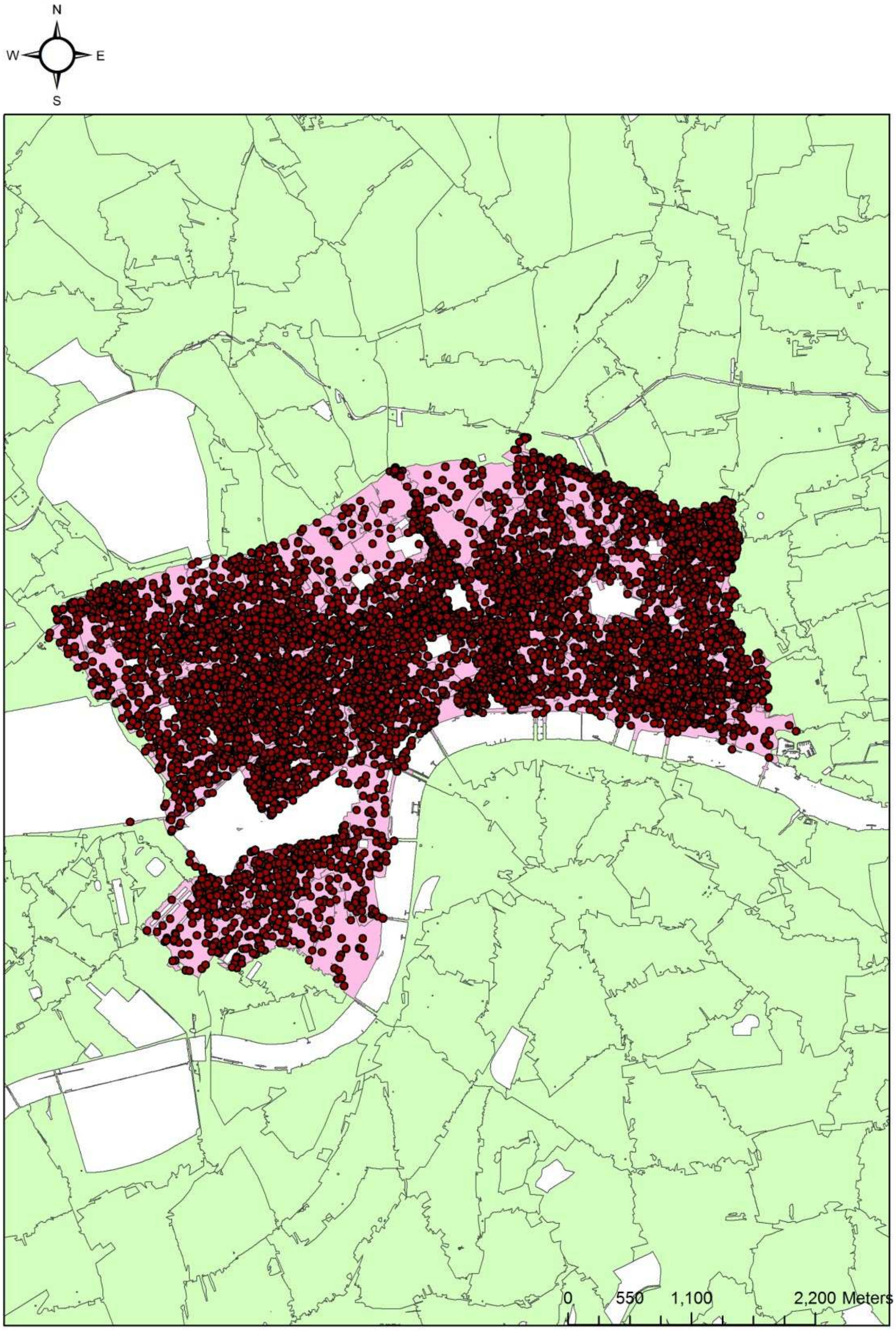
[94] For further reference see Fotheringham, Brunsdon, and Charlton (2007, p.28).

Analysis

We begin by depicting the locations of our office sales and the office stock in central London in the five figures directly below. Comparing Figure 14 and Figure 15 we see that even though office property locations appear to be relatively evenly spread east to west across central London, there is considerably more office space located in the City of London market to the east[95].

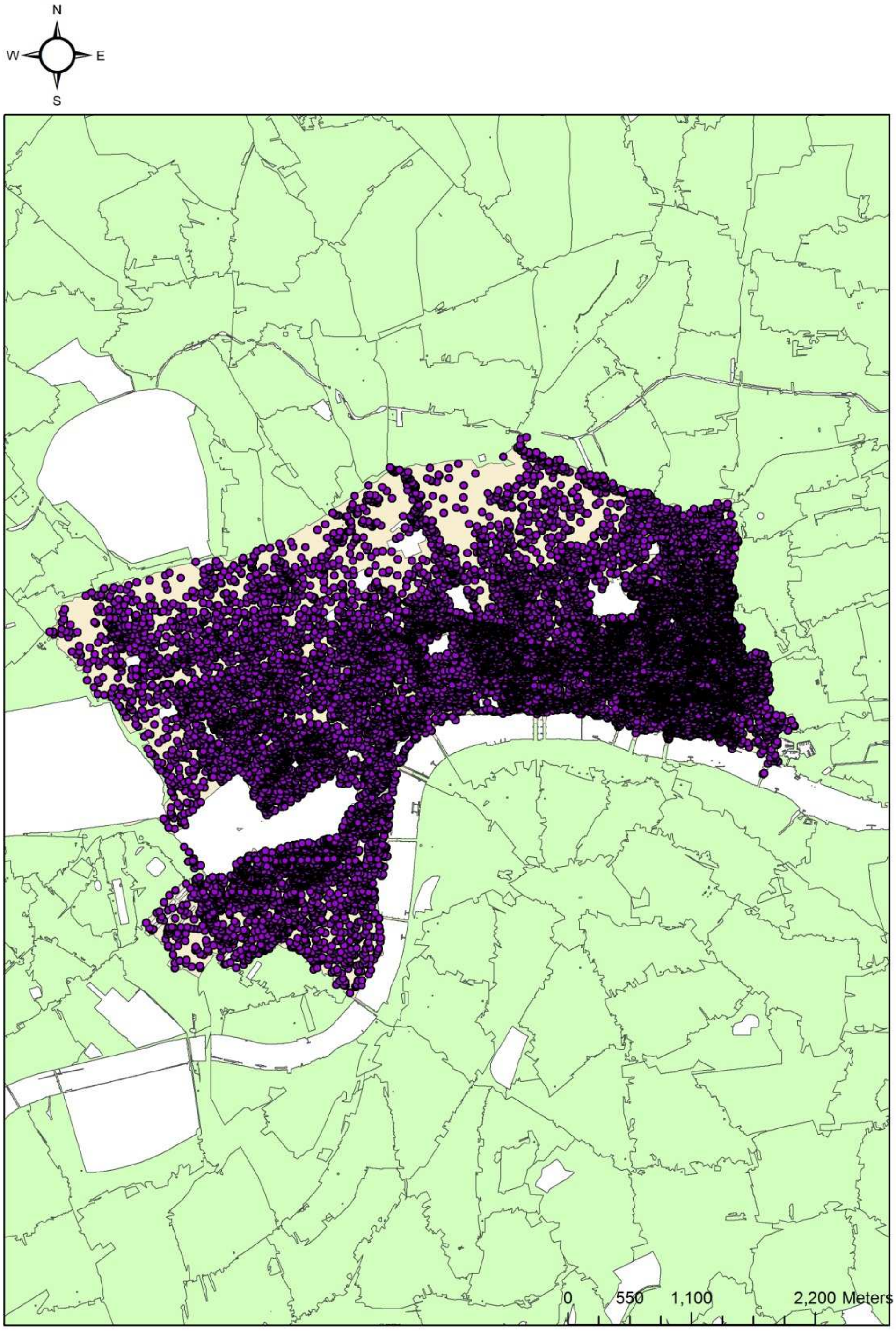
[95] See Figure 25.

Figure 14: Office building locations by postcode sector 2002 (central London only)



Source: PMA

Figure 15: Office floorspace m^2 by postcode sector 2002 (central London only)



Source: PMA

Figure 16 below shows the location of the 409 office properties in central London sold between 2000-08, which did not have a repeat sale-transaction for any years between 1990-2011. Figure 17 shows the location for the 173 repeat-sales occurring in central London between 2000-08.

Figure 16: Sales only - never repeat-sold (409 total, 2000-08, central London, 244 postcode sectors)

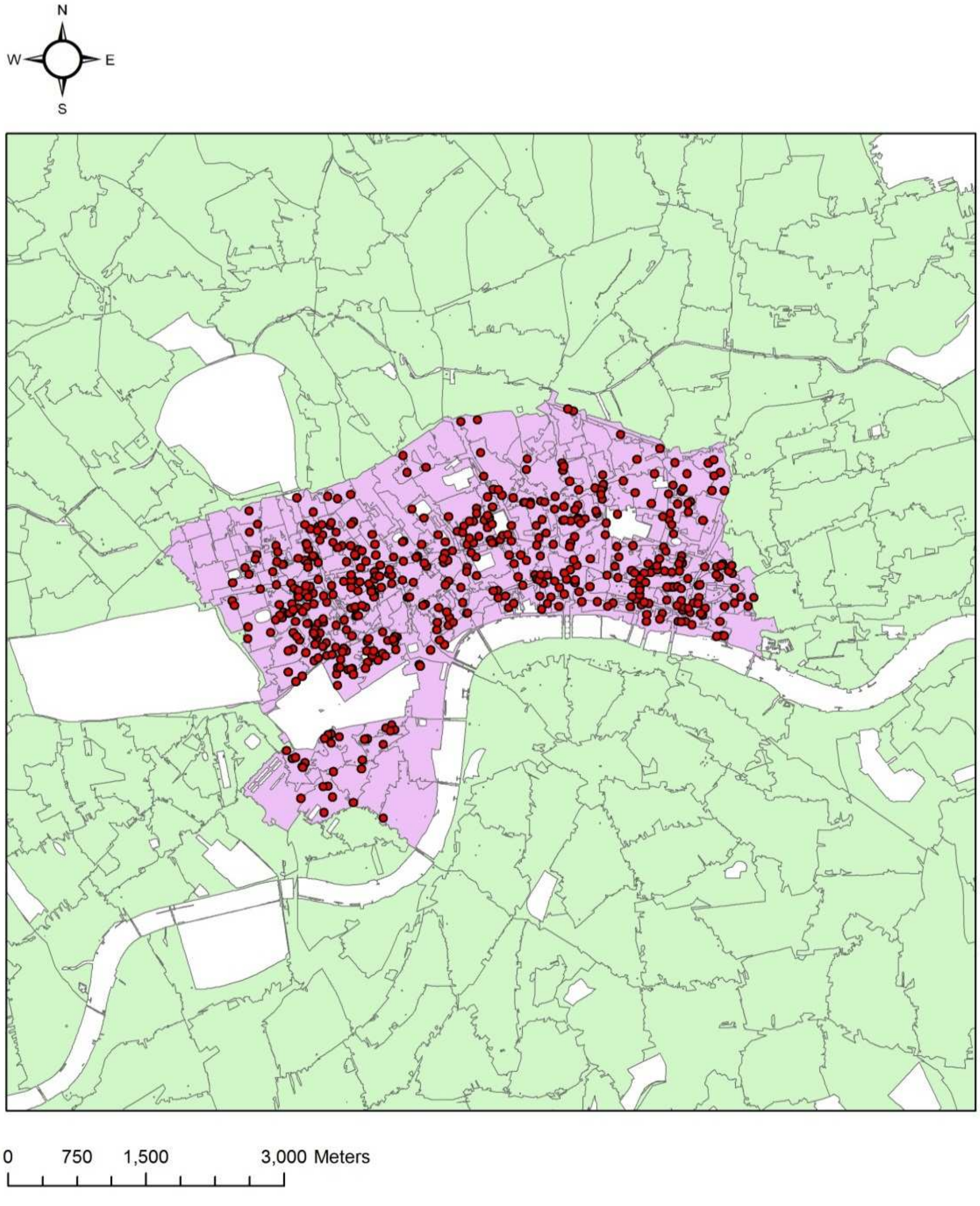


Figure 17: Repeat-sales only – second sale or more (173 total, 2000-08, central London, 244 postcode sectors)

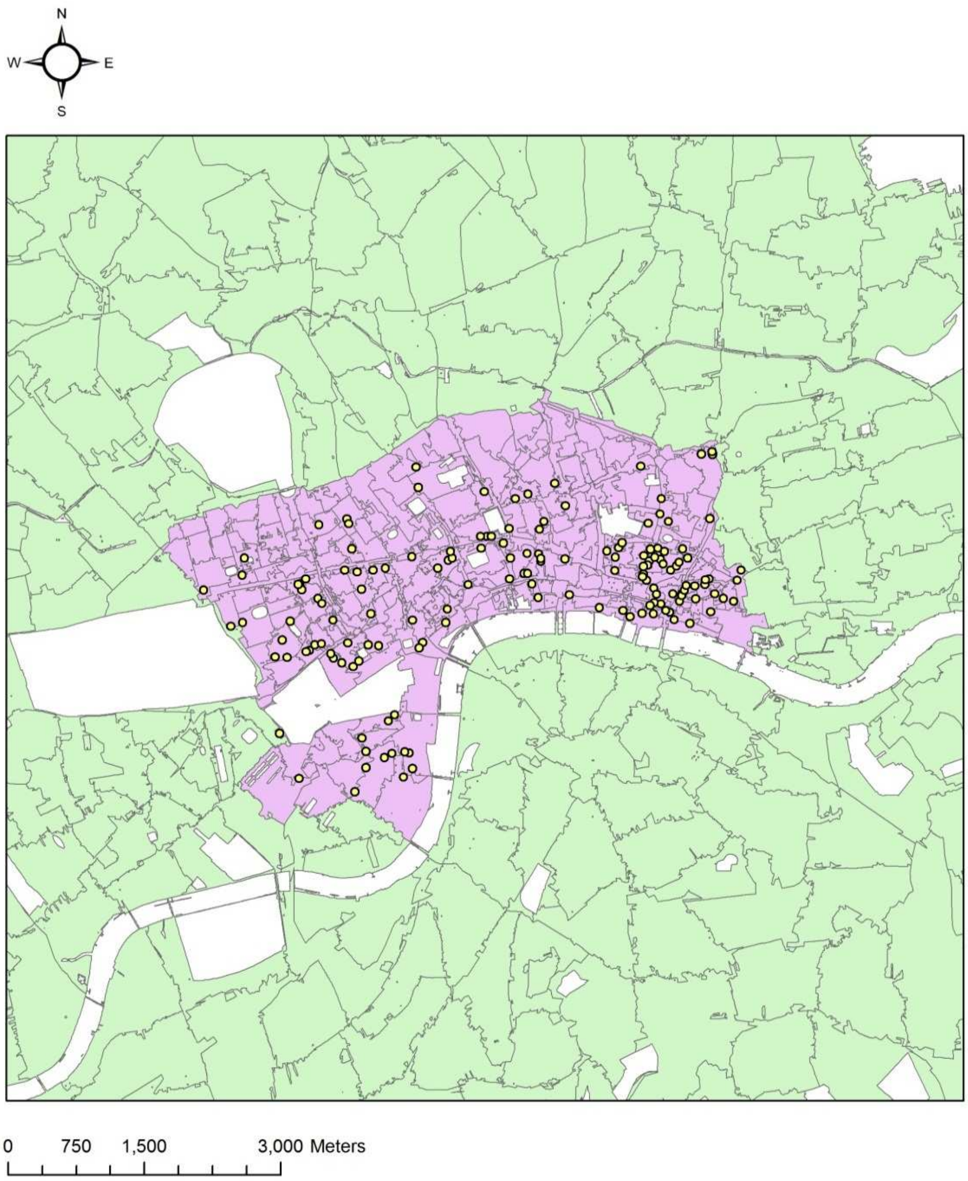
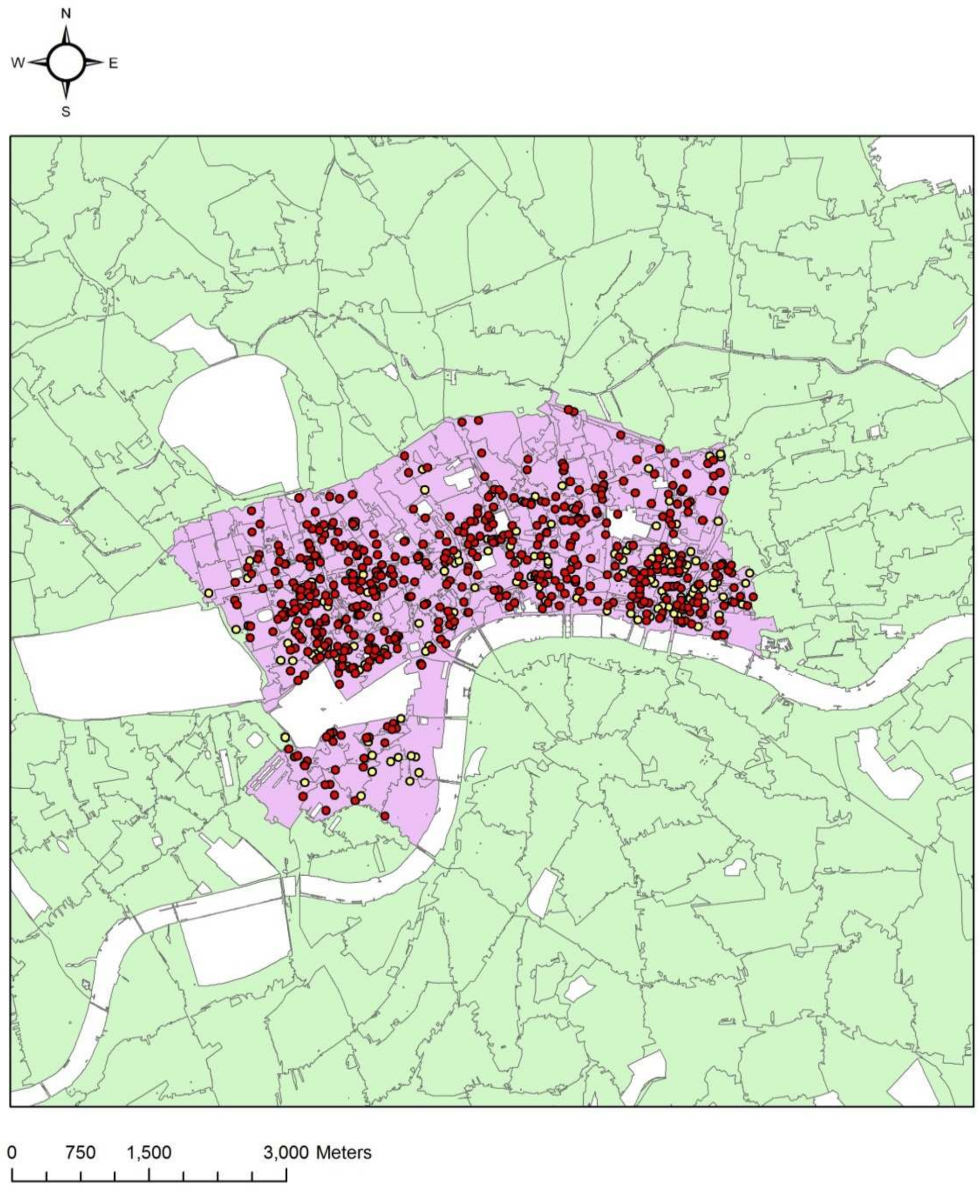


Figure 18: Sales and Repeat-sales (582 total, 2000-08, central London, 244 postcode sectors)



One test that we can perform on the above data is to see whether all sold floorspace and repeat-sold-only floorspace occur in proportion to the amount of office space within each postcode sector. If this is not the case, then this will immediately suggest that sales and/or repeat-sales are not spatially representative of the office stock as a whole.

Observed sample heterogeneity

Table 24 regresses the floorspace sold per postcode sector on the stock of floorspace in that sector. This analysis will test the extent to which sales and repeat-sales are actually occurring in areas in proportion to the amount of stock within that area.

Table 24: Proportion of Sale and Repeat-sales floorspace sold in each postcode sector as a function of the proportion of total floorspace in the postcode sector.

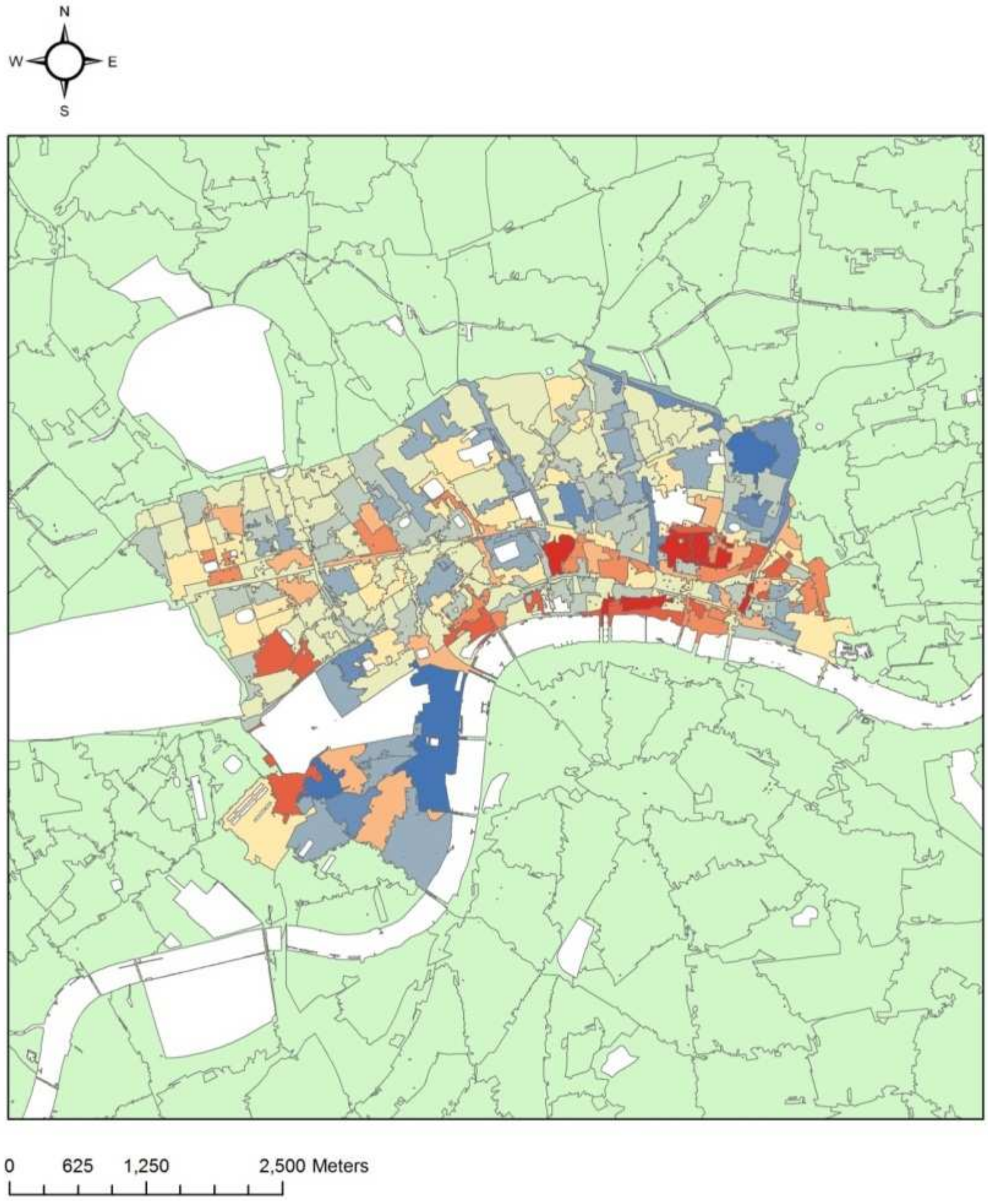
VARIABLES	(1) Proportion of Sold Floorspace in Postcode Sector	(2) Proportion of Repeat-sold Floorspace in Postcode Sector
Proportion of Total Floorspace in Postcode Sector	0.980***	1.028***
	(0.0812)	(0.138)
Constant	8.48e-05	-0.000119
	(0.000443)	(0.000755)
Observations	244	244
R-squared	0.383	0.191

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

As we can see proportion of total floorspace is a highly significant predictor for the amount of sale and repeat-sales floorspace. The relevant null hypothesis however is that there is an equiproportionate relationship between the two. Hypothesis tests for the coefficient on total floorspace being different from 1 yield p-values of 0.8048 and 0.8388 respectively, and therefore the null hypothesis that the coefficients equal 1 are not rejected. Notice however that the R-squared on repeat-sales floorspace is half that of sale floorspace, suggesting that there is greater variation (error) in the location of repeat-sales floorspace with respect to the office stock. Of course, this increased error rate could also arise partially or entirely because there are fewer observations repeat-sales observations (173) in specification 2 than there are total postcode sectors (244). So although this finding is consistent with the hypothesis that repeat-sales occur with greater ‘error’ relative to the location of the office stock, this finding is by no means definitive.

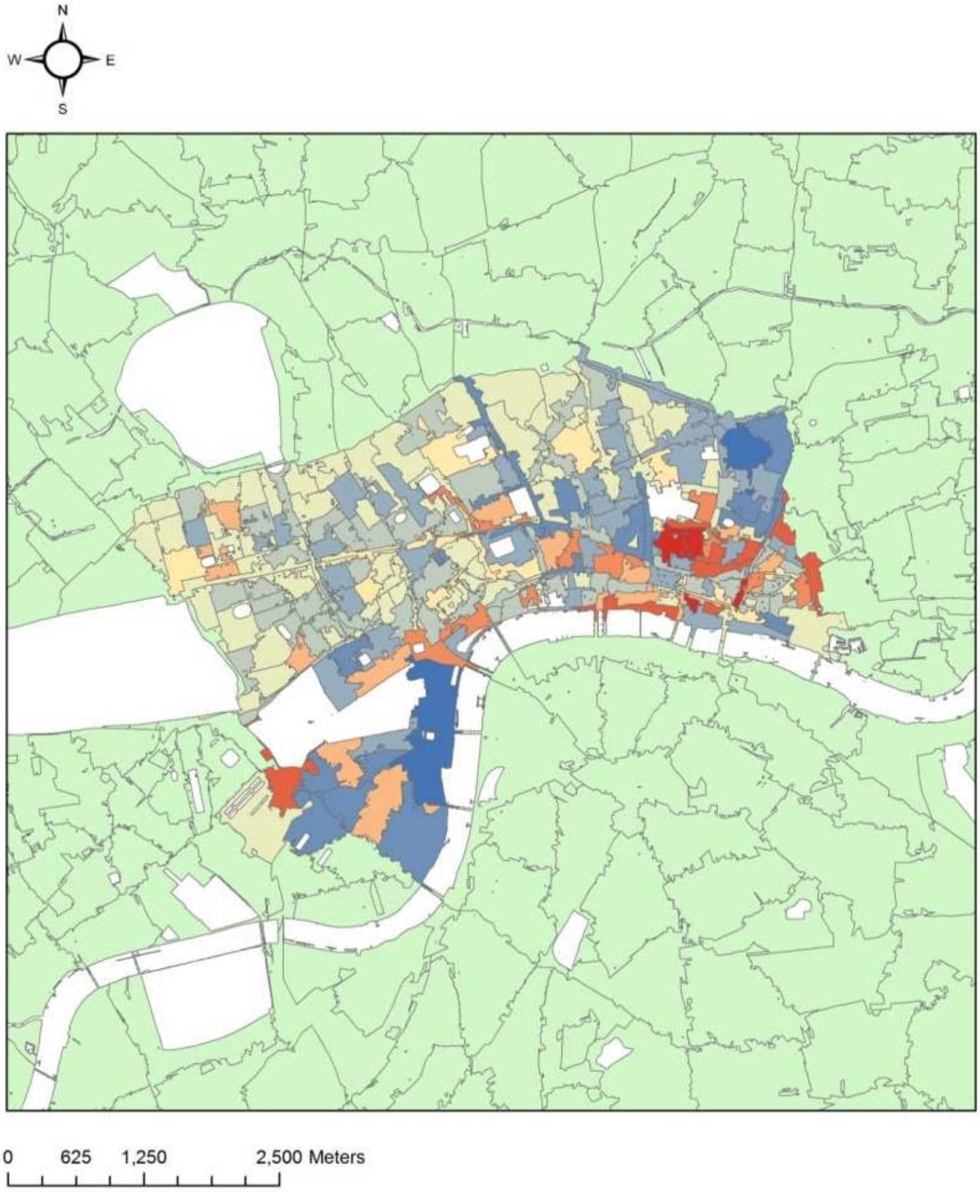
It is informative to examine the residuals of the above regressions with respect to each postcode sector, as these will highlight areas experiencing relatively greater and lower sale and repeat-sales turnover with respect to the amount of total office stock. From East to West in Figure 19 we see that sales tend to occur at a disproportionately high level with respect to the amount of office space in area surrounding the bank of England (Postcode districts EC2R, EC2V), the area south of St Paul’s Cathedral on the Thames (EC4V), and along the southern end of the Holborn Viaduct north of St Paul’s Cathedral (EC4A, EC4M), south of Covent Garden (WC2E, WC2R), and surrounding Green Park station in Mayfair (W1J). On the other hand the northern fringes and areas around the houses of parliament in the south (SW1) experience disproportionately lower sales for their given amount of office stock.

Figure 19: Sales 2000-08 residual with respect to office stock.



Turning our attention to the repeat-sales' residuals, we can see from Figure 20 that the incidence of repeat-sales with respect to the office stock occurs with similar spatial clustering to sales. The most marked difference between the spatial distribution of sales and repeat-sales is the relative sparsity of repeat-sales in the West End (W1).

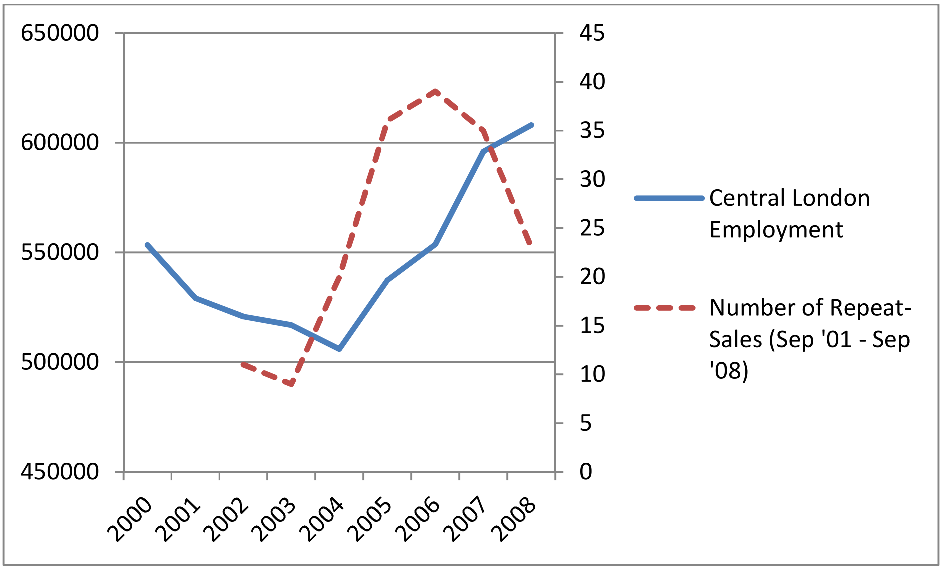
Figure 20: Repeat-Sales 2000-08 residual with respect to office stock



Although sales and repeat-sales between 2000-08 tend to follow the location of the office stock on average, there is evidently a degree of spatial variation and perhaps clustering in these sales. Among the reasons this may be occurring is that certain areas are either more popular with speculative investors who have short-time horizons, and/or particular areas may have experienced local changes that induced greater sale activity.

Central to the desirability of an office location is the density of employment. Locating close to other workers may facilitate knowledge spillovers, agglomeration economies, and signal quality to customers and employees (Jacobs, 1969; Porter, 1990; and Duranton and Puga, 2004). Employment density also varies considerably within a city inter-temporally. Employment numbers in central London between 2000-08 are shown in Figure 21 below.

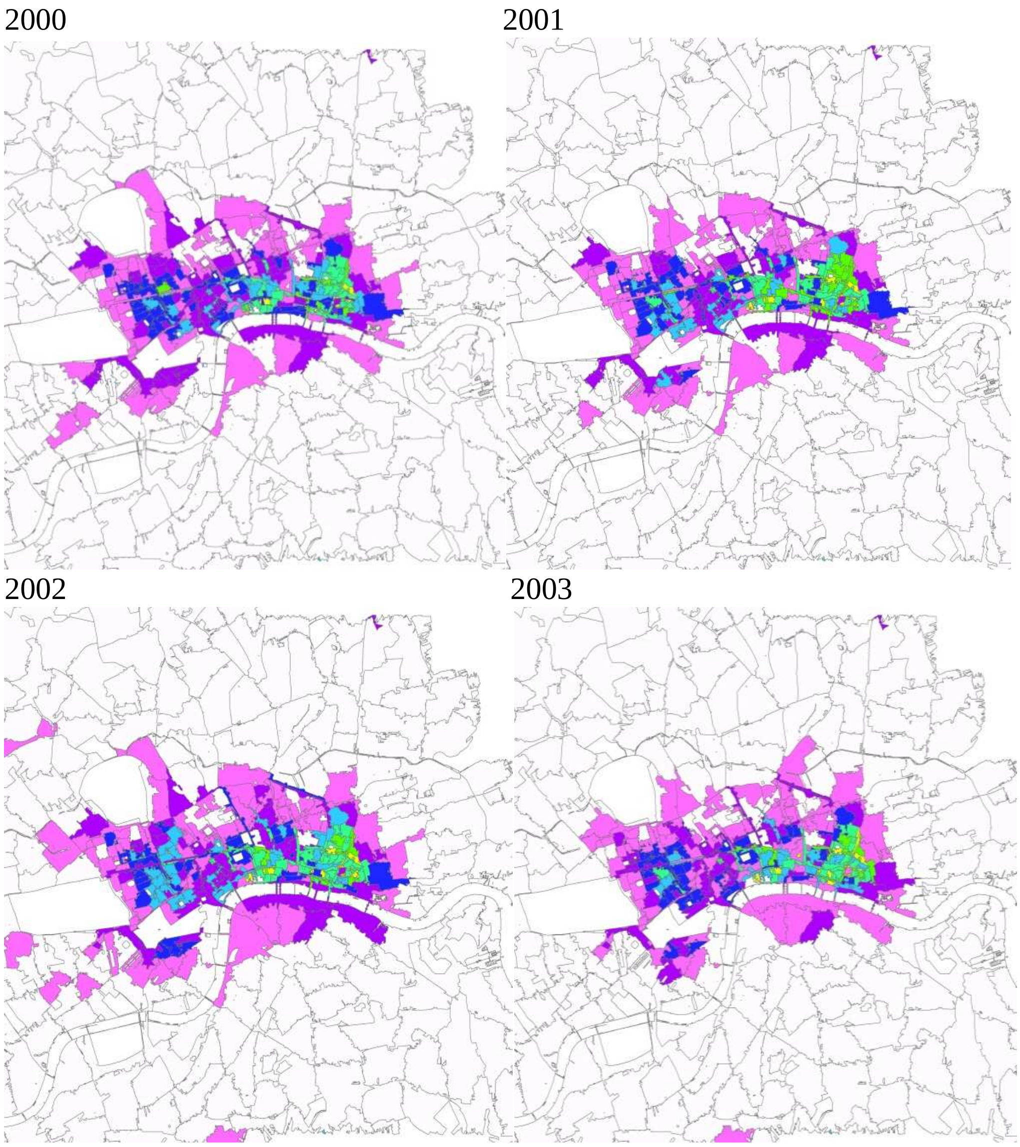
Figure 21: Employment levels and Repeat-sales



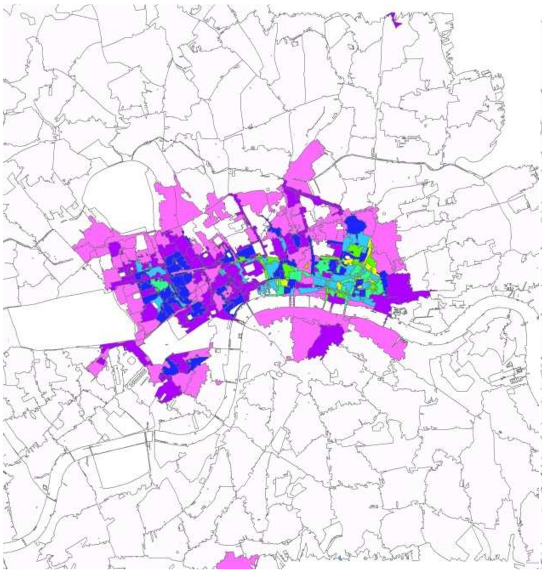
Employment numbers represent Annual Business Survey Employee Analysis 2003 SIC codes J and K representing the banking, finance, and business service industries in the 244 postcode sectors above. Due to a structural break in 2005-6 values are rescaled pro rata using the scaling factor provided by ONS for London SIC codes J and K using the pre-2005 methodology. Employment numbers are collected from surveys administered in September of the corresponding year.

This inter-year variation also plays out spatially across central London. The images in Figure 22 below show the change in employment density across central London between September 2000 to September 2008. The notable changes evident from this time-series of images are the systemic increase in employment density across postcode sectors in the West End, Midtown, and the City of London between 2000-02, followed by a fall in employment density between 2003-08 primarily experienced in the West End and Midtown, with the City of London only losing employment density from 2003-05, and then regaining earlier levels into 2008.

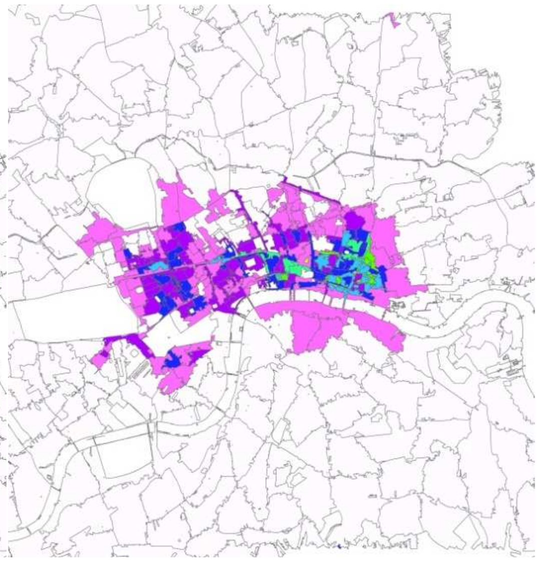
Figure 22: Spatial distribution of London employment 2000-08



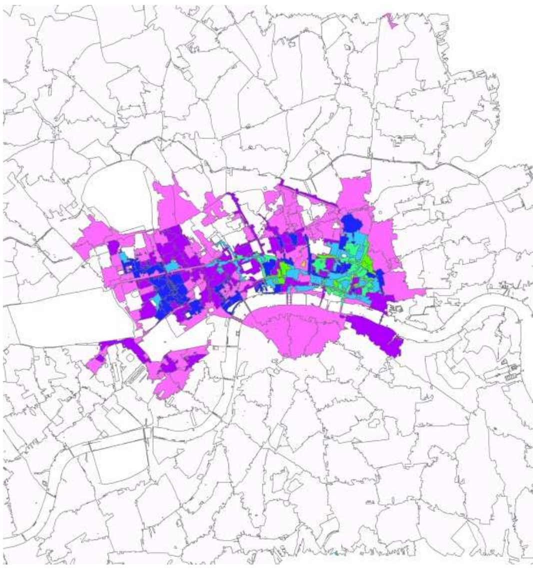
2004



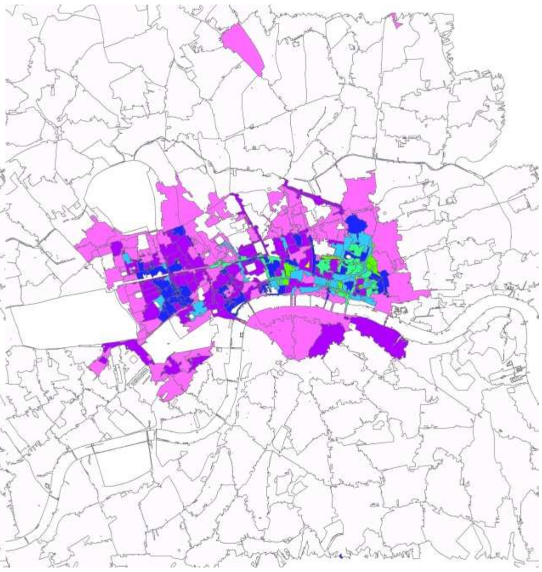
2005



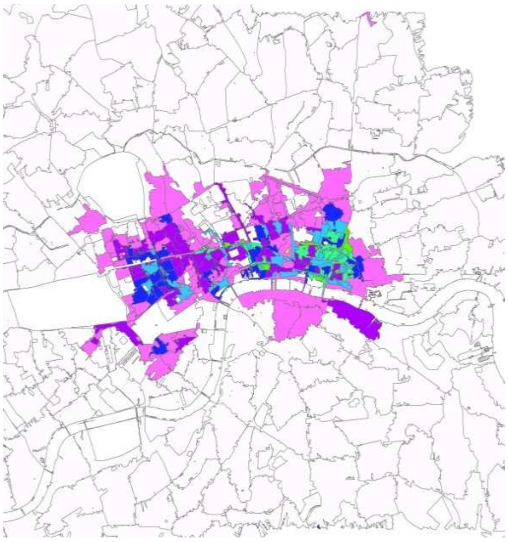
2006



2007



2008



Employment density change bias

If it is the case that the frequency of sales in a given location is influenced by changes in employment density, and if these local changes in employment density are not experienced universally across the whole market, then this selectivity in observed sales may impart bias into measured price indices. To test whether employment density changes are different for repeat-sales compared to the office stock as a whole we first construct a simulation for the employment numbers within 600m at each of the 6,848 synthetic office properties within central London for 2000-08. Then each synthetic property comprising this stock was randomly given a first and second sale date pair identical to one of the 173 properties which actually sold. Using these first and second sale dates the employment density change (EDC) between these hypothetical sale-pairs was calculated. In order to achieve greater accuracy, employment numbers were scaled pro-rata between the current and subsequent year values according to the month in which the property sold. In addition, for every property actually repeat-sold, an identical number of unsold synthetic office comparisons from the same post-code sector and with the same sale-pair dates were removed from the sale sample. This produced 6,848 – 173 = 6,675 non-repeat sold comparisons.

In order to compare sales with repeat-sales we also construct the change in employment density over the previous year (PYEDC)[96]. Similarly for the comparison between stock and sales, the synthetic stock was randomly assigned an actual sale date from the actually sold properties, and an identical number of sales and repeat-sales from the same postcode sector and with the same sale date were removed from the comparison sample. Therefore we have a total of 6,848 – 582 = 6,266 never-sold comparisons. We utilize a probit regression to test whether the probability of repeat and non-repeat sale vs. non-sale is correlated with the previous year change in local employment density. For repeat-sales we use a probit to test whether EDC over the holding period is similar for synthetic and actual repeat-sales.

Table 25: Probit of the probability of sale vs no-sale on employment density changes.

VARIABLES	(1) PROBIT Repeat-Sales	(2) PROBIT Sales†	(3) PROBIT Repeat-Sales	(4) PROBIT Only Third Repeat-Sales‡	(5) PROBIT No Third Repeat-Sales
EDC	1.109***			2.114***	0.657*
	(0.354)			(0.610)	(0.388)
PYEDC		0.589	1.642***		
		(0.375)	(0.558)		
Constant	-2.164***	-1.963***	-3.645***	-2.839***	-2.227***
	(0.0476)	(0.385)	(0.577)	(0.0975)	(0.0502)
Observations	6,848	6,848	6,848	6,848	6,848

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
†Sales include repeat-sales.
‡The subset of repeat-sales pairs consisting of the second and third instance of sale (29 instances).

Interestingly we see from Table 25 specification 1 that the EDC is higher for repeat-sales properties than for the stock as a whole. Specifications 2 and 3 also show that although combined sales and repeat-sales are not related to changes in PYEDC, repeat-sales only are. Therefore repeat-sales are occurring with greater frequency relative to the office stock and non-repeat-sales in areas which have experienced greater increases in employment density. Interestingly, there were 29 instances of properties which sold three times in the repeat-

[96] Since non-repeat-sales are not sold twice and therefore have no holding period, Employment Density Change between sales cannot be used to compare them with repeat-sales, and PYEDC is used to compare sales and repeat-sales instead.

sales sample of 173. Comparing specification 4 and 5 we see that these ‘third repeat-sales’ also saw even greater increases in employment density than the repeat-sales which did not sell again. Therefore much, but not all, of the selection effect of employment density changes is in fact due to these third sales.

From the probit regression results in Table 25 above it is apparent that whereas non-repeat sale properties do not have statistically different PYEDC from the office stock, repeat-sales properties have different PYEDC than the stock of properties and non-repeat-sales. In and of itself the difference between repeat-sales and the office stock will not necessarily bias the measurement of price-indices unless changes in employment density also influence the sale-prices achieved in repeat-sales transactions. In order to test for bias imparted by employment density changes to the repeat-sales price index, we construct a repeat-sales price index from the 173 repeat-sales properties and include a variable measuring the change in local employment density within 600m. If the coefficient on changes in employment density is statistically different from zero (theory and evidence leads us to believe that it will be positive), then we can confirm that not only do repeat-sold properties experience greater increases in employment densities compared to the market as a whole (Table 25), but that this selectivity introduces a bias into the naïve calculation of price indices.

However, employment density changes are likely to be endogenous with respect to prices and therefore non-causal. Within a repeat-sales regression this will be the case if unobserved building or environmental *changes*[97] are correlated with employment density changes. Changes that would potentially confound the effect of EDC include; greater transportation connectivity, the arrival of a new local amenity such as a prominent retailer,

[97] Since the repeat-sales method is essentially a differencing approach to index measurement, fixed building and/or environmental characteristics will drop out of the estimation. Note that buildings with observed structural changes between sales (redevelopments, refurbishments) were removed from the repeat-sales sample.

or increases in the occupancy-rate of the building in question[98]. A valid instrument in this case will be both correlated with employment density changes, but uncorrelated with the unobserved building and environmental changes.

In an attempt to control for this potential endogeneity two-sets of instruments are tested separately and concurrently. The first set comprises both the total floorspace of office stock within 600m of the building as of 2002, and the completed office floorspace within 600m of the building between 2002-2011. The argument behind instrument relevance is straightforward. In terms of exogeneity it could be argued that new construction takes many years to plan, permit, and build, and therefore any changes in the local environment (cyclic or otherwise) which may have precipitated new development may no longer be relevant by the time the space has filled. By the same token, it is not clear whether existing office stock is a net competitive impediment or incentive for the creation of new local amenities relative to other areas.

The second set of instruments comes from the 1981 census and consists of the density of financial service workers, the density of financial service office-workers, and the density of all workers; all at the local authority level. In a similar vein to Ciccone and Hall (1996), the rationale behind the inclusion of historical employment density instruments is that places with high employment density in the past may be favoured today in terms of employment density increases. But if enough time has passed, the historical employment density levels will not necessarily be indicative of areas which experience local amenity changes today.

Table 26 below shows the results of a restricted repeat-sales index which omits controls for employment density changes in specification 1, specification 2 includes employment density, and specification 3 and 4 instrument employment density with the office stock variables and historic employment density as discussed above, while specification 5 utilizes both sets of employment density instruments. All indices are annual since there are

[98] While increasing the building's occupancy rate would simultaneously raise local employment density, the effect of greater revenue on the building sale price would falsely register as an entirely external market effect (see 'Appendix D: Results of separately tested factors on repeat-sales').

insufficient observations to produce quarterly price-level estimates, and all time-dummies are fractionally time-weighted according to Bryan and Colwell, 1982[99] in order to minimise temporal aggregation bias.

[99] See ‘Transaction-based price indices’ in Chapter 3.

Table 26: Repeat-sales price Index including Previous Year Employment Density Changes. Dependent variable is the natural-log of the price-relative.

VARIABLES	(1) OLS Ln(Price-Relative)	(2) OLS Ln(Price-Relative)	(3) IV2SLS Ln(Price-Relative)	(4) IV2SLS Ln(Price-Relative)	(5) IV2SLS Ln(Price-Relative)
2000†	1.177***	1.196***	1.203***	1.184***	1.182***
	(0.313)	(0.314)	(0.312)	(0.309)	(0.306)
2001	0.0832	0.0760	0.0347	0.00683	0.0184
	(0.0890)	(0.0890)	(0.0906)	(0.0878)	(0.0896)
2002	0.0327	0.0362	0.0380	0.0487	0.0425
	(0.0937)	(0.0936)	(0.0926)	(0.0901)	(0.0915)
2003	-0.110	-0.104	-0.121	-0.131	-0.124
	(0.0887)	(0.0887)	(0.0878)	(0.0854)	(0.0868)
2004	0.171**	0.161**	0.136*	0.0991	0.125
	(0.0794)	(0.0797)	(0.0801)	(0.0786)	(0.0791)
2005	0.114*	0.0999	0.105	0.0940	0.0999
	(0.0642)	(0.0651)	(0.0636)	(0.0619)	(0.0629)
2006	0.211***	0.208***	0.187***	0.171***	0.182***
	(0.0602)	(0.0602)	(0.0605)	(0.0588)	(0.0597)
2007	-0.0512	-0.0757	-0.0743	-0.0990	-0.0876
	(0.0745)	(0.0771)	(0.0744)	(0.0727)	(0.0739)
2008	-0.130	-0.0864	-0.174	-0.216	-0.161
	(0.175)	(0.178)	(0.174)	(0.170)	(0.171)
EDC		0.441***			
		(0.164)			
Predicted EDC with office stock instruments			2.007**		
			(0.911)		
Predicted EDC with employment instruments				3.814***	
				(1.009)	
Predicted EDC with all instruments					2.605***
					(0.885)

Observations	173	173	173	173	173
R-squared	0.699	0.712	0.708	0.724	0.714
F-stat on inclusion of EDC variable	-	7.17***	4.85**	14.29***	8.66***
(p-value)		(0.0082)	(0.0291)	(0.0002)	(0.0037)

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
†Omitted year dummy is 1999, which is part of the specification due to fractional time-weighting of the dummy variables, see chapter 3.

As can be seen in the table above, all four coefficients representing EDC are significant predictors of price changes and in the expected direction. However it should be noted that the office stock instruments and the historic employment density instruments are weak: with F-statistics on the first-stage regression less than 10 (Staiger and Stock, 1997). Furthermore, Sargan-Hansen tests reject exogeneity of the office stock and historic employment density instruments[100].

With these difficulties in mind we can tentatively infer that employment density increases not only raise the probability of repeat-sales, but also increase the resultant sale prices of properties which then go under the hammer. In order to truly argue causality and not mere correlation, it is customary to invoke a story as why this phenomenon may be occurring. Perhaps the most straightforward explanation is simply that the owners of properties which pursue a second sale within the timeframe analysed have shorter investment horizons than the general population of investors. These investors may notice that demand in their local market has increased relative to the market as a whole, and that therefore selling now is also an opportunity to outperform that market. Notice that this argument is subtly different than a market-timing argument. While the market-timing argument would imply that these owners have special knowledge of the direction of future price movements, in our case the owners are engaging in sales because of the advantages of doing so relative to the market. From the point of sale, local demand could either increase or decrease, so there is no onus on the sellers to possess superior information and no onus on buyer to possess inferior information. The incentive for these owners to sell in this scenario may simply be that many are in fact professional investors who merely want to be able to look good in front of their clients or superiors upon their next evaluation. Alternatively, like Steele and Goy (1997), one could also invoke information asymmetry between the buyers and sellers of repeat-sale properties, with sellers being more sophisticated than the two. As argued by Steele and Goy this may be plausible since real estate markets are heterogeneous and it is costly to undertake research, and therefore the law of one price need not hold. In particular, informed investors could identify local trends that the broader market wasn't aware of.

[100] Details of the first-stage regression results are contained in 'Appendix A: EDC Instrumental variable first-stage regressions'.

Moreover, although the returns from holding such properties would be greater than the market as a whole, since the acquisition of this information may be costly this does not necessarily imply that the returns accruing to these investors are disproportionate.

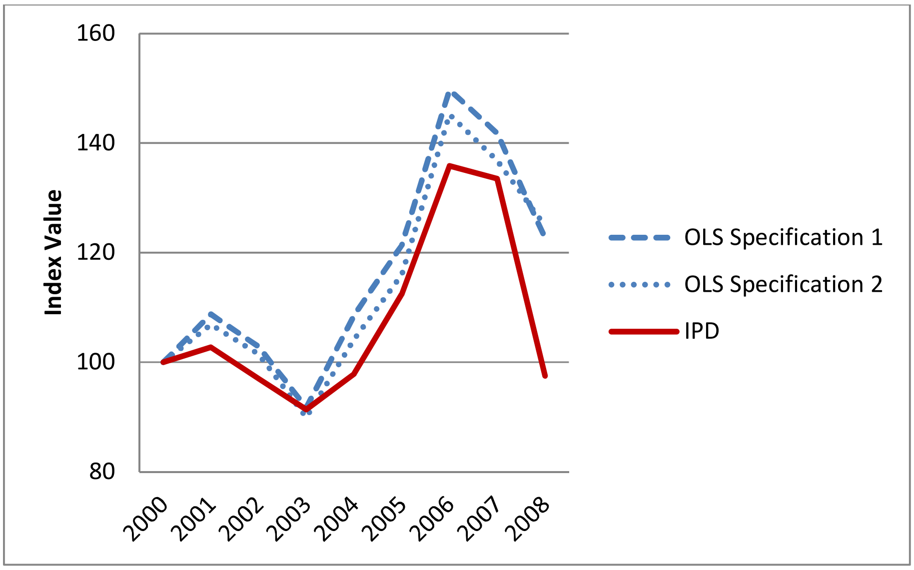
One potentially possibility with the interpretation that employment density changes are driving repeat-sales and sale prices is that this could merely be an effect of new development. In particular, an empty office building could be erected, sold, then tenanted and finally resold. In this case 'local' employment density increases would be associated with both a sale and higher sale prices due to greater occupancy of the very building being sold. Fortunately, few office developments proceed in this manner in London, with many projects being mothballed or cancelled due to a lack of pre-let interest. In addition, there are only 8 buildings in our sample 173 repeat-sales whose first sale was in the same year as the building's most recent refurbishment or redevelopment.

Having confirmed the effect of employment density on price levels in Table 26 we now use the results from this table to construct a repeat-sales price index and compare these with the Investment Property Databank (IPD) appraisal-based capital growth index for inner London[101]. Despite the potential problems of using such valuation-based indices in measuring accurate price-levels (further discussed in chapter 3), this index is adopted here as a comparison merely in order to confirm the plausibility of the estimated repeat-sale values. A repeat-sales price index is constructed for all five specifications in Table 26 in Figure 23 and Figure 24 below. Since the year-dummy coefficients in Table 26 specification 1 represents the change in price each year, the repeat-sales price index flows directly from these values. To construct the indices for specifications 2-5 however, we must specify the levels of previous year employment density change. Because we are interested in the market-wide levels of EDC and not just the levels attributable to the properties which have sold, we multiply each coefficient by the average EDC across all 6,848 properties each year. This adjustment will remove the bias associated with employment density

[101]The inner London index consists of properties located in the West End, Midtown, the City of London, and the surrounding inner boroughs. It is the closest geographic analogue for the location of office sales in our sample which IPD publishes at an annual frequency.

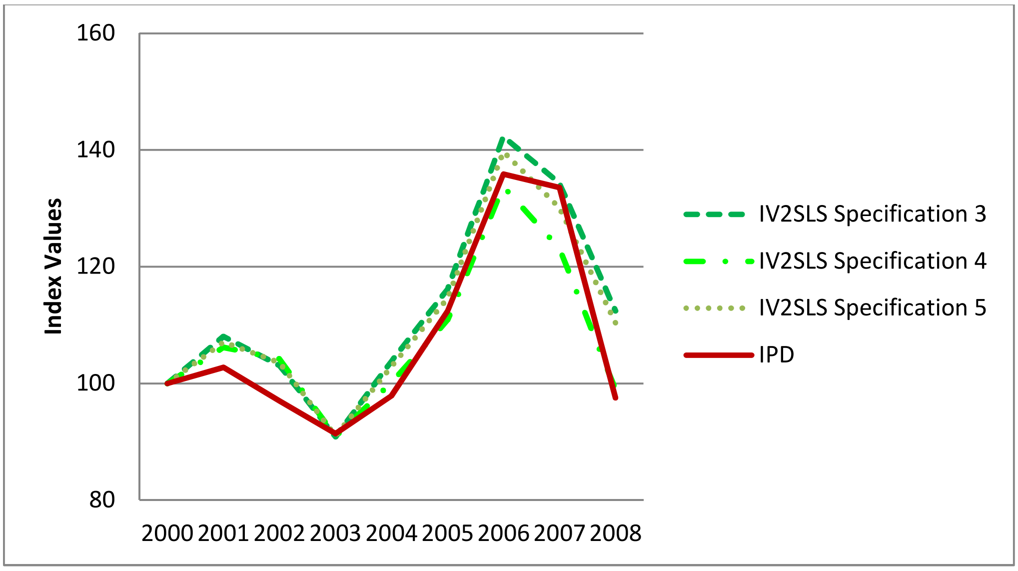
increases driving repeat-sales. Furthermore, due to the semi-log model specification, all estimated coefficients are reconciled for transformation bias according to Kennedy (1981).

Figure 23: OLS price index comparison



As we would expect, OLS specification 1 which omits a control for EDC exhibits a positive bias relative to specification 2 which directly includes EDC. This bias is on average 3% above specification 2. It is interesting to note as well that the EDC correction drives index values closer to the IPD inner London index, which is considered to be the industry standard in the UK.

Figure 24: IV2SLS price index comparison



Comparing Figure 23 with Figure 24 we see that the IV index estimates are secularly lower than the OLS estimates, and importantly, also below specification 1 which excludes controls for EDC altogether. These results are consistent with our expectation that the existence of EDC biases a restricted index upward (specification 1), but that since EDC is endogenous with respect to prices due to omitted variables, EDC must be instrumented in order to yield accurate coefficient estimates. Looking closer at these IV indices, specification 3 using office stock instruments for EDC is slightly higher than the IPD index, while specification 4 using historic employment density is the lowest. Specification 5 which is composed of both the office stock and employment density instruments is the closest match of all 5 specifications to the IPD index.

Although the presence of bias due to employment density changes appears robust across the OLS and IV specifications, one must use care when interpreting the magnitudes indicated in Table 26 because exogenous and valid instruments for EDC were not found. Therefore the various coefficients on EDC may be inconsistent or biased (Chao and Swanson, 2005). In spite of this fact, the results point to a non-trivial bias (even if inaccurately measured) of EDC on prices and estimated repeat-sales price index returns.

We see from the results above that the repeat-sales price index more closely resembles its IPD counterpart when it is corrected for the observed selection effect of EDC. Although the composition of the IPD index may also be problematic in that it only reflects the particular class of properties favoured by institutions, because it based on regular appraisals it does not suffer the problem of only observing the prices of properties which are sold[102]. With EDC influencing sales and sale prices, the fact that not all properties are repeat-sold each period would account for the observed selectivity found here. Even though the series above appear visually dissimilar, in an ideal world we would run tests to verify whether the series presented above are in fact statistically 'different'. However, due to the short duration of the time-series and comparatively large size of the indices' time-coefficient standard errors this is regrettably infeasible.

Submarket bias

The next section examines the possible existence of another selectivity problem with repeat-sales, that of non-representative spatial aggregation. Consistent with real estate market practice, research into commercial office submarkets has shown that not only do submarkets exist, but that their influence is economically meaningful relative to the market as a whole[103]. If the incidence of sales across submarkets varies from year to year, and if these submarkets have different rates of price change overall, then this spatial selectivity could induce another form of bias into price indices. Submarket bias may also be distinct from the effect of EDC, such as for instance, the imposition of tighter supply controls in a given borough generating a relatively larger change in price for any given change in demand.

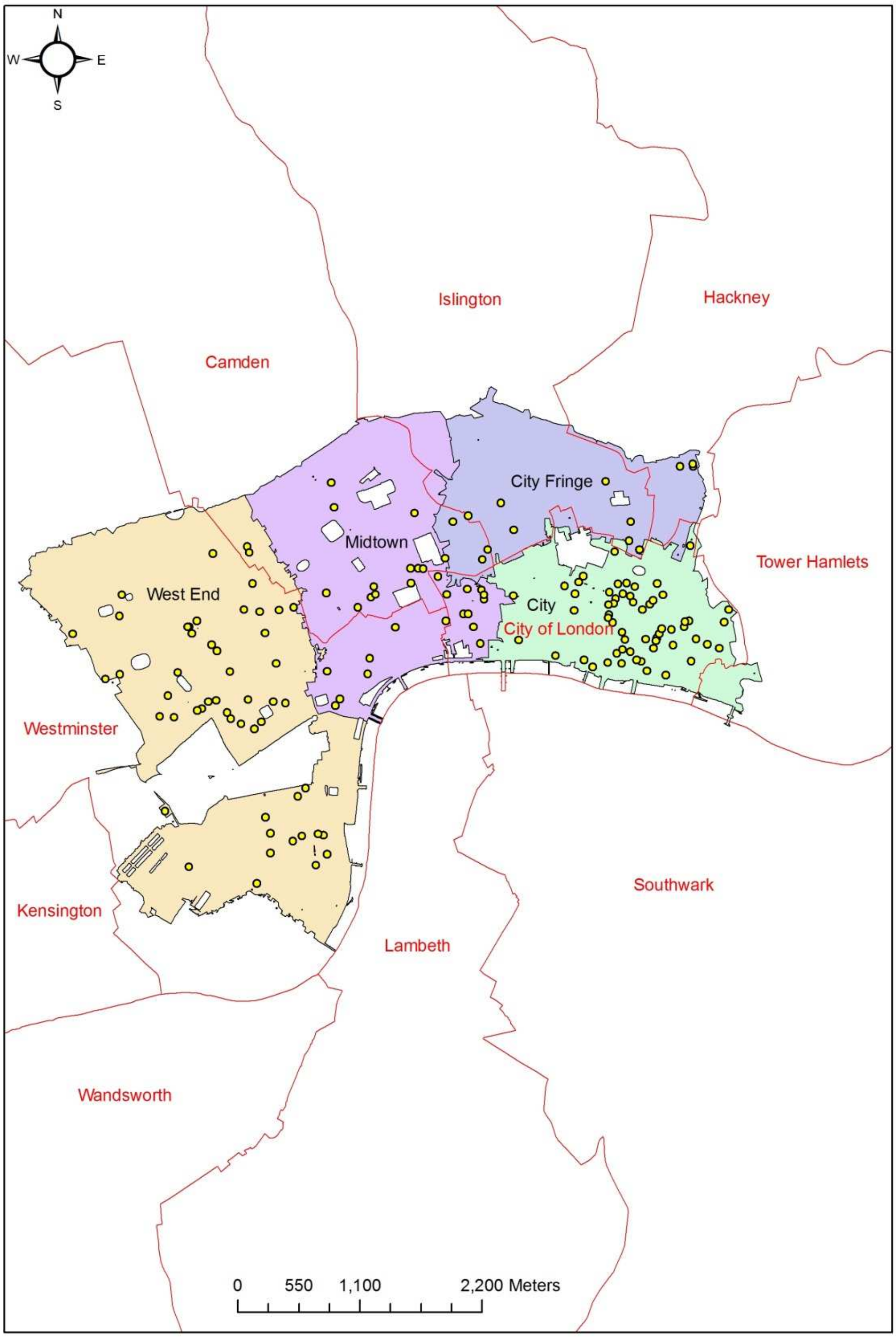
Even though central London is only about 6km across, there may be substantial intra-market variation. From West to East the real-estate professionals recognise three main

[102] Although an appraisal is not equivalent to a market transaction it observable and is an attempt to proxy for one.
[103] See for instance Taylor, Rubin and Lynford (2000), Dunse and Jones (2002), and Stevenson (2007).

submarkets within this area[104]; these are the West-End, Midtown, and the City of London. This paper also follows Estates Gazette (EG) submarket definitions and includes the City of London Fringe (City Fringe) as a valid submarket within central London. These submarkets tend to cater to different industry clusters, with the West End predominantly tenanted by creative industries, hedge funds and private equity firms, Midtown by legal, media and publishing, the City of London dominated by financial services, whereas the City Fringe is less specialised. Rental levels currently are some 25% higher in the West End compared to the rest of central London. In terms of administration, the West End is run primarily by the City of Westminster and to a lesser extent by Camden, Midtown is divided between the City of Westminster, Camden and the City of London, and the City submarket is governed by its namesake along with a sliver of Tower Hamlets. Areas included in the City Fringe, as defined by EG, are administered by; Camden, Islington and small portions of Hackney and Tower Hamlets. A map of central London framed against the boundaries of these boroughs is shown below.

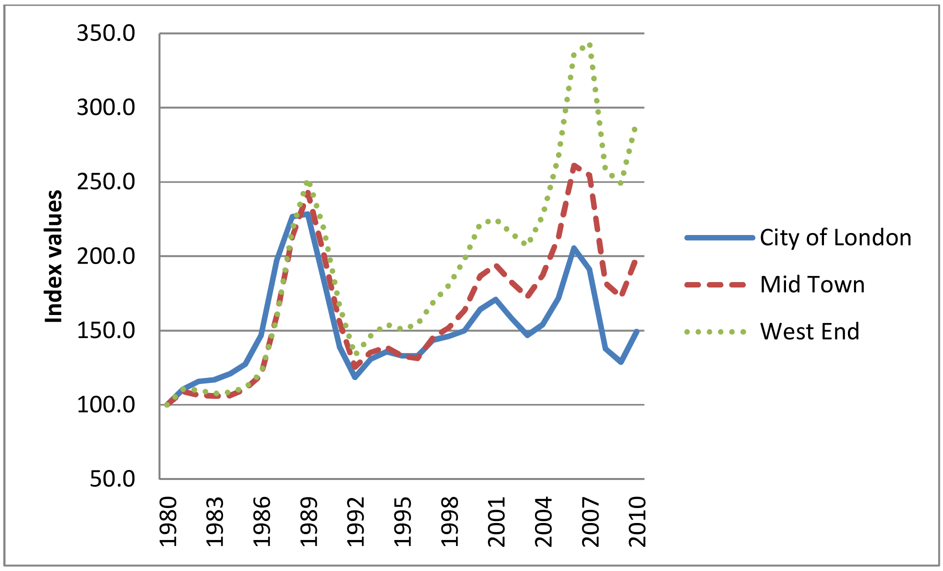
[104] Docklands/Canary Wharf is another major office submarket, but they located in inner and not central London.

Figure 25: London Boroughs, Submarkets, and Repeat-sales Locations



We also have reason to believe a priori that the sample selection of repeat-sales in London could be a problem because these submarkets have historically appreciated at markedly different rates according to series produced by IPD. Moreover, previous research by Hoesli, Lizieri and MacGregor (1997) found that the price movements of the City of London and the West End + Midtown office submarkets clustered differentially. The figure below shows the annual capital growth of these submarkets between 1980-2010 estimated by IPD[105].

Figure 26: Annual IPD central London Submarkets Price-Index comparison 1980-2010



Interestingly, the series begins in the 1980s with the City of London exhibiting the most year-on-year price growth. But after the property crash of the late '80s, capital growth in Midtown and particularly the West End outstrips that of the City. Among the possible causes for this reversal of fortune is the relative relaxation of development restrictions in the City of London. Cheshire and Hilber (2008) argue that the City of London radically reduced its planning restrictiveness starting from the mid-1980s in response to the threat of a new financial-services cluster developing in the neighbouring Docklands. They note that

[105]IPD's definition of City of London is contains both Estates Gazette's definition of City of London and City Fringe.

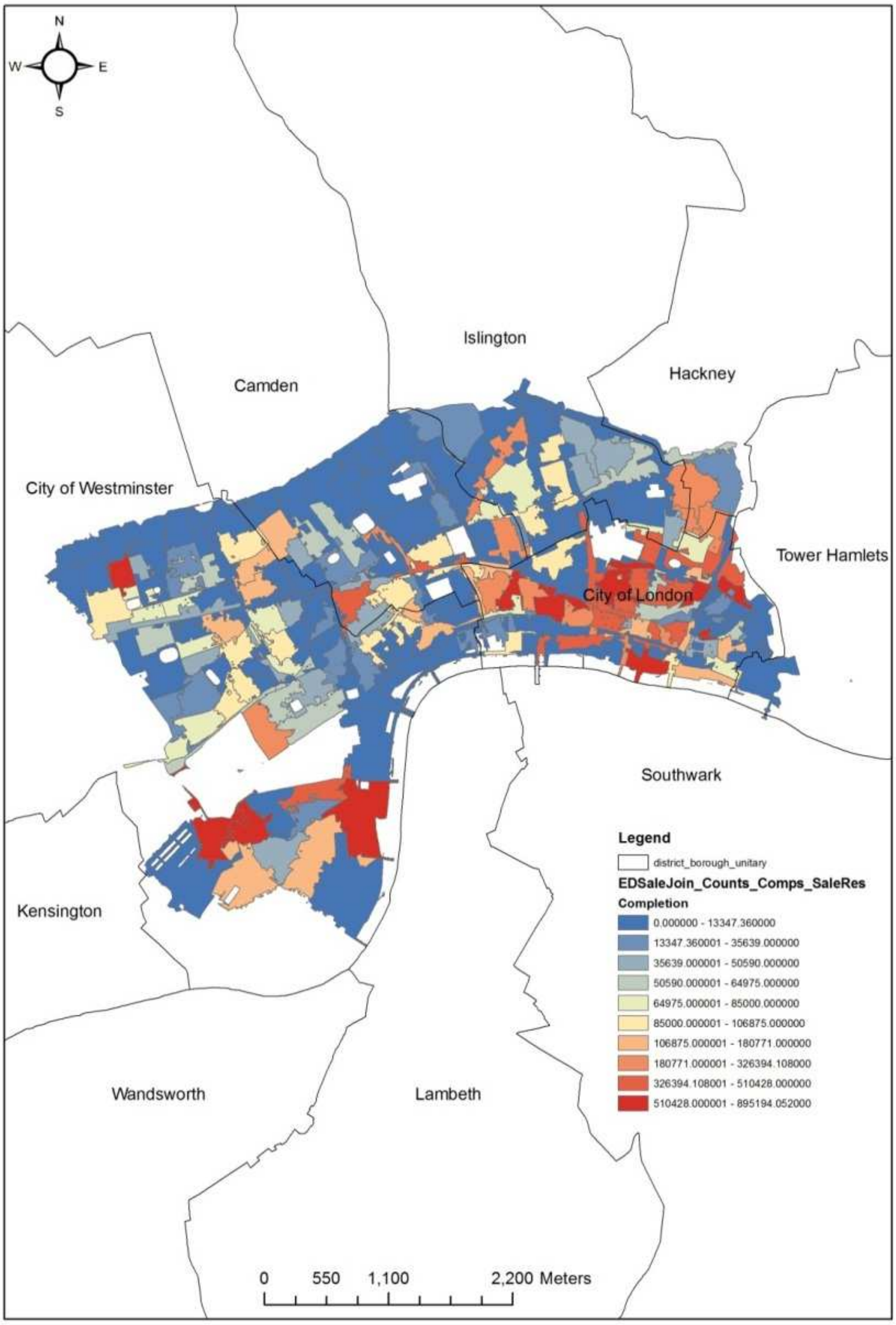
at this time the City began to free up additional land for development, and fixed-plot-ratio limits on building size were enlarged by 25% and then finally removed with the Unitary Development Plan 1994 (Fainstein, 1994). In subsequent years this policy change made possible the construction of many new skyscrapers in the City of London. In contrast, permission to build at large-scale in the West End and Midtown has been all but non-existent since the late 1960s.

Moreover, as the City of London was becoming more permissive with regard to new office development, the other boroughs in central London may have simultaneously been becoming less so. As noted by Cheshire and Hilber (2008) in 1990 there was a 'radical change' to the taxation of all office property across the UK with the implementation of the Local Government Finance Act 1988. Before 1990 office property taxes had been set and collected by the local boroughs in accordance with the General Rate Act 1967. But in response to some boroughs imposing what the then conservative government believed to be anti-business rates of taxation aimed at redistribution, the central government replaced the local office tax rates with a uniform nation-wide rate, the so-called Uniform Business Rate (UBR). Crucially, all revenues associated with the UBR were now pooled by the central government and then redistributed to the local boroughs via Formula Grant (DCLG, 2012). As a result of this legislation, local boroughs now faced a disincentive to permit new office development: bearing the additional fiscal burden associated with new development but now being unable to directly recoup social benefits through taxation[106]. Uniquely, the City of London was granted a special exemption from the UBR to continue to set local rates and directly retain some of the revenues so raised. This policy change may have incited an

[106] Cheshire and Hilber (2008) argue that the sole remaining channel incentivising boroughs to allow commercial development is the local unemployment rate. However, this may not hold exactly as section 106 of the Town and Country Planning Act 1990 does permit local boroughs to be compensated for new developments, often in the form of contributions to infrastructure improvements, maintenance fees, public education, subsidised housing, and land concessions. However these are one-off payments as compared with recurring rental taxation. By way of comparison, the UBR stands between 42.6% and 45.3% of assessed annual rents in central London (Knight Frank, 2012), and nationally UBR receipts were a substantial 4.3% of total tax revenues in 2010-11 (HM Treasury, 2012) . The Tower Hamlets council on the other hand was set to receive a one-time payment of £7m through their section 106 agreement (Greater London Authority, 2009), or 1.75% of estimated construction costs for the recently approved large-scale office known as Columbus Tower in Canary Wharf (Gardiner, 2011). If we conservatively assume capital yields of 5% and a sale-price to construction cost ratio of unity, estimated rents would be £20m and UBR payments would be £9m per annum.

increase in the restrictiveness of the other boroughs in central London relative to the City, and this may be a further reason for the divergence in capital returns beginning in the 1990s seen in Figure 26. Indeed, according to Pennington (2000), the "role of centrally raised taxation in the financing of UK local government may have been a key factor in explaining the general tendency towards anti-growth planning regimes", pp.162. This difference in planning restrictiveness by borough also appears to be borne out in the relative office space completions in central London from 2002-2011 by postcode sector shown in Figure 27 below.

Figure 27: Central London office space completions 2002-2011

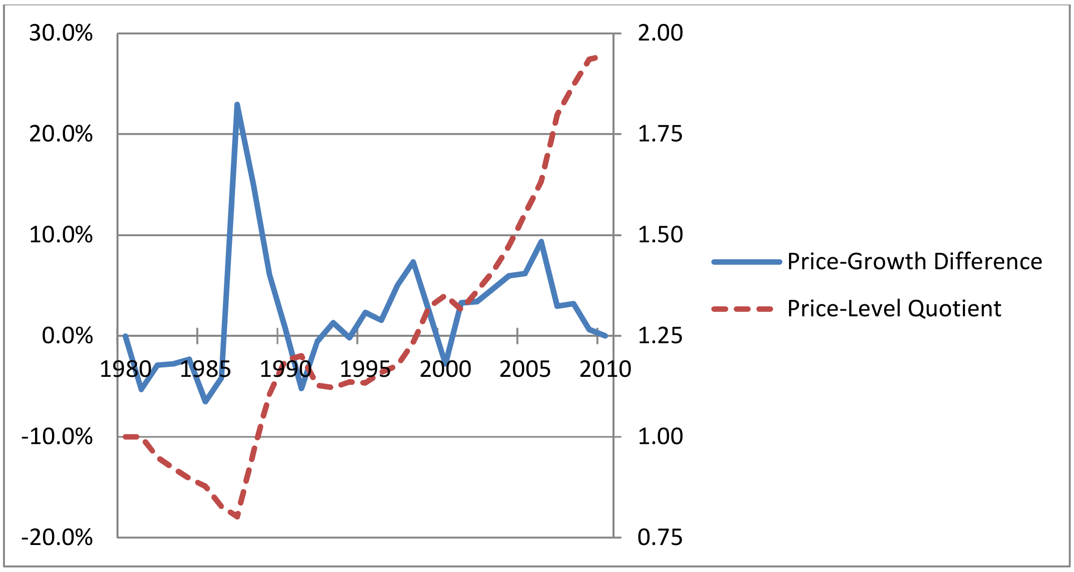


Source: PMA

It is clear from Figure 27 that the majority of new office space added to central London over the past decade has been built within the City of London. Although the West End, particularly in the south around Victoria and Westminster has also seen significant new development, over the same time-frame the West End has also experienced considerable office to residential conversions which the map above does not register[107]. By contrast the City of London sees its primary remit as promoting the growth of business, and is more reluctant to allow office conversions to residential use. Further evidence for the supply restrictions hypothesis is evident in that approximately 75% of the West End is designated as a conservation area where buildings cannot be altered externally, whereas the corresponding figure for the City of London is only 25%. In any case, the divergence between capital values in the City and the West End observed in Figure 28 has grown nearly monotonically since the Local Government Finance Act 1988. This gradual change in relative prices is what one would expect if supply constraints are in fact binding, as the effect of binding supply constraints on price grows cumulatively over time (Cheshire, 2005).

[107] Unfortunately only data on *gross* and not *net* office completions by postcode sector could be obtained.

Figure 28: IPD West End vs the City of London annual price-growth and price-level differences

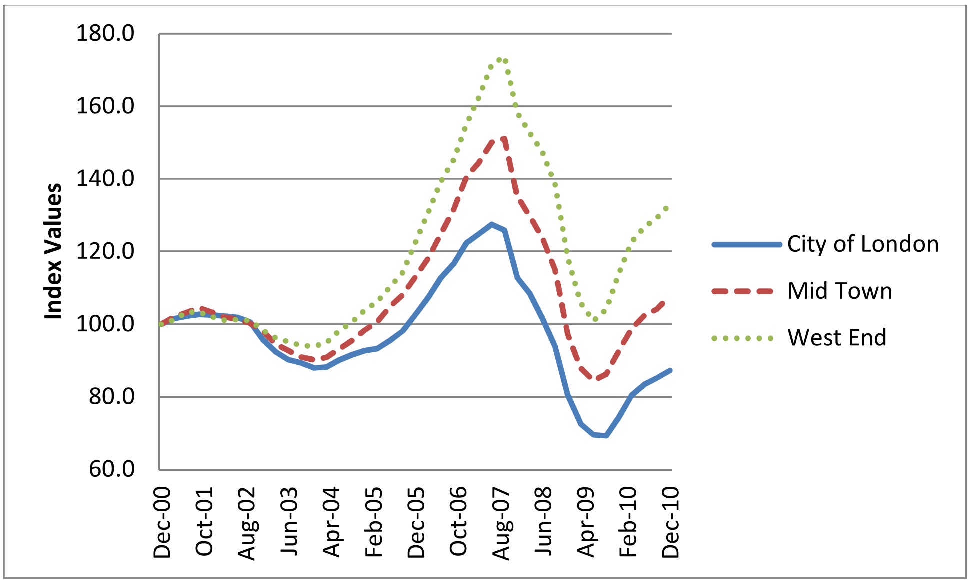


Price-growth difference = West End capital growth rate – City capital growth rate
Price-level quotient = West End price-level / City price-level

Another possible compounding factor for the growth-rate reversal seen in central London submarkets since 1988 is that it coincides with the development of Canary Wharf as a rival financial services cluster to the east of the City. By contrast, the West End does not compete as directly as the City does with Canary Wharf by nature of its older stock of buildings and different tenant clientele. Consistent with the hypothesis that Canary wharf has been cannibalising demand for City office space is that we also see from Figure 26 that Midtown, which is located between the West End and the City, initially commoved with the West End for the first decade of the series, but then began to move secularly lower than West End series around the time tenants first began to occupy Canary Wharf in 1991.

Regardless of the source of this variation, for the time-frame under consideration here West End offices have shown considerable price appreciation relative to the City and Midtown. As we can see from the quarterly IPD submarket series below, it is estimated that since Q4 2000 alone the West End has experienced 25% greater appreciation than Midtown and 50% greater appreciation than the City.

Figure 29: Quarterly IPD London submarket price-index Dec 2000-Dec 2010



It is clear that these large variations in submarket price movements could easily engender bias in repeat-sales indices if the locations of repeat-sales are not representative of the market as whole. To examine this possibility, the table below shows the extent to which office submarket sales and repeat-sales between 2000-08 reflect the submarket location of office stock.

Table 27: Sales, Repeat-Sales, and Office building stock by submarket 2000-08

	City Core	City Fringe	Midtown	West End	Total
Office Stock (Proportion)†	1,123 (16.4%)	1,354 (19.8%)	1,691 (24.7%)	2,680 (39.1%)	6,848 (100%)
Sales‡ (Proportion)	88 (21.5%)	56 (13.7%)	91 (22.2%)	174 (42.5%)	409 (100%)
Repeat-Sales‡ (Proportion)	79 (45.5%)	13 (7.7%)	26 (15.3%)	55 (31.5%)	173 (100%)

†Number of buildings
‡Chi-squared tests find a significant difference at the p = 0.01 level in the submarket locations of the Office Stock and Sales (Chi-squared = 17.41), and the submarket locations of the Office Stock and Repeat-Sales (Chi-squared = 115.37).

From Table 27 we see that sales and repeat-sales occur disproportionately in the City Core compared to the locations of office stock in central London as a whole. In addition, non-repeat-sales appear to be much more representative of office stock locations than repeat-sales. Probit regressions shown below on sales and repeat-sales bear this relationship out. All submarket coefficients are significantly negative relative to the omitted dummy (City Core or City), and t-stats on repeat-sales are substantially more significant than those of sales. We also see from specification 3 that EDC has a selection effect on repeat-sales that is independent from submarket location.

Table 28: Probit regression of Sales and Repeat-Sales on submarket location

VARIABLES	(1) PROBIT Sales	(2) PROBIT Repeat-Sales	(3) PROBIT Repeat-Sales	(4) PROBIT Repeat-Sales
EDC			0.954***	
			(0.367)	
City Fringe	-0.328***	-0.896***	-0.794***	
	(0.0817)	(0.124)	(0.130)	
Midtown	-0.204***	-0.609***	-0.585***	-0.206***
	(0.0740)	(0.0941)	(0.106)	(0.0721)
West End	-0.113*	-0.507***	-0.544***	-0.131**
	(0.0662)	(0.0791)	(0.0791)	(0.0584)
Constant	-1.423***	-1.507***	-1.714***	-1.619***
	(0.0547)	(0.0578)	(0.0707)	(0.0403)
Observations	6,848	6,848	6,848	6,848

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Specifications 1-3 omitted submarket dummy is City Core
Specification 4 omitted submarket dummy is City = City Core + City Fringe

It is interesting to speculate on what could be driving the disproportionate amount of repeat-sales in the City relative to the other submarkets. Perhaps the most likely explanation is that there is greater institutional and international interest in the City of London and as a result greater turnover compared to the rest of central London.

Whatever the cause of this disparity in liquidity, because of the additionally lower price growth in the City of London recorded by IPD, it appears as though sample selection by submarket location may be a biasing factor for repeat-sales indices of central London offices. Given the relative sparsity of repeat-sales in the high capital-growth submarkets of Midtown and West End and the markedly greater price appreciation in the West End, we would expect a naïve repeat sale index to under-represent the true degree of price appreciation experienced by central London as a whole. A repeat-sales regression is run below with submarket dummies included in the specification to test for statistically significant differences in capital appreciation within our dataset. Although ideally each time period would be interacted with each submarket dummy, limited sample size precludes those interactions here. Therefore the submarket dummy variables represent the average additional return accruing to each submarket relative to the City of London throughout the entire analysis period.

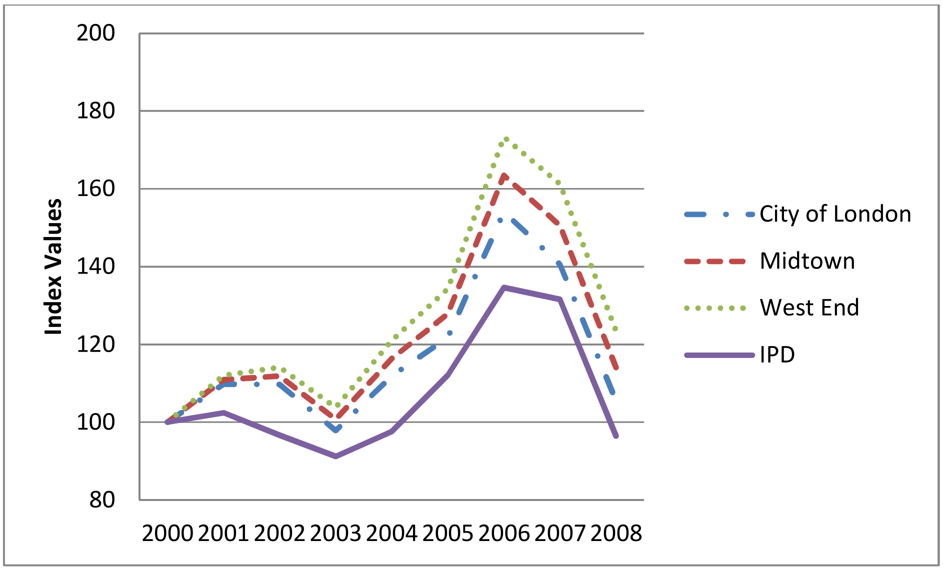
Table 29: Repeat-sales regression with submarket dummy variables

VARIABLES	(1) OLS	(2) IV2SLS
2000	1.265***	1.433***
	(0.478)	(0.485)
2001	0.109	0.0497
	(0.0838)	(0.0888)
2002	-0.00620	0.0155
	(0.0893)	(0.0912)
2003	-0.109	-0.113
	(0.0840)	(0.0861)
2004	0.142*	0.116
	(0.0756)	(0.0790)
2005	0.0860	0.0994
	(0.0615)	(0.0620)
2006	0.243***	0.181***
	(0.0564)	(0.0593)
2007	-0.0989	-0.0768
	(0.0681)	(0.0728)
2008	-0.211	-0.225
	(0.146)	(0.181)
City Fringe	0.0464	0.0183
	(0.0698)	(0.0741)
Midtown	0.0801*	0.0460
	(0.0445)	(0.0473)
West End	0.151***	0.118***
	(0.0352)	(0.0385)
Predicted EDC with all instruments		0.0543
		(0.0394)
Observations	173	173
R-squared	0.725	0.728

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Omitted submarket dummy is City Core

Consistent with our priors we see from Table 29 that properties located in Midtown and the West End have seen statistically greater average price appreciation than properties in the City Core. In addition, price changes in the City Fringe are not statistically different from the City Core, and therefore following IPD we no longer recognize a difference between the two in the subsequent analysis. An F-test that all the submarket dummies are equal to zero yields a p-value of (0.0005). Clearly submarket location matters with respect to estimated rates of return on commercial office repeat-sales. Specification 2 sees the instrumented EDC and Midtown lose their statistical significance, whereas the influence of the West End submarket remains strong even when EDC is included. The fact that submarket location removes the significance of EDC may suggest that employment density changes have been correlated with submarket location throughout the study period. On the same token it could also be indicative of an omitted variable[108]. Table 29 specification 1 is used to calculate the repeat-sales index for each submarket in Figure 30 below. The index values represent the average price level growth achieved in each submarket throughout 2000-08 as indicated in Table 29 specification 1.

Figure 30: Repeat-sales indices by submarket

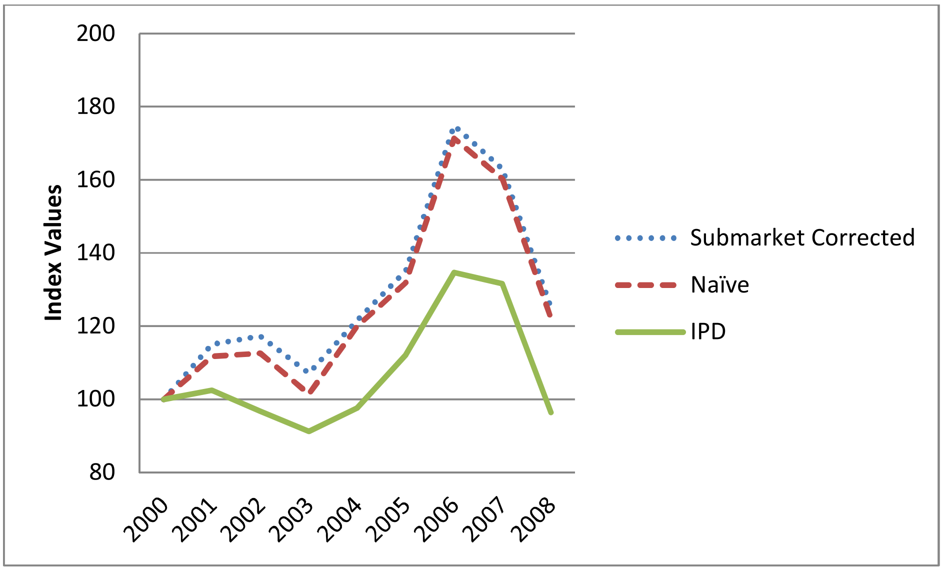


As we can see from Figure 30, the repeat-sales regression not only picks up a substantial difference in index levels between the City, Midtown and West End submarkets, but like the IPD series these differences appear to be economically meaningful. The extent to which these submarket differences could influence a repeat-sales index of all of central London will depend upon the spatial (un)representativeness of the repeat-sales (Table 28).

[108] In fact what we find in Table 31 is that submarket dummies are simultaneously proxying for both local employment density (demand) and the restrictiveness of new development (supply).

Figure 31 below compares a naïve repeat-sales index which neglects the influence of its submarket composition with an index-corrected for this effect by weighting the index values by the actual proportion of the office stock within each submarket (Table 27).

Figure 31: Comparison of Naïve and Submarket-Corrected Repeat-sales price indices



Interestingly the impact of correcting for submarket composition in the repeat-sales index varies by period, with a relative increase in the early years and a decrease relative to the naïve index in later years. This pattern broadly follows the spatio-temporal spread of repeat-sales, with a greater proportion of first and second sales occurring in the City early in the naïve series (except 2001), and a consistently greater proportion of transactions in the West End taking place during the 2007-08 fall in prices. We can see this trend reflected in Table 30 below which disaggregates the submarket selection effect on repeat-sales according to year.

Table 30: Proportion of First and Second Sales of Repeat-sales pair by year and submarket

	City	Midtown	West End	Chi-square Statistic p-value
2000	0.67	0.16	0.16	0.434
2001	0.42	0.15	0.44	0.142
2002	0.60	0.16	0.24	0.321
2003	0.63	0.15	0.22	0.015**
2004	0.56	0.16	0.29	0.017**
2005	0.48	0.26	0.26	0.150
2006	0.52	0.11	0.37	0.020**
2007	0.46	0.18	0.36	0.385
2008	0.48	0.17	0.35	0.478

** $p<0.05$

As shown in Table 30, for the years 2003, 2004 and 2006 chi-square tests find statistically different submarket compositions of repeat-sales and unsold buildings, while 2001 and 2005 are close to statistical significance. We also see that from 2003-08 the proportion of repeat-sales occurring in the West End increased relative to the City of London. If the West End appreciates faster than the City, as in the IPD series, this change in composition would cause the naïve index to increase over time relative to the submarket-corrected index, and that is exactly what we see in Figure 31. As a result of the different rates of price appreciation across these submarkets, naïve repeat-sales price indices may partly reflect the particular submarket composition of the locations where sales occur rather than the price-movements attributable to the market as a whole. Again, although we would like to test whether the observed differences between the naïve and submarket corrected indices in Figure 31 are statistically significant, the short duration of the series and size of the standard errors (Table 31) precludes such analysis.

The role of office supply restrictions

As mentioned earlier, differences in office space supply restrictions across the local boroughs may be a factor in driving the spread of rates of return across the central London submarkets. According to Cheshire (2005), “there can be no real argument that in the UK our planning system raises the price of all categories of real estate very substantially[109]." In order to test whether differences in planning restrictiveness across boroughs accounts for the observed variations in capital growth we require a measure for the planning restrictiveness of each borough. The most obvious candidate is of course the refusal rate of proposed office development applications. Data on the planning application rejection rate by local authority for the period 1990-2008 was provided from the research of Hilber and Vermeulen (2010). However, as noted by Hilber and Vermeulen (2012) this direct measure of planning restrictiveness has at least two sources of endogeneity with respect to prices. The first stems from the fact that planning rejection rates will likely co-move with the economic cycle. When prices are high councils may be inundated with development applications and local opposition to new projects may be strongest. In contrast, during economically sluggish periods with high unemployment the incentives for councils to allow development are highest (Cheshire and Hilber 2008). Like Hilber and Vermeulen (2012), this pro-cylical endogeneity is controlled for by using the planning refusal rate averaged across the entire 1990-2008 period.

The second source of endogeneity arises from the fact that the costly decision on the part of the developer to submit an application is dependent in the first place upon the developer's perception of the likelihood of acceptance. Therefore low rejection rates could be more indicative of many discouraged developers anticipating rejection than a particularly pro-growth stance from the local council. Following the insight of Hilber and Vermeulen (2012), the identification strategy we use is to exploit the exogenous variation from the introduction of the Best Value Performance Indicator 109 (BV 109) enacted in April 2002 which replaced the government's earlier single target to decide 80% of all planning applications within 8 weeks, with three separate targets to decide 60% of major[110] planning applications within 13 weeks, 65% of minor applications within 8 weeks, and 80% of all other application within 8 weeks. The specific change Hilber and Vermeulen identify is that

[109] According to Cheshire's estimates planning controls have, "incrementally over time approximately doubled total occupation costs for non-residential property."

[110] Major developments are defined as those involving either 10 or more new residential dwellings or office, industrial and retail developments involving at least 1,000 square metres of floorspace or where site areas are 1 hectare or over (DCLG, 2007).

with BV 109 local planning authorities could no longer indefinitely delay major project decisions while simultaneously expediting decisions on minor applications and still meet the new government targets as they could with the old targets.

The identifying assumption is that the 2002 policy reform caused more restrictive boroughs to switch from delaying major projects to quick rejection. This policy change should have had the effect of exogenously decreasing the delay-rate for major applications the most in the boroughs which were also in fact the most restrictive. As a robustness check for this hypothesis we should therefore see the 'previous year change in the delay rate[111] for major applications' (PYCDR) and the 'previous year change in rejection rate for major applications' (PYCRR) to be uncorrelated pre and post-reform and then negatively correlated around the time of the reform. Although we do not have sufficient data on boroughs (5) to statistically determine whether PYCDR and PYCRR are uncorrelated for office applications pre and post-reform and negatively correlated during the reform, Cheshire, Hilber, and Kaplanis (2011) show that this is indeed the case for residential and retail applications in Local Planning Authorities across England. Therefore we use 'change in delay rate for major applications' (CDR) pre and post-reform (not previous year) for offices as an instrument to identify the potentially endogenous average planning application refusal rate between 1990-2008.

Following Hilber and Vermeulen (2012), we define pre-reform CDR to be the average of the years 1994-96 and post-reform CDR to be the average of the years 2004-06. Hilber and Vermeulen state that 1994-96 is certainly before BV 109 could have been anticipated and it corresponds to a period where PYCDR and PYCRR are clearly uncorrelated, while 2004-06 empirically corresponds to the period of greatest negative correlation between PYCDR and PYCRR. Therefore 2004-06 should be the period when adjustment to the new policy was primarily taking place. In addition to office planning application refusal rates, we also instrument for dwellings applications in an identical manner. The first-stages of these instruments are shown in 'Appendix B: Planning application refusal rate instrumental

[111] The denominator of this ratio is; Total major office applications + Total minor office applications + Total major dwelling applications + Total minor dwelling applications.

variable first-stages'. Table 31 below shows planning refusal rates added as an additional control in the repeat-sales regression.

Table 31: Repeat-sales and Instrumented Planning Refusal Rates

VARIABLES	(1) OLS Ln(Price-Relative)	(2) IV2SLS Ln(Price-Relative)	(3) IV2SLS Ln(Price-Relative)	(4) IV2SLS Ln(Price-Relative)	(5) IV2SLS Ln(Price-Relative)
2000	1.435***	1.480***	1.376***	1.272***	1.188**
	(0.488)	(0.483)	(0.485)	(0.444)	(0.461)
2001	0.0980	0.0813	0.0636	0.0734	0.0717
	(0.0863)	(0.0843)	(0.0881)	(0.0815)	(0.0820)
2002	0.0270	0.0428	0.0346	-0.0471	-0.0493
	(0.0913)	(0.0806)	(0.0899)	(0.0847)	(0.0852)
2003	-0.119	-0.129	-0.129	-0.0486	-0.0411
	(0.0864)	(0.0759)	(0.0851)	(0.0797)	(0.0807)
2004	0.157**	0.147*	0.149*	0.122*	0.118
	(0.0781)	(0.0775)	(0.0785)	(0.0729)	(0.0735)
2005	0.0976	0.0927	0.0892	0.0873	0.0857
	(0.0636)	(0.0620)	(0.0628)	(0.0603)	(0.0607)
2006	0.244***	0.236***	0.234***	0.232***	0.233***
	(0.0588)	(0.0583)	(0.0587)	(0.0552)	(0.0556)
2007	-0.0706	-0.0947	-0.108	-0.0519	-0.0491
	(0.0724)	(0.0813)	(0.0726)	(0.0680)	(0.0685)
2008	-0.337*	-0.266	-0.167	-0.414**	-0.426**
	(0.181)	(0.170)	(0.169)	(0.183)	(0.185)
Office Refusal Rate	0.445***				
	(0.169)				
Predicted Office Refusal Rate		0.194***	0.0278**	0.127***	0.0453
		(0.061)	(0.0128)	(0.0477)	(0.119)
Predicted EDC with all instruments			4.042***	3.534**	3.595***
			(1.112)	(1.358)	(1.377)
Predicted Dwelling Refusal Rate				-0.191*	-0.0340
				(0.103)	(0.235)
Midtown					0.0198
					(0.0552)
West End					0.0682
					(0.0922)
Observations	173	173	173	173	173
R-squared	0.715	0.720	0.726	0.781	0.781

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

As expected we see from Table 31 specifications 1 and 2 that office planning refusal rates have a statistically significant positive effect on the price difference between repeat-sales.

In addition, we see in specification 3 that the effect of office planning controls is robust to the inclusion of employment density changes. In specification 4 the instrumented major dwelling refusal rate is added, and perhaps surprisingly we see that its coefficient is significantly negative at the 10% level. The negative coefficient implies that the more lenient the local planning authority is with respect to allowing new residential developments, the greater the office price appreciation within that borough. If this effect is true there are at least two possible interpretations for it. The first is that residential space may be a complement to office space, so boroughs which allow more residential development increase the value of neighbouring office space. Although Thibodeau (1990) found that residential property located close (but not too close) to office space enjoyed a price premium, the converse may also be true in that offices located close to potential employees become more valuable locations. If true, then new residential developments approved in these boroughs may increase the prices of local offices. The second perhaps more powerful explanation is that the addition/conversion of more residential space serves as a further constraint on office supply. As noted earlier, the West End has seen considerable office to residential conversion in the last decade. In fact, according to the Greater London Authority (2012) over the period 2000-08 the City of Westminster (which is the primary borough comprising the West End) lost 120,000m^2 or 8.1% of its total office stock. By contrast office stock in the City of London grew by 6.5% over the same period. Furthermore, when potential office sites are developed into residential property it lowers the expectation of future competing supply. Therefore it is plausible that the negative and significant coefficient on residential refusals could be picking up the *reduction* in present and future competing local office supply that stems from greater residential development.

Table 31 specification 5 adds dummy variables for the Midtown and West End submarkets. When these additional controls are included, the refusal rate for offices and dwellings become insignificant while EDC retains its significance. Note the contrast of Table 31 specification 5 with Table 29 specification 2, where EDC became insignificant with the inclusion of submarket dummies. As EDC is a measure of local demand and the Office and Dwelling Refusal Rate are measures of supply (restrictiveness), it seems plausible that when you control for both these factors submarket dummies lose their ability to explain repeat-sales price movements. In fact, the R-squared of specification 5 is no larger than specification 4 which omits the submarket dummies. Therefore it appears that when submarket location dummies are included in a repeat-sales regression they are functioning as a surrogate for both employment density changes (a measure of demand) and the restrictiveness of new development (a measure of supply).

Unobserved sample heterogeneity

Having examined the effect of *observable* sample heterogeneity on repeat-sales indices, we now turn our attention to the possibility of *unobserved* sample heterogeneity. Although we cannot explicitly control for unobserved sample heterogeneity with an unrestricted regression, the Heckman (1979) correction allows for this bias to be modelled indirectly. As in the case of observed heterogeneity, the Heckman procedure treats the sample censoring[112] as a specification error in which a variable is incorrectly omitted from the proper estimation equation. And similarly, the expected value of the error term in an uncorrected estimation equation is non-zero, resulting in biased coefficient estimates depending on the correlation with the error. Heckman's solution to model unobserved heterogeneity is to use a probit regression with a set of instruments to estimate the probability that the dependent variable is censored from the sample. The estimated probit errors are then used to model the selection bias in the outcome regression with the inverse Mills-ratio or hazard-rate (Amemiya, 1985). The Mills-ratio is then included as an additional independent variable in the now correctly specified estimation equation.

The key requirements in order to perform the Heckman correction is that we have data on the entire population of buildings and instruments which influence selection but which will not lead to misspecification when omitted from the outcome regression (Johnston and Dinardo 1997). Following Gatzlaff and Haurin (1997) we use characteristics of the surrounding environment and macroeconomic variables in order to model selection. Owner attributes and physical characteristics of properties which may yield additional explanatory

[112] Censoring in the sense that not all office properties in central London are sold and observed each period.

power in the probability of sale as in Fisher, Geltner, Gatzlaff and Haurin (2004) and Devaney and Diaz (2011) are unfortunately unavailable.

The selection variables used are; EDC, submarket, CDR, postcode district[113], interest-rates[114], Euro exchange rate[115], US$ exchange rate[116], quarterly submarket vacancy rate, quarterly submarket take-up, quarterly submarket availability[117], quarterly London unemployment rate[118], current quarter office price levels, and cumulative office returns over the previous 4 quarters[119]. By including submarket dummies and postcode sectors, the postcode sectors should primarily represent areas which experience the highest sales turnover net of submarket price-trends (see Figure 20 above of repeat-sales turnover by postcode sector). In addition, since local areas in cities and in London in particular are often associated with broadly similar office stock characteristics (Taylor, Rubin and 2000, and Stevenson 2007)[120], location data at the postcode sector level may be granular enough to also partly control for heterogeneous building characteristics omitted here. Euro and US$ exchange rates were chosen as US and European buyers account for 71% of all foreign buyers and 42% of all buyers foreign and domestic in the City of London (Lizieri, Reinhart and Baum, 2011). Commercial real estate transaction volume has been shown to be pro-cyclic with market conditions (see Fisher, Geltner, Gatzlaff and Haurin, 2003 and 2004), which forms the basis for the inclusion of the real estate and labour market performance indicators.

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[113] Some 23 of the 70 postcode districts had to be merged with other districts in order to ensure all districts contained uncensored observations and thereby assisting model convergence in the first-stage. These postcode districts were merged to adjacent districts.
[114] End month UK banks' base interest rates. Source: Bank of England.
[115] End month spot exchange rate Euro into Sterling. Source: Bank of England.
[116] End month spot exchange rate US$ into Sterling. Source: Bank of England.
[117] Real estate submarket data on vacancy rates is from Land Securities. Submarket data on take-up and availability comes from CBRE.
[118] Unemployment data consists of all people economically active but unemployed living in the London Region. Source: NOMIS.
[119] Price levels and changes derived from repeat-sales regression of 354 Inner London office properties 1998-2010, see Chapter 3.
[120] This fact has become increasingly true since the introduction of conservation areas in 1967 and the desire to maintain the distinctiveness of each particular area. Other planning rules such as the London View Management Framework would also confine certain types of buildings to particular locations, see City of London (2010).

An important difference with the Heckman-based correction for selectivity employed by Gatzlaff and Haurin (1997)[121] is that this paper uses a standard Heckman's correction, whereas the Gatzlaff and Haurin paper especially derive and apply a bivariate sequential Heckman's selection for repeat-sales. Gatzlaff and Haurin use this sequential selection estimation equation because they are concerned with the possibility of sample selection bias occurring at the time of both sales. The standard Heckman procedure was chosen here instead because evidence for sample selection bias was found to be present only in properties that sold twice or more during the study period and not in non-repeat-sales (see Table 25 and 'Appendix C: Heckman corrections on hedonic regressions'). Hwang and Quigley (2004) for instance also find that only repeat-sales and not single-sale properties appear to exhibit selection bias. In the absence of selection at the time of the first-sale Gatzlaff and Haurin's sequential selection procedure collapses to a simple univariate probit. To see this we begin with the two selection equations. The selection equation for first sales is;

$$S_i^{1^*} = \sum_m^M \gamma_m Z_{im} + v_i^1 \} \; S_i^1 = 1 \; if \; S_i^{1^*} \geq 0, \text{ and 0 otherwise} \quad \textbf{(6)}$$

And the selection equation for second sales is;

$$S_i^{2^*} = \sum_m^M \gamma_m Z_{im} + v_i^2 \} \; S_i^2 = 1 \; if \; S_i^{2^*} \geq 0, \text{ and 0 otherwise}$$

Where;

$S_i^{1^*}$ = threshold value of office *i* observing a first-sale

$S_i^{2^*}$ = threshold value of office *i* observing a second-sale

[121] This is the only other example that was found in the literature of a Heckman's correction being used to remedy selection bias in a real-estate repeat-sales index.

S_i^s = indicator variable for sale number $s = 1,2$

γ_m = coefficient on Z_m

Z_{im} = characteristic *m* of office *i* which influences the probability of sale

v_i^s = normally distributed error term on office *i* at sale number $s = 1,2$.

As in Gatzlaff and Haurin (1997) we assume that the specifications of both selection equations are identical, but the coefficients in both equations are estimated separately.

As in equation (2) and (3), first and second sale prices are assumed to be determined by;

$$P_i^1 = \sum_{j=1}^{J} \beta_j X_{ij}^1 + \sum_{t=1}^{T} I_t D_t^1 + \epsilon_i^1$$

$$P_i^2 = \sum_{j=1}^{J} \beta_j X_{ij}^2 + \sum_{t=1}^{T} I_t D_t^2 + \epsilon_i^2 \quad \textbf{(7)}$$

Where the variables are defined as previous. The covariance matrix of the four equation errors $[v_i^1, v_i^2, \epsilon_i^1, \epsilon_i^2]$ is;

$$\begin{bmatrix} 1 & \sigma_{12} & \sigma_{13} & \sigma_{14} \\ \sigma_{12} & 1 & \sigma_{23} & \sigma_{24} \\ \sigma_{13} & \sigma_{23} & \sigma_{33} & \sigma_{34} \\ \sigma_{14} & \sigma_{24} & \sigma_{34} & \sigma_{44} \end{bmatrix} \quad \textbf{(8)}$$

With unobserved selection bias the expectation of the first log sale-price conditional on sales being observed in both periods is;

$$E[P_i^1|S_i^2 = 1, S_i^1 = 1] = \sum_{j=1}^{J} \beta_j X_{ij}^1 + \sum_{t=1}^{T} I_t D_t^1 + E[\epsilon_i^1|\, S_i^2 = 1, S_i^1 = 1]$$

Which reduces to;

$$E[P_i^1 \big| S_i^2 = 1, S_i^1 = 1] = \sum_{j=1}^{J} \beta_j X_{ij}^1 + \sum_{t=1}^{T} I_t D_t^1 + \delta_{13}\lambda_1 + \delta_{23}\lambda_2 \qquad \textbf{(9)}$$

And the expectation of the second log sale-price conditional on sales being observed in both periods is;

$$E[P_i^2|S_i^2 = 1, S_i^1 = 1] = \sum_{j=1}^{J} \beta_j X_{ij}^2 + \sum_{t=1}^{T} I_t D_t^2 + E[\epsilon_i^2|\, S_i^2 = 1, S_i^1 = 1]$$

Which becomes;

$$E[P_i^2|S_i^2 = 1, S_i^1 = 1] = \sum_{j=1}^{J} \beta_j X_{ij}^2 + \sum_{t=1}^{T} I_t D_t^2 + \delta_{14}\lambda_1 + \delta_{24}\lambda_2 \qquad \textbf{(10)}$$

Again assuming $\forall i \forall j (X_{ij}^1 = X_{ij}^2)$, differencing equations (9) and (10) yields;

$$E[P_i^2 \big| S_i^2 = 1, S_i^1 = 1] - E[P_i^1|S_i^2 = 1, S_i^1 = 1]$$
$$= \sum_{t=1}^{T} I_t (D_t^2 - D_t^1) + (\delta_{14} - \delta_{13})\lambda_1 + (\delta_{24} - \delta_{23})\lambda_2 \qquad \textbf{(11)}$$

In the event of selection in the first and second-sale, equation (11) will produce unbiased estimates of the index levels I_t. However with selection in the second-sale only, λ_1 is zero and the first selection equation (6) collapses to a purely random error term that cannot be correlated with the error in second outcome equation (10)[122]. Therefore the δ_{23} term in variance-matrix (8) is also zero, and equation (11) collapses to a standard Heckman;

$$E[P_i^2 | S_i^2 = 1] - P_i^1 = \sum_{t=1}^{T} I_t(D_t^2 - D_t^1) + \gamma\lambda_i$$

Whose estimation equation becomes;

$$P_i^2 - P_i^1 = \sum_{t=1}^{T} I_t(D_t^2 - D_t^1) + \gamma\lambda_i + \varepsilon_i \qquad \textbf{(12)}$$

Equation (12) will estimate unbiased coefficients when there is possible unobserved sample selection bias in the second-sale only. Therefore a standard Heckman's correction should be sufficient to capture the relevant structure of repeat-sales selectivity in our sample. Furthermore, there can be much to lose by adopting Gatzlaff and Haurin's sequential selection method in the absence of selection in both sales, as models with multiple selection are often non-robust and especially sensitive to sample size and departures from normality.
Table 32 and Table 33 below present the selectivity-corrected repeat-sales indices, and then successively include the instrumented EDC and submarket variables into the outcome equation for comparison

[122] Moreover, the results of Gatzlaff and Haurin (1997) which test for selection in both sales are consistent with errors from the first sale occurrence only being correlated with the first sale price, and the second sale occurrence only being correlated with the second sale price. Therefore it is plausible that δ_{23} could be zero even if there were selection in both sales.

Table 32: Heckman's corrected Repeat-sales indices: Naïve and Instrumented EDC

VARIABLES	(1) Heckman Ln(Price-Relative)	(2) Selection Equation	(3) Mills-Ratio	(4) Heckman Ln(Price-Relative)	(5) Selection Equation	(6) Mills-Ratio
2000	0.972*	-0.151		0.948	-0.151	
	(0.583)	(1.309)		(0.578)	(1.309)	
2001	-0.0361	-0.0193		-0.0384	-0.0193	
	(0.0956)	(0.220)		(0.0947)	(0.220)	
2002	0.0910	-0.0354		0.0940	-0.0354	
	(0.0931)	(0.208)		(0.0923)	(0.208)	
2003	-0.180**	0.00748		-0.181**	0.00748	
	(0.0873)	(0.199)		(0.0865)	(0.199)	
2004	0.105	0.00447		0.103	0.00447	
	(0.0793)	(0.190)		(0.0786)	(0.190)	
2005	0.0722	-0.00226		0.0681	-0.00226	
	(0.0614)	(0.158)		(0.0610)	(0.158)	
2006	0.183***	0.0154		0.182***	0.0154	
	(0.0598)	(0.161)		(0.0592)	(0.161)	
2007	-0.0839	-0.0216		-0.0968	-0.0216	
	(0.0744)	(0.204)		(0.0751)	(0.204)	
2008	-0.351**	0.0877		-0.332**	0.0877	
	(0.165)	(0.422)		(0.165)	(0.422)	
Postcode Sector Dummies		YES			YES	
Interest Rate		0.0547			0.0547	
		(0.217)			(0.217)	
Euro FX		0.120			0.120	
		(0.942)			(0.942)	
US FX		-0.111			-0.111	
		(0.826)			(0.826)	

Vacancy Rate		0.000616			0.000616	
		(0.0342)			(0.0342)	
Take Up		-0.000665			-0.000665	
		(0.00442)			(0.00442)	
Availability		0.00141			0.00141	
		(0.0119)			(0.0119)	
Unemployment Rate		-0.00210			-0.00210	
		(0.160)			(0.160)	
Cumulative Office Return over Previous 4 Qtrs		0.0742			0.0742	
		(0.282)			(0.282)	
Office Price Level		-0.000243			-0.000243	
		(0.00772)			(0.00772)	
EDC		1.069***			1.069***	
		(0.405)			(0.405)	
Predicted EDC with all Instruments				0.704		
				(0.786)		
Predicted Office Refusal Rate		-8.701			-8.701	
		(17.17)			(17.17)	
Predicted Dwelling Refusal Rate		6.346			6.346	
		(9.284)			(9.284)	
Midtown		-1.214***			-1.214***	
		(0.408)			(0.408)	
West End		-0.785*			-0.785*	
		(0.431)			(0.431)	
Lambda			0.0668***			0.0398
			(0.0187)			(0.0354)
Constant		-1.869			-1.869	
		(2.716)			(2.716)	
Observations	6,848	6,848	6,848	6,848	6,848	6,848

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

From column (1) and (3) we see from the significant lambda term that the standard repeat-sales regression contains unobserved sample heterogeneity. The lambda term is positively-signed which establishes that the error terms in the selection and outcome equations are positively correlated. Therefore, unobserved factors which make repeat-sales more likely tend to be associated with higher price-relatives. As a result, the coefficients in the outcome equation are biased (primarily upward), and the resulting index will overestimate actual returns. We can see that the insertion of predicted EDC into outcome equation (4) halves the coefficient on Heckman's lambda and removes its statistical significance. Therefore when EDC is observed, unobserved characteristics appear to be no longer biasing the coefficients of the outcome equation. Table 33 below extends this analysis by including office and dwelling refusal rate and submarket location as controls for unobserved sample heterogeneity.

Table 33: Heckman's corrected Repeat-sales indices: Submarkets and Instrumented EDC

VARIABLES	(1) Heckman Ln(Price-Relative)	(2) Selection Equation	(3) Mills-Ratio	(4) Heckman Ln(Price-Relative)	(5) Selection Equation	(6) Mills-Ratio
2000	0.906	-0.462		1.044*	-0.462	
	(0.576)	(1.656)		(0.564)	(1.656)	
2001	-0.0164	-0.191		-0.0167	-0.191	
	(0.0949)	(0.272)		(0.0927)	(0.272)	
2002	0.0798	0.0711		0.0584	0.0711	
	(0.0918)	(0.249)		(0.0900)	(0.249)	
2003	-0.163*	-0.0803		-0.153*	-0.0803	
	(0.0860)	(0.230)		(0.0840)	(0.230)	
2004	0.109	0.0782		0.105	0.0782	
	(0.0786)	(0.216)		(0.0766)	(0.216)	
2005	0.0675	0.0521		0.0624	0.0521	
	(0.0605)	(0.174)		(0.0591)	(0.174)	
2006	0.182***	-0.0356		0.201***	-0.0356	
	(0.0591)	(0.173)		(0.0583)	(0.173)	
2007	-0.103	0.0544		-0.112	0.0544	
	(0.0745)	(0.216)		(0.0728)	(0.216)	
2008	-0.295*	0.185		-0.286*	0.185	
	(0.166)	(0.443)		(0.163)	(0.443)	
		(1.736)			(1.736)	
Postcode Sector Dummies		YES			YES	
Interest Rate		0.0766			0.0766	
		(0.249)			(0.249)	
Euro FX		-0.548			-0.548	
		(1.048)			(1.048)	
US FX		-0.447			-0.447	

		(0.948)			(0.948)	
Vacancy Rate		0.00268			0.00268	
		(0.0413)			(0.0413)	
Take Up		0.00115			0.00115	
		(0.00506)			(0.00506)	
Availability		0.0125			0.0125	
		(0.0138)			(0.0138)	
Unemployment Rate		-0.117			-0.117	
		(0.182)			(0.182)	
Cumulative Office Return over Previous 4 Qtrs		0.164			0.164	
		(0.319)			(0.319)	
Office Price Level		0.00602			0.00602	
		(0.00869)			(0.00869)	
EDC		1.407***			1.407***	
		(0.453)			(0.453)	
Predicted EDC with all Instruments	1.074			0.740		
	(0.941)			(0.955)		
Predicted Office Refusal Rate	-0.483	39.11***		-0.282	39.11***	
	(0.537)	(3.024)		(0.530)	(3.024)	
Predicted Dwelling Refusal Rate	0.360	-11.36***		0.332	-11.36***	
	(0.489)	(1.736)		(0.482)	(1.736)	
Midtown		-0.719		0.0612	-0.719	
		(0.444)		(0.0524)	(0.444)	
West End		-0.471		0.115**	-0.471	
		(0.455)		(0.0449)	(0.455)	
Lambda			0.0169			-0.00184
			(0.0179)			(0.0191)
Constant		-2.785			-2.785	
		(3.061)			(3.061)	
Observations	6,848	6,848	6,848	6,848	6,848	6,848

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Indeed we see that the office refusal rate in specification (1) and that the combined effect of the office refusal rate and submarket dummies in specification (4) further decreases the relevance of Heckman's lambda. The inability of Heckman's lambda to explain price movements when the additional controls for EDC and planning refusal rate are included is consistent with the hypothesis that the data is no longer being biased by unrepresentative external effects. Although it would be premature to conclude that there are no other factors at work that are imparting bias on this repeat-sales index, this result is at least encouraging that much of whatever external bias exists is contained within these two measures.

Conclusion

The primary advantage of repeat-sales indices is that their construction requires no more than the sales price, the identity of the property and the dates of paired sales. However, the assumptions that allow this procedure to produce an accurate price index may be violated in practice with important consequences. This study showed that repeat-sales of office properties in London are over-weighted by their specific temporal and locational attributes relative to the office stock as a whole. The factors contributing to this bias were found to be employment density changes and the restrictiveness of office supply in the corresponding local authority area. This bias arises because of the effect of employment density and supply restrictions on prices and the fact that repeat-sales occur disproportionately in areas where these attributes differ compared to the stock as a whole. Although other factors not examined here may be simultaneously causing bias in the repeat-sales index, when employment density changes and planning restrictiveness are controlled for, a Heckman's correction for unobserved sample heterogeneity loses its ability to explain index levels. These findings are consistent with the conjecture that employment density changes and development restrictiveness are the key external drivers of sample heterogeneity and bias. The methodological contribution to this paper is that it may be enough to run a standard Heckman's correction when there is only selection occurring in the second-sale.

Although these findings are compelling they may not be conclusive as there were a number of potential problems encountered by this research. A key problem with the employment density analyses was that an exogenous instrument could not be identified, and the instruments that were used were weak. As a result, the magnitude of the effect of employment density changes on prices is still an open question. Fortunately, the planning refusal rate instruments encountered no such difficulties. Of perhaps foremost concern however is the fact that the sample size of 173 repeat-sales is modest. It could be the case that as more data is collected the issues of sample bias encountered with this study will fade. In fact, it might even appear logical to argue that this could undoubtedly be the case since practically every property eventually sells twice[123], and the information contained between sales will eventually be made available to researchers. However as Wang and Zorn (1999) note this is not necessarily true. Although practically every property may indeed sell twice, these sales may not be usable in a repeat-sales regression because of refurbishments or redevelopments between sales. Moreover, even if all properties eventually sell, the fact that other properties which differ on relevant dimensions are selling with greater frequency can still impose biases on the index. In a word, even as the sample size grows indefinitely large there is no guarantee that the sample of repeat-sales observed will resemble the actual stock. A further difficulty encountered by this research is that the sample of sales is not the total population of all repeat-sales (as may possibly be obtained through tax-records), but rather the sample of repeat-sales which were made available to RCA and EG, and for which relevant data could be obtained. Therefore if this particular sample of repeat-sales differs from the actual population of repeat-sales these results would fail to be generalisable.

One potential implication of the modest sample size is that although selection bias for employment density changes and planning restrictiveness were found to be statistically significant in a regression setting, the resulting price indices derived from them were not statistically different from the naïve repeat-sales index[124]. This might be expected as the index only reports price levels at the annual rather than quarterly frequency. Moreover this finding is common in much of the commercial property literature, as sample size

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[123] As perhaps a counterexample the Grosvenor estate consisting of 300 acres of land in the West End has practically never sold any property since 1677 as a matter of policy.
[124] Although it is not reported here, the standard errors are large enough in both instances that one standard error exceeds all index corrections above.

restrictions often make bias corrections of indices statistically insignificant. For instance, in analysis of commercial office sales in Phoenix, US, Munneke and Slade (2000) find evidence for sample selection bias when utilizing a Heckman's correction. However, when the Mills-ratio adjusted values are applied to the resulting price index in general they did not change the index values more than a confidence interval of 10% in both directions. Clapp and Giacotto (1992) find a similar result in modelling the representativeness of house price indices in US cities. Even though the corrected indices here were not statistically different from uncorrected indices, the differences between the two may still be practically important. Where these indices are used as performance benchmarks or in order to assess the cross-correlation of returns with respect to other assets for investment purposes, accurate indices are essential to informed decision-making. As such, perhaps a more relevant metric than statistical significance is economic significance for the particular question at hand.

The correlation between planning restrictiveness by submarket and the realized returns of office properties within that submarket has important implications. As argued by Cheshire (2005), to a large extent the current level of office prices in the United Kingdom is a product of the system of planning controls currently in force which effectively restrict supply. There is no denying the fact that office prices in London are among the highest in world. Comparing the price of office space in UK cities to similar metropolises in other developed nations shows a marked price gap between the two (Cheshire and Hilber, 2008). Moreover, it is not just in the arena of office space that these controls appear to have had a serious effect. Research by Cheshire, Hilber and Kaplanis (2011) has demonstrated that the productivity of retail space has been curtailed as a result of the further expansion of these policies into 'town centre first' initiatives. Moreover, Hilber and Vermeulen (2012) show that house prices have also been very substantially inflated in the London area by planning restrictions. This present study is entirely consistent with those findings and provides additional evidence for the inflationary effect of planning restrictiveness on office property price levels.

In spite of the problems with sample selection bias identified here, the relative ease with which RSPIs can be created makes them still useful in the context of other index construction methods. This is especially true in the case of commercial price indices, where the characteristics of individual properties tend to be highly idiosyncratic and therefore the advantages of controlling a property's characteristics with previous observations through a fixed effects method are greater. Although the measured biases were not statistically significant, in the context of constructing price indices for use in industry EDC may very well be important to control for, and the difference observed in submarket returns is notable, even if the measured bias from these effects were small.

Practically speaking however, it is unlikely that controlling for employment density in repeat sales will enter into industrial protocol in the near future. Aside from the fact that it is doubtful that such a process could be mechanised, currently there is a three year gap between when NOMIS collects and then publishes employment data. Due to this considerable time-lag, employment density corrections are likely to only be feasible in the arena of academic work and historical record-keeping. Of course, cities other than London may have more timely employment reporting, and therefore it may be possible that some commercial uses such as perhaps performance benchmarking may prove viable. Submarket corrections however are much more simply controlled for and would not suffer time-lags in reporting the way that employment density corrections in London do. Looking forward, London may yet produce a commercially viable repeat-sales index for use in industry and finance. At such time that it does so, it is hoped that the findings of this paper can be used to inform market participants of the potential pitfalls of this index, and therefore to help them better position it within the universe of existing alternatives.

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Appendix A: EDC Instrumental variable first-stage regressions

Table 34: Dependent variable is Previous Year Employment Density Change

VARIABLES	(1) OLS Employment Density Change	(2) OLS Employment Density Change	(3) OLS Employment Density Change
Density of office completions 600m, 2002-11	8.91e-07**		9.16e-07**
	(4.12e-07)		(4.34e-07)
Density of office stock 600m, 2002	-3.58e-05**		-3.45e-05**
	(1.52e-05)		(1.57e-05)
Density financial service workers 1981		0.0139	0.0134
		(0.0112)	(0.0111)
Density financial service office workers 1981		1.68e-05	1.62e-05
		(1.36e-05)	(1.34e-05)
Density total workers 1981		-0.0103	-0.00991
		(0.00820)	(0.00813)
Constant	1.059***	1.064***	1.083***
	(0.0112)	(0.0252)	(0.0272)
Observations	173	173	173
R-squared	0.032	0.011	0.041
F-test on regression	2.78*	0.63	1.41
(p-value)	(0.065)	(0.599)	(.2218)
Sargan-Hansen test	6.82***	10.92***	17.68***
(p-value)	(0.009)	(0.0042)	(0.0013)

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Appendix B: Planning application refusal rate instrumental variable first-stages

Table 35: Dependent variable is Planning Refusal Rate Average 1990-2008

VARIABLES	(1) OLS Average Office Refusal Rate 1990-2008	(2) OLS Average Dwelling Refusal Rate 1990-2008
Change in Delay Rate Major Offices 1994-96, 2004-06	22.21***	
	(2.282)	
Change in Delay Rate Major Dwellings 1994-96, 2004-06		-7.719***
		(0.972)
Constant	0.270***	0.0914***
	(0.0211)	(0.0128)
Observations	173	173
R-squared	0.357	0.269
F-test on regression	94.74	63.08
(p-value)	(0.000)	(0.000)
Sargan-Hansen test†	-	-
(p-value)		

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

†Sargan-Hansen tests cannot be performed unless the number of instruments exceeds the number of endogenous variables. Since these are equal in both cases above we cannot run this exogeneity test.

Appendix C: Heckman corrections on hedonic regressions

In Table 36 below we run our hedonic model of London office prices with a Heckman's correction on the sample of properties which were not repeat-sold (single-sale only) and for which we have the required hedonic data (173 observations, coincidentally the same as the number of total repeat-sales). We combine this with 6,848 – 173 = 6,675 synthetic offices proxying for the office stock. The synthetic offices are located in the same postcode sector as the actual offices they represent. The 6,675 synthetic offices are randomly 'sold' between 2000-08, and the corresponding characteristics for use in the selection instruments are calculated at this sale date. The relevant question from this exercise then is whether the lambda coefficient in the Heckman's correction is statistically significant, which would indicate the presence of unobserved sample selection bias.

Table 36: Heckman's correction of Non-Repeat-sales sample hedonic regression

VARIABLES	(1) Heckman Ln(Price-Relative)	(2) Selection Equation	(3) Mills-Ratio
EDC		1.088	
		(0.705)	
Midtown		0.200	
		(0.380)	
West End		-0.0962	
		(0.464)	
Postcode Sector Dummies		YES	
Interest Rate		-0.319**	
		(0.154)	
Euro FX		0.267	
		(0.680)	
US FX		1.168**	
		(0.532)	
Vacancy Rate		0.0109	
		(0.0269)	
Take up		0.00120	
		(0.00417)	
Availability		-0.0193**	
		(0.00775)	
Unemployment Rate		0.0668	
		(0.136)	
Previous Period Office Return		-0.262	
		(0.385)	
Office Price Levels		0.00560	
		(0.00479)	
Within Conservation Area	-0.0458		
	(0.0742)		
Listed	-0.0655		
	(0.0859)		
Ln(Office Refusal Rate)	0.0498*		
	(0.0274)		
Built 1950s	-0.464***		
	(0.127)		
Built 1960s	-0.239*		
	(0.126)		
Built 1970s	-0.226*		
	(0.121)		
Built 1980s	-0.0360		
	(0.0860)		
Built 1990s	0.0195		
	(0.0924)		
Built 2000s	0.211**		
	(0.0996)		
2001	6.203***		
	(1.011)		
2002	6.147***		

	(1.038)		
2003	5.857***		
	(1.056)		
2004	6.101***		
	(1.050)		
2005	6.048***		
	(1.023)		
2006	6.339***		
	(1.013)		
2007	6.477***		
	(1.009)		
2008	6.328***		
	(1.001)		
Midtown	0.152*		
	(0.0863)		
West End	0.499***		
	(0.0995)		
Ln(Employment Density 500m)	0.174**		
	(0.0816)		
Ln(Conservation Area Density 300m)	-0.0164		
	(0.0749)		
Ln(Listed Bldg Density 300m)	0.158**		
	(0.0763)		
Ln(Park and Garden Density 300m)	0.00300		
	(0.00456)		
Adjacent to Park or Garden	0.101		
	(0.0840)		
Ln(Nearest Rail Station Distance)	-0.169***		
	(0.0526)		
Ln(Total Floors)	0.0547		
	(0.106)		
Ln(Depreciation Age)	-0.00366		
	(0.0105)		
Ln(Basements/Total Floors)	-0.0125		
	(0.0158)		
A/C	0.232		
	(0.184)		
EG Office Grade A/B	-0.0152		
	(0.0779)		
EG Office Grade A	0.0543		
	(0.0695)		
Ln(Percent Occupied)	0.0173		
	(0.0109)		
Multiple Tenant Bldg	-0.123**		
	(0.0595)		
Ln(Parking Spaces)	0.0105*		
	(0.00627)		
Lambda			-0.0560
			(0.121)
Constant		-4.835**	
		(2.367)	
Observations	6,848	6,848	6,848

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

As we can see the lambda coefficient is not statistically significant, demonstrating that unobserved sample heterogeneity does not appear to be biasing coefficients in the non-repeat-sales sample. This finding is consistent with our earlier results which show that non-repeat-sales are more spatially representative of the office stock than repeat-sales, and sometimes indistinguishable (Table 25 and Table 28).

Table 37 below runs the same hedonic model with a Heckman’s correction on the sample of repeat-sales for which we have the required hedonic data. Uncensored observations equal 83, and therefore there are 6,848 – 83 = 6,765 censored synthetic office observations proxying for the building stock. As previously, these synthetic offices are located in the same postcode sector as the actual offices they proxy for, and the values of their instruments in the selection equation were derived by capturing their values at a random date between 2002-08 as if they had sold.

Table 37: Heckman's correction of Repeat-sales sample hedonic regression

VARIABLES	(1) Heckman Ln(Price-Relative)	(2) Selection Equation	(3) Mills-Ratio
EDC		2.177**	
		(0.860)	
Midtown		-0.251	
		(0.435)	
West End		-0.293	
		(0.341)	
Postcode Sector Dummies		YES	
Interest Rate		-0.290	
		(0.204)	
Euro FX		-0.907	
		(0.837)	
US FX		0.867	
		(0.709)	
Vacancy Rate		0.00299	
		(0.0361)	
Take up		-0.000523	
		(0.00531)	
Availability		-0.00510	
		(0.0104)	
Unemployment Rate		0.303*	
		(0.172)	
Previous Period Office Return		-1.116**	
		(0.512)	
Office Price Levels		0.0117*	
		(0.00632)	
Within Conservation Area	-0.0565		
	(0.0476)		
Listed	0.158**		
	(0.0715)		
Ln(Office Refusal Rate)	0.0288		
	(0.0223)		
Built 1950s	0.344***		
	(0.103)		
Built 1960s	-0.327**		
	(0.146)		
Built 1970s	-0.215**		
	(0.106)		
Built 1980s	-0.0951		
	(0.0744)		
Built 1990s	0.209***		
	(0.0664)		
Built 2000s	0.0641		
	(0.0627)		
2003†	-0.0180		
	(0.112)		

2004	-0.0126		
	(0.0976)		
2005	0.334***		
	(0.103)		
2006	0.306***		
	(0.0991)		
2007	0.459***		
	(0.0950)		
2008	0.205*		
	(0.113)		
Midtown	0.0552		
	(0.0689)		
West End	0.750***		
	(0.0846)		
Ln(Employment Density 500m)	0.440***		
	(0.0412)		
Ln(Conservation Area Density 300m)	0.0750		
	(0.0457)		
Ln(Listed Bldg Density 300m)	0.127***		
	(0.0481)		
Ln(Park and Garden Density 300m)	-0.00734**		
	(0.00334)		
Adjacent to Park or Garden	-0.139*		
	(0.0713)		
Ln(Nearest Rail Station Distance)	0.0134		
	(0.0350)		
Ln(Total Floors)	0.222***		
	(0.0665)		
Ln(Depreciation Age)	0.0141		
	(0.0146)		
Ln(Basements/Total Floors)	-0.0630***		
	(0.0151)		
A/C	0.902***		
	(0.130)		
EG Office Grade A/B	0.210***		
	(0.0688)		
EG Office Grade A	0.192***		
	(0.0651)		
Ln(Percent Occupied)	-0.0974***		
	(0.0228)		
Multiple Tenant Bldg	-0.0109		
	(0.0444)		
Ln(Parking Spaces)	0.00228		
	(0.00437)		
Lambda			0.128**
			(0.0647)
Constant		-6.289**	
		(2.923)	
Observations	6,848	6,848	6,848

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
†No repeat-sales with complete hedonic data are observed in 2000 or 2001.

In contrast to non-repeat-sales, when a hedonic regression is performed on the repeat-selling properties we see a significant lambda term in Table 37 indicating that the uncorrected regression is subject to unobserved sample heterogeneity bias. Of course the sample of uncensored observations at 83 is relatively small, but again the finding that repeat-sales differ from non-repeat-sales is consistent with our earlier results.

Appendix D: Results of separately tested factors on repeat-sales

Congestion Charge

A test for the effect of the congestion charging zone (CCZ) was also run on the repeat-sales sample. This was done by coding the CCZ dummy variable 1 if the congestion charge had been imposed since the previous sale and remained in force at the time of the current sale, and it was coded -1 if the congestion charge was in force at the time of the previous sale but was rescinded at the time of the current sale (Western CCZ only).

The CCZ variable is applied to the repeat-sales sample with successive controls in Table 39. The CCZ remains significant with controls for employment density change, and office refusal rate, but loses significance when the dwelling refusal rate is added as well. Given this mixed result it is difficult to infer causality of the CCZ on office prices one way or the other, as the imposition of the congestion charge may have also been contemporaneous with increased residential conversions in central areas, and this may be biasing specifications 1-3. Notice that if specification 2 did not find a significant result for the CCZ this would not necessarily be evidence against the effect on the CCZ, as one of the channels through which this could occur is through making greater employment densities feasible.

Regardless of the CCZ's effect on office prices, the imposition of the CCZ will only bias repeat-sales indices if the location of repeat-sales inside and outside of the zone was also influenced by this policy. To test this we utilize a sample of 354 repeat-sales occurring both inside and outside of the central London to run a probit testing for a difference before and after the imposition of the CCZ. As Table 38 shows no differences was found. Therefore regardless of the existence of an independent effect of the CCZ on prices, there is no evidence to suggest that significant bias will be registered in a price index derived from repeat-sales.

Table 38: Probability of Repeat-sales outside the Congestion Charging Zone (CCZ)

EQUATION	VARIABLES	(1) Outside CCZ
	Congestion Charging Zone Imposed	0.368
		(0.356)
	Constant	-1.565***
		(0.344)
	Observations	354

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 39: Congestion charge Repeat-sales regression

VARIABLES	(1) OLS Ln(Price-Relative)	(2) IV2SLS Ln(Price-Relative)	(3) IV2SLS Ln(Price-Relative)	(4) IV2SLS Ln(Price-Relative)
2000	1.454***	1.532***	1.391***	1.270***
	(0.492)	(0.482)	(0.480)	(0.446)
2001	0.127	0.0664	0.0879	0.0720
	(0.0877)	(0.0885)	(0.0880)	(0.0825)
2002	-0.0611	-0.0491	-0.0474	-0.0423
	(0.101)	(0.0990)	(0.0978)	(0.0917)
2003	-0.237**	-0.243**	-0.242**	-0.0397
	(0.105)	(0.102)	(0.101)	(0.103)
2004	0.211***	0.168**	0.186**	0.120
	(0.0806)	(0.0803)	(0.0798)	(0.0757)
2005	0.0932	0.0765	0.0804	0.0877
	(0.0642)	(0.0631)	(0.0624)	(0.0606)
2006	0.226***	0.205***	0.219***	0.233***
	(0.0598)	(0.0589)	(0.0586)	(0.0560)
2007	-0.0480	-0.0875	-0.0929	-0.0530
	(0.0733)	(0.0730)	(0.0722)	(0.0685)
2008	-0.182	-0.212	-0.172	-0.414**
	(0.171)	(0.168)	(0.167)	(0.183)
Ln(Predicted EDC with all instruments)		2.466***	3.946***	3.514**
		(0.873)	(1.096)	(1.367)
Ln(Office Refusal Rate)			0.0263**	0.118***
			(0.0120)	(0.0441)
Ln(Dwelling Refusal Rate)				-0.184*
				(0.101)
Congestion Charge	0.171**	0.162**	0.158**	-0.0112
	(0.0811)	(0.0795)	(0.0785)	(0.0808)
Observations	173	173	173	173
R-squared	0.711	0.725	0.733	0.781

Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Occupancy

An obvious channel through which repeat-sales could produce biased estimates is through changes in the property occupancy-rate between sales. A subset of 191 of the 354 repeat-sales used in the Congestion Charge example has accurate data on the occupancy-rate at the time of both sales, and is used to test for an omitted effect of change in occupancy rate in Table 41 below. As we can see the effect is only significant at the 10% level and is not robust to the inclusion of submarket dummies. Unfortunately we do not have data on occupancy rates of office buildings across London to compare the sample of repeat-sales with the market. However, we can compare the repeat-sales occupancy rate with that of sales. Table 40 below shows that there does appear to be a small selection effect of higher occupancy rates being associated with repeat-sales. Perhaps some speculative owners are purchasing properties with high vacancy rates, restoring their income streams by filing them with new tenants, and then selling them on quickly. However, the occupancy rate is different from the change in occupancy, and only if we could compare the change in occupancy rates from unsold buildings could we infer whether repeat-sales are biased by occupancy rate differences.

Table 40: Repeat-sales vs Sales on Occupancy rate probit

EQUATION	VARIABLES	(1) Repeat-sales
	Occupancy Rate	0.358*
		(0.211)
	Constant	-0.713***
		(0.200)
	Observations	600

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 41: Occupancy-rate Repeat-sales regression

VARIABLES	(1) OLS Ln(Price-Relative)	(2) OLS Ln(Price-Relative)
1995	1.233**	1.473***
	(0.500)	(0.521)
1996	0.393	0.317
	(0.407)	(0.429)
1997	-0.295	-0.481
	(0.382)	(0.375)
1998	0.217	0.311
	(0.295)	(0.284)
1999	-0.207	-0.128
	(0.169)	(0.168)
2000	0.230*	0.0949
	(0.125)	(0.126)
2001	0.0379	0.0522
	(0.120)	(0.115)
2002	0.0458	0.0636
	(0.130)	(0.125)
2003	-0.0830	-0.135
	(0.112)	(0.109)
2004	0.0985	0.101
	(0.0787)	(0.0806)
2005	0.129*	0.104
	(0.0705)	(0.0704)
2006	0.276***	0.279***
	(0.0714)	(0.0685)
2007	-0.276***	-0.293***
	(0.0729)	(0.0712)
2008	-0.0855	-0.139**
	(0.0599)	(0.0589)
Occupancy Rate Change	0.157*	0.112
	(0.0869)	(0.0840)
City Fringe		0.0726
		(0.0668)
Docklands		-0.281
		(0.236)
Midtown		0.0811
		(0.0503)
North Central		0.276*
		(0.158)
South Central		-0.00572
		(0.0900)
Southern Fringe		-0.00385
		(0.122)
West Central		0.0435
		(0.0895)
West End		0.171***
		(0.0371)
Observations	191	191
R-squared	0.593	0.646

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Sale Leaseback

Although the previous analyses have focused on attributes of the building and its location, a further characteristic that may influence prices is the structure of financing. In particular, cheaper credit or the ability to purchase the building with less capital may increase sale prices achieved. Along this vein we analysed the same subset of 191 properties above for which we also had data on whether or not the property was financed with a Sale-Leaseback structure. A sale-leaseback is where the building and land are purchased but the land is then sold and the building owner now subsequently leases the land. The advantage of this strategy is that it requires less capital to finance building purchases, and the lessee can reap tax shield benefits from lease payments. As a result, potential buyers may be willing to pay a premium if they are able to execute a sale-leaseback deal on the transaction (Rutherford 1990, Sirmans and Slade, 2000).

To test for the effect of sale-leaseback financial structure, the dummy variable is coded 1 if the building was sold as a sale-leaseback in the second-sale but not in the first, and the dummy variable is coded -1 if the building was sold as a sale-leaseback in the first-sale but not the second. Including change in sale-leaseback in Table 43 shows that there is no measurable effect. However, the small effect of occupancy rate remains when it is included. Comparing sales with repeat-sales in Table 42, we see that there appears to be a preference for repeat-sales not to be financed by sale-leasebacks. However since repeat-sales will only pick up *changes* in financial structure between sales, the significant result in Table 42 would not be immediate evidence for potential bias on sale-leasebacks even if a significant coefficient had been found in Table 43.

Table 42: Repeat-sales vs Sales on Sale-leaseback probit

EQUATION	VARIABLES	(1) Repeat-Sale	(2) Repeat-Sale
	Sale-Leaseback	-0.815**	-0.842**
		(0.330)	(0.331)
	Occupancy Rate		0.386*
			(0.212)
	Constant	-0.360***	-0.708***
		(0.0561)	(0.201)
	Observations	600	600

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 43: Sale-leaseback Repeat-sales regressions

VARIABLES	(1) OLS Ln(Price-Relative)	(2) OLS Ln(Price-Relative)
1995	1.235**	1.233**
	(0.510)	(0.502)
1996	0.390	0.393
	(0.415)	(0.408)
1997	-0.298	-0.295
	(0.390)	(0.383)
1998	0.220	0.217
	(0.301)	(0.296)
1999	-0.142	-0.207
	(0.169)	(0.170)
2000	0.157	0.230*
	(0.123)	(0.126)
2001	0.0555	0.0379
	(0.122)	(0.120)
2002	0.0223	0.0456
	(0.132)	(0.130)
2003	-0.0810	-0.0825
	(0.115)	(0.113)
2004	0.111	0.0979
	(0.0817)	(0.0805)
2005	0.123*	0.130*
	(0.0729)	(0.0717)
2006	0.297***	0.275***
	(0.0723)	(0.0718)
2007	-0.287***	-0.276***
	(0.0743)	(0.0732)
2008	-0.0943	-0.0855
	(0.0608)	(0.0600)
Sale-Leaseback Change	0.0229	0.00297
	(0.0792)	(0.0794)
Occupancy Rate Change		0.156*
		(0.0888)
Observations	191	191
R-squared	0.576	0.593

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Chapter 3 Transition

The previous chapter dealt with sources of bias arising in repeat-sales indices of commercial offices. It was shown that unrepresentative employment density changes and development restrictiveness were the primary drivers of this bias. Knowledge of these effects may be used to improve future repeat-sale indices constructed for London, and potentially for other cities which produce such indices as well. Although corrections for these biases were undertaken in the previous paper, in many practical instances such modifications may prove infeasible, with possibly deleterious consequences for stakeholders relying on repeat-sales indices as a representation of the actual market. Fortunately, repeat-sales are just one of a number of price indices available for use in real estate industry and research. Indeed, within industry the most prevalent indices are currently valuation-based, whereas hedonic indices are favoured in economic research for their versatility in tackling a variety of causal questions. However, like the issues identified with the repeat-sales index examined above, different index construction methods may in turn possess problems of their own, with greater or lesser potential for correction depending on the case in question.

The final paper builds on the previous chapters' analyses of capital returns in the London office market by comparing and contrasting an inclusive array of transaction and valuation-based indices. This comparison finds substantial differences in the timing of market turning points and various descriptive statistics of these indices. Although it cannot be known *a priori* which of these indices represent the most accurate depiction of the actual market, this paper is able to uniquely demonstrate that a transaction-based hedonic model is not only feasible for London, but surprisingly that it outperforms the repeat-sales index due to the greater inclusivity of sale observations. Furthermore, by comparing and contrasting many different indices in concert while taking into account the inherent limitations specific to each, it is hoped that the most authentic impression of historical market movements can be obtained.

Chapter 3: Commercial real estate price indices: A comparative analysis of the London office market

Abstract

This paper sheds light on the history of London office market prices between 1998-2010; a period containing two of the most significant boom and bust real estate cycles experienced in recent times. As no universally accepted real estate price index exists, this is done by comparing seven indices produced by competing methodologies of index construction. These indices include; valuations, desmoothed valuations, transaction-linked indices, real estate securities, stock market equities, repeat-sales, and a sophisticated hedonic model of London office property. This comparison finds significant differences between the valuation and transaction-based indices primarily related to inertia and dampened price movements, especially in the most recent market gyrations beginning in 2007. In addition, it is shown that our well specified hedonic index appears to outperform the repeat-sales index due to sensitivity of transaction-based indices to sample selection bias, and the greater inclusivity of observations possible with hedonic estimation. This result is derived from the use of a nearly identical sample of observations in both the hedonic and repeat-sales indices to confirm the validity of the hedonic specification employed in this paper. Other notable results include the fact that the 3SLS procedure conventionally used to correct for heteroskedasticity in housing appears to be superfluous with regard to office property, and that the valuation desmoothing technique developed by Geltner (1993b) appears to exaggerate the price movements of actual transaction-based series. Finally, an original fractional-time weighting procedure for repeat-sales is developed which allows for simpler calculation of transformation-bias while maintaining a minimum of temporal aggregation bias.

Introduction

The construction of an accurate price index to assess the performance real estate has been a constant source of research and debate. In contrast to stock markets whose assets are divisible, highly liquid and centrally traded, real estate is indivisible, transactions are infrequent, and bid, offer and price information remain primarily private. Moreover stock markets can benchmark a broad-based index of assets trading in the same marketplace, whereas real estate often lacks ready definitions of the extent of their respective markets. To compound these problems real estate assets are highly heterogeneous (if not unique) across physical characteristics and space. This definitionally calls into question the representativeness of samples and precludes the use of naïve first moments to measure prices. All of these features impede the creation of representative price indices in commercial real estate to a greater or lesser degree depending upon the market and time-frame in question.

As a result of these difficulties there are often multiple price indices competing for status as the industry standard within any given marketplace. In the UK, the focus of this analysis, the primary source of real estate indices comes from large agents which have access to transaction data through their proximity to deals or specialist industry and research organisations. Due to the relatively closed-nature of the UK market and since trading in commercial markets is infrequent, not only do valuation-based return indices dominate the landscape, no institution currently publishes a transaction-based index for use in industry. This is a key deficiency in the coverage of the market as transaction-based indices may both present a more objective picture of actual price levels and vary markedly from indices based on valuations.

This paper utilizes a unique dataset of office sales in the London to construct transaction-based hedonic and repeat-sales indices during the period 1998-2010. These indices are then compared with each other and with valuation-based IPD (Investment Property Databank) and desmoothed IPD indices, the new transaction-linked IPD series, and real estate securities. Our purpose in comparing and contrasting these various indices is not to crudely claim that one method is superior to another, but rather to see what insights we gain by analysing their respective price movements while casting a critical eye on the assumptions and methodology lying behind each index. Since the conceptual weaknesses and supporting assumptions underlying each index are different, we may interpret the common messages that emerge across all indices as a relatively robust indicator of historical reality. This comparison finds significant differences between the valuation and transaction-based indices primarily related to inertia and dampened price movements, especially during the pronounced market oscillations experienced in the latter half of the 2000s.

With our unique dataset this paper is able to further develop previous comparisons of commercial real estate. We find that the use of the hedonic method to produce time-series of commercial offices is not only feasible but likely superior to the more common method adopted in the real estate industry of repeat-sales. This result holds due to the reduction in effective sample size and the concomitant decrease in representativeness that occurs as a result of the need to exclude all property sales which do not occur in comparable multiples over the study period. We can be confident in this result due to the introduction of a novel methodology for verifying the validity of our hedonic model: comparing the hedonic price index with a repeat-sales index consisting of the same sample of sales.

With regard to repeat-sales this paper finds that the 3SLS procedure conventionally used to correct for heteroskedasticity in housing is indistinguishable from an uncorrected OLS regression. In addition, this paper also introduces an original fractional-time weighting procedure for repeat-sales that allows for simpler calculation of transformation-bias while maintaining a minimum of temporal aggregation bias. Other notable findings include the fact that, contrary to previous research, real estate securities in the UK follow the movements of London office property more closely than the stock market as a whole, the method of desmoothing valuations as introduced by Geltner (1993b) produces lead-lag relationships that are a surprisingly close analogue to transaction-based series but which appear to exaggerate price movements, and that IPD’s new transaction-linked index is extremely similar to its primitive uncorrected valuation series.

This paper continues with an overview of the two valuation-based and five transaction-based indices compared in this paper, along with an original fractional time-weight matrix for use in simplifying the correction of transformation bias in repeat-sales. Next the original dataset used to produce the hedonic and repeat-sales index is presented, followed by the datasets of the other indices, and a comparison of all seven indices. The paper then proceeds to discuss these results and concludes.

Valuation-based price indices

Valuations

Valuation indices dominate the market for commercial property in both the US and the UK. The primary advantage of valuation-based indices in principle is continuous observation of prices (simulated liquidity), even though as valuations these 'prices' are only a subjective approximation of market values. This observability mitigates problems inherent with low transaction volume, such as high standard estimation errors and sample selection bias. However with regard to price index construction, valuations suffer limitations of their own related to: (i) the accuracy of price levels at any given point in time, (ii) the representativeness of asset price variance, and (iii) lethargic reactions to actual market price movements[125]. Typically all three of the problems are present in valuation-based indices and are known collectively as 'smoothing'.

Valuation accuracy

The problem of valuation accuracy was first highlighted to dramatic effect in a paper published by Hager and Lord (1985). This paper contained an analysis of two properties appraised by a random sample of 11 professional valuers. The results of this exercise were standard deviations of nearly 10% with some valuations differing more than 25% from the mean. This finding deeply troubled the valuation industry and initiated a series of more formal academic inquiries into the accuracy of property valuations. Among the first of these was Miles, Cole, and Guilkey (1990), who found that office properties had a 10% average

[125] Although valuers can impart their own bias on individual transactions, and individual sales may be unrepresentative of the market, these idiosyncratic errors are less relevant to price-index construction because should cancel out when the population of valuations are aggregated in an index (RICS, 2011).

bias in estimated average annual performance over an 8-year period, and that valuations underestimate prices when returns are high and over overestimate prices when returns are low (that is to say, actual peaks and troughs are more pronounced than valuations suggest). Similarly, Adair et al (1994) also recorded around a 10% mean variation in office valuations, but did not test whether these errors were systemically biased or varied with the real estate cycle. In perhaps the largest study to date, the co-founder of IPD, Ian Cullen used proprietary data on 7,000 sale-valuation pairs and found that two-thirds of sales (one standard deviation) were within 20% of the most recent valuation, and valuations tended to systemically fall below realized prices and under-represent market movements (1994). Webb (1994) also noted that the direction of valuation error was inverse to market movements, and was additionally related to low quality properties and high vacancy rates. However unlike previous studies he found that these errors averaged out over time such that over long-periods there was no bias in estimated returns. Matysiak and Wang (1995) reported standard deviations on the difference between valuations and sales prices of 20% with a 7% undervaluation of properties on average, and their valuations also showed inertia (lagged adjustment) with respect to market movements. Blundell and Ward (2008) also found an average undervaluation of 7%, a standard error of 18%, and undervaluation in rising markets and overvaluation in falling markets.

The common theme of these valuation performance analyses is that they tend to underestimate (overestimate) price levels in rising (falling) markets, and valuation accuracy across a sample of properties, as defined by standard errors, appears to lie between 10-20%. The fact that many of these studies find that valuation indices tend to under-report prices on average is almost certainly because nominal and real real estate asset prices have continued to rise over time[126]. For instance, it is telling that the annual rate of inflation in the UK over these studies' sample periods; covering the 1970s and 1980s, is commensurate with the magnitude of the downward errors found in these papers: close to 7% (ONS, 2012). Therefore in spite of cyclical variation, at any given moment it is most probable that appraised properties have undergone or are in the process of undergoing price increases,

[126] Real estate prices have secularly risen in nominal and real terms due to the imposition of discretionary central bank-led money creation without a gold-standard and strict land-use controls.

and since these price increases only enter valuation indices with a time-lag, we observe valuation-based indices under-reporting prices.

Valuation variance

In addition to the problem of valuation accuracy at a given point in time, there has also been concern about the representativeness of valuation variance across time-periods. In contrast to market prices, price-indices based on valuations tend to understate the true volatility of their underlying assets. Valuations may also miss some apparent price movements altogether or only register them long after the fact, especially when the market moves rapidly or in opposite directions. For instance in the late 1980s the US NCREIF valuation index failed to register significant declines in commercial property values at a time when many financial institutions were being declared insolvent, with sharply falling real estate values being cited as the primary cause of their insolvency (Fisher et al, 1994). Another shorter but also remarkable episode occurred in the third quarter of 1998, where the US real estate market suffered a sharp decline but quick recovery that was altogether missed by the NCREIF index, and institutional investors looking to the index as a gauge of risk cried foul (Fisher and Geltner, 2000).

Lai and Wang (1998) identify an additional potential source of variance dampening. In the same way that accountants may face institutional pressure to announce official figures for their clients that are more favourable than the underlying reality, valuers may be under pressure from fund managers to embellish their reported price fluctuations. For instance, Crosby, Lizieri, and McAllister (2010) find that the identity of the client influenced the rate at which valuers reported losses in the end-2007 recession. It has even been suggested that successive valuations are anchored by the most recent valuation. Instead of, as is best practice, beginning each successive valuation *de* novo, valuers may be influenced by previous valuations, and in order to appear consistent may base consecutive valuations off of previous ones.

Variance dampening can also arise less deliberately from the fact that although valuations in an index will be conducted at different points in time within a computation period, they will all be pinned to a common date when constructing the index. When non-synchronous valuations are aggregated in an index, this creates a potentially non-trivial degree of smoothing known as temporal aggregation bias (Geltner, 1993a). Naturally this problem is inversely proportionate to the duration of computation period, and could easily be eliminated by dating valuations precisely and using this information to fractionally time-weight the index[127]. In practice this problem is now mitigated by index producers by requiring that valuations be stated as at the end of each month, or no more than ten working days previous to that date. Therefore it is not surprising that Bond and Hwang (2007) only found weak evidence for non-synchronous appraisal in the UK with the IPD index, and no evidence in the US with the NCREIF (National Council of Real Estate Investment Fiduciaries) index.

Valuation inertia

As noted in the section on valuation accuracy above, it has been widely documented that price-indices based on valuations tend to lag behind movements in the actual market[128]. A major cause of valuation variance error appears to arise from the valuer's need to filter out random noise in the variation of property prices from true market signals. Any given sale-price is a reflection of not only current price levels, but also random noise in the form of observational error, asymmetric negotiation skills, asymmetric information, and unique motivations of the sellers and buyers (Crosby, 1991). Therefore, in order to reduce the component of random noise in valuations it may be rational for valuers to combine the most recent comparable sale with other sales from the more distant past (Geltner, 1989, 1991; and Ross and Zisler, 1991). Incorporating this older information implies that current valuations will not only contain some dated information, but that the estimated current prices will also be smoothed over time reflecting a type of moving average rather than a true spot price. Thus the valuer faces an inherent trade-off. Recognising more (fewer) previous sales decreases (increases) the timeliness of price fluctuations, but also reduces

[127] See 'Appendix B: FTW level-based index time-weights' Table 54 for an example of how this would work in practice for valuations dated with monthly precision.
[128] For instance, Lee, Lizieri and Ward (2000) found that the IPD monthly index lagged behind the FTSE Real Estate price series, with a highest correlation of 0.27 at a 7 month lag vs. 0.04 contemporaneously.

(increases) the random error associated with the idiosyncratic characteristics of the comparable sales. This tradeoff between transaction error and market movement error in the valuation process is modelled in the literature as follows[129];

$$V_t^* = \alpha V_{t-1}^* + (1-\alpha)V_t \quad \textbf{(13)}$$

Where;

V_t^* = property valuation in period t

V_t = true market property value in period t

α = a fraction between 0 and 1 which governs the relationship between the previous valuation, true market value, and optimal present valuations

Solving for V_t we have;

$$V_t = (V_t^* - \alpha V_{t-1}^*)/(1-\alpha) \quad \textbf{(14)}$$

As is evident from equation (13) and (14), larger values of α are indicative of greater smoothing within the original time-series, and therefore a greater proportion of the previous valuation must be removed from the current valuation in order to arrive at the true market value of the property, V_t.

Another potential driver of valuation inertia is the valuation and reporting regime of property companies themselves. In quarterly valuation-based price indices, property companies have been known to report previous-period valuations in lieu of revaluing the properties each period, in accordance with the index-reporting frequency. Naturally an

[129] For example see Booth and Marcato (2004b).

index which unwittingly incorporates these stale valuations in current periods will be lagged by construction.

Although over sufficiently long periods valuation indices should reflect a relatively unbiased metric of the true appreciation of the real estate market, in the presence of smoothing the index will be lagged and the variance of short-interval returns across time and the covariance of these returns with other assets will be biased towards zero. Following Markowitz (1952) and successive work on portfolio theory, for purposes of optimal asset allocation and diversification it is these variances and cross-correlations that are of interest to asset managers. Booth and Matysiak (2004) show that adjusting for valuation smoothing along these criteria makes a material difference to asset allocation decisions. In practice consultants already use assumptions to adjust for volatility not captured by valuation-based real estate indices, and institutional investors only allocate between 5-10% of their portfolios to real estate in spite of the fact that naïve models not accounting for this distortion would weight real estate much higher (Marcato and Key, 2007).

Recent years have also seen growth in the interest for property derivatives. Property derivatives have the potential to increase the efficiency of risk-allocation and address the long-standing issues in real estate markets of; high-transaction and management costs, lack of liquidity, and inability to sell short. However, in order for real estate derivatives trading to achieve these putative benefits they must be based off of an accurate index of prices. A practical problem common to both valuation and transaction-based indices however, is that as new transaction information comes into the index over time[130], the index will need to recalculated, invalidating previously reported price levels. The standard method of dealing with this problem in industry is to simply 'freeze' old index values at their formerly reported levels, while incorporating the new information in all subsequently published values. Although this means that the reported historical values will be technically 'wrong',

[130] In the case of valuation-based indices this would come about due to the recruitment of new data providing members. For repeat-sales indices, future-sales invariably create new sale-pairs. And for hedonic indices, unless all hedonic variables are time specific (which is data intensive), new sales will change the hedonic coefficients, driving corrections in previous time-dummies.

this method at least has the benefit of being temporally consistent, precluding the need for continual updating and trading compensation. Valuation-based indices in particular have additional problems when used for derivatives trading related to accuracy and smoothing. These problems have been the principal motivating factors driving both the use of transaction-based indices and the development of 'desmoothing' techniques for valuation data.

Desmoothed Valuations

Rather than abandon valuation-based indices due to their smoothing problems, an alternative is to attempt to desmooth these indices explicitly. In order to desmooth a valuation-based time-series it is necessary to assume the structure of the smoothing with a formal model. This assumed model is then inverted in order to arrive at what the original desmoothed series would have looked like if the assumptions of the smoothing model were true. Naturally the effectiveness of this technique rests entirely upon the validity of the assumed model of smoothing. One common approach is to assume that, while the smoothed valuation returns are generally positively auto-correlated, the returns of the true series are uncorrelated from one period to the next (Quan and Quigley, 1991). This assumption is essentially the classical hypothesis of weak-form efficiency in asset markets, and amounts to saying that successive returns are unpredictable based on past information. Using the efficient market assumption, the parameters of the smoothing model can be empirically estimated with regression analysis. Fisher, Geltner, and Webb (1994) produce such a model of smoothing and expand upon it by additionally assuming that, like the consensus of real estate practitioners, the true volatility of commercial real estate valuation-based returns is approximately one half that of the domestic stock market.

Although informational efficiency assumption appears to hold quite well for relatively transparent and liquid markets such as securities, real estate markets are noted for their cyclicality and the fact that successive returns tend to resemble those of the recent past (Case and Shiller, 1989; Lee, Devaney and Young, 2007). Rather than invoking the efficient market assumption in order to empirically choose values for α in equation (14), Geltner (1993b) instead proposes to reverse engineer valuation indices by subjectively assuming a plausible value for α[131]. The benefit of this method is that it does not require that real estate markets be informationally efficient, which is likely to parallel reality more closely.

The two model-based desmoothing procedures described above all imply a constant smoothing parameter. However, if valuation bias is period specific, then the application of a constant smoothing parameter will result in a series containing a mixture of under and oversmoothed terms. Based off of Geltner's (1993b) methodology, Chaplin (1997) proposes a model which allows for the desmoothing parameter to vary according to the volume of transactions, and therefore, the degree to which prior information is being incorporated into current valuations. Lizeri, Stachell and Wongwachara (2012) introduce a regime-switching approach which uses indicators for market performance to switch between high and low smoothing regimes. However, Clayton, Geltner and Hamilton (2001) while confirming the hypothesis that greater valuation smoothing occurs during periods of illiquidity when fewer transactions are consummated, they also find that the approximation of this time-varying smoothing parameter with a constant may not lead to grossly different price index results.

Transaction-based price indices

Hedonic

Hedonic price indices are based on the method introduced by Rosen (1974) for pricing the constituent elements of composite goods. In the case of real estate, hedonic indices replace the valuation process with an econometric evaluation procedure in which the index value for each calendar period is based on the actual *ex post* transaction prices of the properties which have sold. The hedonic variables in the regression control for the location, composition and quality of these properties relative to the market as a whole. At present, the use of hedonics in constructing real estate price indices is primarily the domain of single family homes, where samples are far larger and generally more homogeneous than commercial property. Hedonics is also used extensively in applied real estate research to

[131] Geltner (1993b) argues that for annual appraisals the optimal value for α in his data series is around 0.5.

measure the effect of a given property attribute or environmental characteristic on sale or rental prices.

In the hedonic approach property transaction prices (usually per square metre) are regressed onto a vector of property and environmental characteristics and a vector of time-dummies (the intercepts of the cross-sectional model), one for each calendar period. These time dummies are ideally fractionally-time weighted according to Brian and Colwell (1982) so as to peg the estimated return to values representative of the end of each year and minimise temporal lag bias[132]. In theory the hedonic regressors capture the effect that cross-sectional (i.e. across those properties sold within a given time-interval) differences in property characteristics have on average transaction prices for each time period. With the property characteristics (hopefully) adequately controlled for, the time dummies will capture the pure effect of time on a set of constant quality properties, and thus price index levels can be read off of these time-dummy coefficients. The estimation equation in both housing and commercial property has generally been found to be most satisfactory when modelled with a log-log specification, as in the equation used in this paper and outlined below.

$$P_{it} = \gamma_0 + \sum_{j=1}^{J} \beta_j X_{ij} + \sum_{t=1}^{T} I_t D_{it} + \epsilon_{it} \tag{15}$$

Where;

P_{it} = Log sale price per meter for sale of property *I* and time *t*

γ_0 = The constant term

β_j = Coefficient on X_j

[132] See ‘Appendix B: FTW level-based index time-weights’ for these weights.

X_{ij} = Log characteristic *j* of property *i*

I_t = Price-level at time *t*

D_{it} = Dummy variable indicating sale of property *i* at time *t*

ϵ_{it} = *i.i.d.* error term for property *i* and sale at time *t*

Of course, hedonic models are only as good as the specifications used to derive them. If influential variables are omitted, then unless the heroic assumption is made that these variables are also orthogonal to the time-dummy coefficients or other variables of interest, their omission will induce bias on the pure price changes. Furthermore, if the functional form of how property attributes affect price is misspecified, then the resulting error on the property characteristic coefficients will likely transfer through to the time-dummies and the estimated price index.

Another problem frequently noted with the hedonic technique is that if the cross-sectional property characteristic parameters are non-constant, then this non-constancy will be erroneously picked up as part of the time-dummy effect. There are however two ways to mitigate but not eliminate this problem. The first, known as hedonic imputation, is to re-estimate these parameters every time period. With this method parameter constancy is only assumed within each estimated period rather than across the entire timespan of the dataset. However, in general this technique is infeasible when constructing commercial real estate indices due to the sparsity of the available data. The second method that can be adopted to deal with parameter inconstancy is simply to interact the coefficients with the time dummies, but again data constraints in the form of sufficient degrees of freedom often preclude this. In practice the problem of parameter inconstancy is generally ignored, as estimated inter-temporal parameter differences have been shown empirically to be small (Glascock, Kim, and Sirmans 1993; and Dombrow, Knight, Sirmans 1997). Interestingly, the issue of parameter constancy is one area in which valuations could potentially outperform transaction-based indices, assuming valuers indeed have the ability to recognise such changes. But again there would likely be lags to these updates as with the price volatility problems mentioned earlier.

By using actual transaction prices, hedonic indices avoid the smoothing inherent in valuations. However, even with a perfect hedonic model there will still be some smoothing or lagging due to the aggregation of sales that occur at different points in time into a common time-interval. This so-called temporal aggregation bias, can be halved for any given number of time-periods however by utilizing Bryan and Colwell's method mentioned above. Estimation error also injects random noise into the hedonic index, artificially adding volatility into the estimated returns. These estimation errors are purely random and will have the effect of imparting negative first-order (i.e. between successive periods) autocorrelation in the return index. Aside from potentially more accurate price index construction, a working hedonic model of commercial real estate prices could substitute for valuations which can take anywhere from 2-4 weeks to complete, whereas a hedonic analysis, once properly modelled, could be performed within hours and for a fraction of the cost (Crosson, Dannis and Thibodeau, 1996). Repeat-sales on the other hand do not have the same potential as hedonic indices to replace valuations, as they would be infeasible whenever a building had been considerably altered between sales or if it had never previously been sold.

Repeat-sales

Repeat-sales price indices are a variation of the hedonic technique, first introduced as an index modelling procedure in the seminal article by Bailey, et al (1963) and later extended by Case and Shiller (1987). Like hedonics, repeat-sales exclusively use transaction prices. However, as opposed to assembling a wide and complete range of hedonic controls, the repeat-sales technique is a fixed-effects procedure which utilizes previous sales of the property as *the* hedonic control. By matching these comparable sales the entire universe of constant observed and unobserved property characteristics in principle can be controlled for, and changes to prices affected by the environment and market conditions are registered in the index. Therefore repeat-sales should not suffer from the specification problems which plague hedonic indices on the condition that these characteristics are held constant between sales. In order to ensure that the earlier sale of the repeat-sales pair is representative of the later sale, these indices remove properties from the sample which have been altered physically (such as capital improvements) between sale dates. However, repeat-sales indices are themselves problematic in that their estimation requires that sales of the same asset occur in multiples, which usually means that many years must elapse between the start of the dataset and when one can begin to construct a viable index. Furthermore, the fact that the index can only utilize sale-multiples represents an inefficient use of the total transaction data which can result in considerable issues of selectivity (Case et al 1991; Clapp and Giacotto, 1992; and Gatzlaff and Haurin, 1997). In addition, because there is perfect collinearity between the periods-held dummy variables and building age, the effect of structural obsolescence cannot be modelled linearly, and this can lead to a downward bias in the resulting price index[133].

Following equation (15) and assuming separate hedonic estimation equations for both the first and second sale we have;

$$P_i^1 = \gamma_0 + \sum_{j=1}^{J} \beta_j X_{ij}^1 + \sum_{t=1}^{T} I_t D_t^1 + \epsilon_i^1 \qquad \textbf{(16)}$$

$$P_i^2 = \gamma_0 + \sum_{j=1}^{J} \beta_j X_{ij}^2 + \sum_{t=1}^{T} I_t D_t^2 + \epsilon_i^2 \qquad \textbf{(17)}$$

Where;

P_i^s = Log sale price for sale number $s = 1,2$

β_j = Coefficient on X_j

[133] Chau, Wong, and Yiu (2005) however are able to overcome this fact by incorporating non-linear age effects into the model.

X_{ij}^{s} = Log characteristic *j* of property *i* for sale $s = 1,2$

I_t = Price-level at time *t*

D_t^{s} = Dummy variable indicating sale $s = 1,2$ at time *t*

ϵ_i^{s} = *i.i.d.* error term for property *i* and sale $s = 1,2$.

Assuming property characteristics are constant between sales, $\forall i, j(X_{ij}^{1} = X_{ij}^{2})$, differencing equation (3) with equation (2) yields;

$$P_i^2 - P_i^1 = \sum_{t=1}^{T} I_t(D_t^2 - D_t^1) + \mu_i^{1,2} \qquad \textbf{(18)}$$

Where $\mu_i^{1,2} = \epsilon_i^2 - \epsilon_i^1$.

If we assume that sales 1 and 2 occur at time t and $t + \tau$, respectively, the estimation of equation (18) simplifies to;

$$P_i^{t+\tau} - P_i^{t} = I_{t+\tau} - I_t + \mu_i^{t,t+\tau} \qquad \textbf{(19)}$$

From which index levels constructed via the estimated I_t terms. However the method for deriving the index from the I_t terms is dependent upon the particular time-dummy specification used in equation (18). There are two possible types of time-dummy matrix specifications which can be used to produce repeat-sales price indices, but neither has been explicitly named by researchers or industry. For clarity this paper will refer to these two matrix formulations as index-level matrices and index-growth matrices. Both level and growth-based matrices were introduced as possible time-dummy specifications in the seminal paper by Bailey, Muth, and Nourse (1963) and will produce identical uncorrected index estimates when calculated from identical data. In their paper, Bailey, Muth and Nourse chose to use a level-based specification on the grounds that it was computationally simpler. The level-based index matrix is specified as follows; on the date of the first sale the index is coded as -1, on the date of the second sale the index is coded as +1, zeros everywhere else, including in the first column regardless of properties sold in that period. Setting the first column to zeros is done as a normalization which sets the index base value to 1 and to prevent multicollinearity. An example will make this specification clear. Say we have 4 properties; the first sold in 2000 and again in 2003, a second sold in 2001 and again in 2002, a third sold in 2002 and again in 2003, and a fourth bought in 2001 and again in 2003 producing Table 44 below.

Table 44: Example 1, X-marks the sale.

	Year of Sale			
Sale-Pair Observation	**2000**	**2001**	**2002**	**2003**
1	X	-	-	X
2	-	X	X	-
3	-	-	X	X
4	-	X	-	X

The corresponding level-based time matrix with successive sale-pairs represented by rows and successive time-periods represented by columns would then be;

$$\begin{bmatrix} 0 & 0 & 0 & 1 \\ 0 & -1 & 1 & 0 \\ 0 & 0 & -1 & 1 \\ 0 & -1 & 0 & 1 \end{bmatrix} = D_L \qquad \textbf{(20)}$$

The ratio of the second to the first sale prices $(P_{i,t+\tau}/P_{i,t})$ can then be used to estimate the index values $(I_{t+\tau}, I_t)$ at the time of the second $(t+\tau)$ and first sales (t) as follows;

$$\frac{P_{i,t+\tau}}{P_{i,t}} = \frac{I_{t+\tau}}{I_t} \times v_{i,t,t+\tau} \qquad \textbf{(21)}$$

With υ representing an error term unique to the sale of property i at times t and $t + \tau$. Notice that equation (21) is equivalent to an exponentiated equation (19), with $ln(P_{i,t}) = P_i^t$. In logs equation (21) becomes;

$$\ln\left(\frac{P_{i,t+\tau}}{P_{i,t}}\right) = -\ln(I_t) + \ln(I_{t+\tau}) + \ln(\upsilon_{i,t,t+\tau})$$

We can now see how the first two terms on the right-hand side of this equation map out the matrix in equation (20) above. In vector notation we now have;

$$\mathrm{y} = \beta D_L + \upsilon$$

Where y is the vector of logged price relatives, D_L is the level-based time-dummy matrix, β is the vector of logged index values, and υ is the vector of error terms.

Successive price levels in the index can now be estimated as follows.

$$\widehat{I_t} = e^{\widehat{\beta_t}}$$

However because $\widehat{\beta_t}$ is a random variable and not a constant, the estimate for I_t must be corrected for transformation-bias (Goldberger 1968)[134]. If the error term in the logged specification is log-normally distributed, as is conventionally assumed, then following Kennedy (1981) an *almost* unbiased[135] estimator for I_t is;

$$\widehat{I_t}^* = e^{\widehat{\beta_t} - \left(\frac{1}{2}\right)[\widehat{var(\beta_t)}]} \tag{22}$$

[134] Since β_t is a dummy variable and not continuous, it is inappropriate to interpret it directly as a rate of change as is generally done in log-log regressions (Halvorsen and Palmquist 1980).
[135] Although the transform-corrected coefficient estimate is still biased due to the convexity of the exponential function, it is less biased than an uncorrected coefficient (Goldberger 1968). Giles (1982) presents the formulation for the unbiased estimator, however it is computationally inconvenient due to infinite sums and is unlikely to be meaningfully different from Kennedy's (1981) estimator.

Note that the index value and its transformation-bias correction for each period are constructed solely from the coefficient and standard error estimates of the period in question. The independence of the calculation of index levels for each period from other periods is an inherent feature of level-based indices.

Growth-based index estimation

In recent years the second matrix formulation based on the estimation of period price growth-rates has gained popularity in the literature and in the construction of tradable real estate indices (Geltner and Pollakowski, 2007). This matrix specification consists of placing +1 in each of the columns representing the periods for which the property was held, and zeros in columns representing the periods before the property was purchased and after the property was sold. Taking the four property example above the corresponding growth-based time matrix would now be;

$$\begin{bmatrix} 1 & 1 & 1 & 1 \\ 0 & 1 & 1 & 0 \\ 0 & 0 & 1 & 1 \\ 0 & 1 & 1 & 1 \end{bmatrix} = D_G \qquad \textbf{(23)}$$

Again the ratio of the second to the first sale prices is used to estimate the index values, except now the specification uses the base index period to calculate successive index levels indirectly from rates of growth. Following the format above we have;

$$\frac{P_{i,t+\tau}}{P_{i,t}} = I_0 \times e^{r_t} \times e^{r_{t+1}} \times \ldots \times e^{r_{t+\tau}} \times u_{i,t,t+\tau}$$

Now in logs;

$$\ln\left(\frac{P_{i,t+\tau}}{P_{i,t}}\right) = \ln(I_0) + r_t + r_{t+1} + \ldots + r_{t+\tau} + \ln\left(u_{i,t,t+\tau}\right)$$

And in vector notation;

$$y = \Gamma D_G + \mu \tag{24}$$

Now where y is the vector of logged price relatives, D_G is the growth-based time-dummy matrix, Γ is the vector of logged index growth rate parameters, and μ is the error vector. The growth index is then constructed by chained multiplication where the base period is;

$$\widehat{I_0} = e^{\widehat{r_0}} \tag{25}$$

And successive periods are;

$$\widehat{I_{t+1}} = \widehat{I_t} e^{\widehat{r_{t+1}}} \tag{26}$$

Where r_0 is the first element of vector Γ. Again however equations (25) and (26) must be corrected respectively for transformation-bias as follows;

$$\widehat{I_0}^* = e^{\widehat{r_0} - \left(\frac{1}{2}\right) \widehat{var(r_0)}} \tag{27}$$

$$\widehat{I_{t+1}}^* = \widehat{I_t}^* e^{\widehat{r_{t+1}} - \left(\frac{1}{2}\right) var(r_0 + \widehat{r_1 +} \cdots + r_{t+1})} \tag{28}$$

As opposed to level-based indices, the estimated coefficients of growth-based indices represent the rate of price appreciation accruing during the corresponding interval (from beginning to end of period t). Therefore, to construct an index from the estimated growth rates for any given period requires chained multiplication of rates of return from all previous periods. Recall that this differs from level-based estimation, where each period is calculated independently.

Following (25), (27), and (28) we see that when correcting for transformation-bias the calculation of the index levels for a given period $t + \tau$ then becomes;

$$\widehat{I_{t+\tau}}^{*} = e^{\widehat{r_0}+\widehat{r_1}+\cdots+\widehat{r_{t+\tau}}-\left(\frac{1}{2}\right)var(r_0+\widehat{r_1+}\cdots+r_{t+\tau})} \qquad \textbf{(29)}$$

As we can see from (29) the transform-corrected growth index requires calculating the variance of chained sum of current and previous period returns. Since the level-based index calculation (22) can be explicitly rewritten as;

$$\widehat{I_t}^{*} = e^{\widehat{\beta_t}-\left(\frac{1}{2}\right)\widehat{var(\beta_t)}} \qquad \textbf{(30)}$$

Comparing (29) and (30) we see that whereas level-based indices undergoes a simple transformation-bias correction with respect to the current period, growth-based indices must calculate the variance of a sum, which is not generally standard output in statistical packages. Therefore the level-based method of index calculation may be superior in practice as it allows for a simpler calculation of transformation bias.

Fractional time-weighting

If the intervals between time-periods are too short, the estimated dummy variables will excessively register the random component of the time series under analysis due to insufficient observations. If on the other hand the time-intervals are too long, the resulting price-movements may not be able to vary sufficiently and the resulting price-path will be smoothed, missing a part of the seasonal or any other significant intra-period fluctuation (Birch and Sunderman, 2003). Therefore, index construction strategy faces a tradeoff between decreasing (increasing) random noise on the one hand and increasing (decreasing) temporal smoothing error/bias on the other.

In what may represent the best of both worlds, Bryan and Colwell (1982) introduced the possibility to weight explicit time variables in hedonic equations according to the fraction of year (month) in which they are sold such that all fractional time-dummies sum to unity. Henceforth this technique is referred in this paper as fractional time-weighting (FTW). This terminology is not generally accepted in the literature but is adopted here for clarification purposes. The FTW specification reduces intra-year averaging of values and effectively pegs the returns to end-of-year points in time. These annual indexes generally have no lag bias and represent end-of-year to end-of-year price changes. Moreover for each time-period interval they have as little noise as possible given the amount of data that can be collected (Bokhari and Geltner, 2010). However this reduction in temporal smoothing bias comes at the cost of a less efficient use of the data, increasing estimation noise compared with non-fractionally time-weighted matrix specifications; henceforth referred to as unitary time-weighting (UTW). Simulation analysis of repeat sale regressions comparing FTW and UTW by Geltner (1997) however, found that the increase in noise bias arising from FTW was small relative to the concomitant decrease in temporal smoothing bias.

In the repeat-sales literature and industry, FTW has been used to weight the time-matrix for growth-based indices only; such as D_G in equation (24) above. For instance, if we specify the intra-year monthly sale dates of example 1 as follows; the first sold in Jan 2000 and again in Jul 2003, a second sold in Aug 2001 and again in Jul 2002, a third sold in May 2002 and again in Sep 2003, and a fourth sold in Dec 2001 and again in Mar 2003, we can write Table 45 as;

Table 45: Example 2, Monthly sales data

	Year and Month of Sale			
Sale-Pair Observation	**2000**	**2001**	**2002**	**2003**
1	Jan	-	-	Dec
2	-	Aug	Jul	-
3	-	-	May	Sep
4	-	Dec	-	Mar

The corresponding FTW growth-based time matrix would then be;

$$\begin{bmatrix} 11.5/12 & 1 & 1 & 6.5/12 \\ 0 & 3.5/12 & 6.5/12 & 0 \\ 0 & 0 & 7.5/12 & 9.5/12 \\ 0 & 0.5/12 & 1 & 2.5/12 \end{bmatrix} = D_{G_{FTW}} \tag{31}$$

Level-based indices and fractional time-weighting

The index values from the level and growth-based UTW time-matrices outlined above [D_L in equation (20) and D_G in equation (23)] are apodictically identical, but as shown previously the computation of the respective indices from their estimated coefficients are different. Under the time-matrix specifications previously explored in the literature, in order to avoid the more complicated calculation of growth-based indices one would have to use level-based index estimation using a UTW specification (identical to the matrix D_L constructed above) which suffers from temporal aggregation bias. The methodological contribution of this section is to propose a novel matrix specification which combines the simpler transformation-correction of level-based index estimation, with the superior temporal performance of fractional time-weighting, leading to simpler transformation bias correction or more timely index estimation than was possible before.

For the annual case the proposed level-based FTW matrix is as follows. As in UTW, the first sale FTW time-weights sum to -1, but are allocated between the current year and the previous year in proportion to the difference between the current date and the beginning of the current year[136]. The second sale time-weights sum to +1 and are similarly allocated between the current and previous years. As in the UTW case, the first column of time weights matrix is set to zero regardless of first-sales straddling that period as a normalisation. A distinctive characteristic of this specification is that unlike UTW, if the interval between sales is less than two-times the interval between time-periods, the time-weightings on the first and second sale observations may overlap. In this case the time-weight for the overlapping year is constructed by summing the overlapping negative first-

[136] See ‘Appendix B: FTW level-based index time-weights’ for details on the annual and quarterly level-based index fractional time weights. First and second sale quarterly level-based fractional time weights do not overlap for our analysis because sales which occur less than 12 months after the previous sale of the same property are filtered out of the sample.

sale and positive second-sale time-weights. As in the in level-based UTW case, regardless of overlapping the sum of the first and second sale time-weights for each sale pair will sum to 0, unless the property in question has a first sale that straddles the base period. Like the FTW growth-based index specification, this weighting procedure conveniently centres estimated index values at the end of each year.

Applying the level-based FTW matrix specification to the four sale example in Table 45 yields the following weight-matrix.

$$\begin{bmatrix} 0 & -0.5/12 & 0 & 7.5/12 & 4.5/12 \\ 0 & -3.5/12 & -3/12 & 6.5/12 & 0 \\ 0 & 0 & -7.5/12 & -1/12 & 8.5/12 \\ 0 & -0.5/12 & -11.5/12 & 9.5/12 & 2.5/12 \end{bmatrix} = D_{L_{FTW}} \tag{32}$$

Notice that with only four repeat sale observations this level-based FTW matrix now becomes singular due to the addition of a new base column representing the year 1999. However, since a maximum of only one new period-column will need to be added to this matrix in order to accommodate FTW (one before the former base-period), the possibility of singularity arising from this specification is non-existent with statistically viable datasets[137]. A unique feature of the growth and level-based FTW series is that they allow for the estimation of an additional prior year of price levels compared to what is possible with a UTW index. FTW can also estimate price-levels for time periods where data is altogether missing so long as there is data on the subsequent period, such as the dataset in Figure 41 above.

To demonstrate the composition of the indices resulting from the level-based FTW matrix specified above we present two examples below. The first represents the 4th sale from Table 45 whose time-weights for first and second sales do not overlap. Reading from the 4th row of equation (32), estimation for the 4th sale now becomes;

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[137] To encounter this problem in practice, datasets would have to be exactly identified and therefore statistically trivial to begin with.

$$\frac{P_{4,Mar\ 2003}}{P_{4,Dec\ 2001}} = \frac{(I_{2003})^{2.5/12} \times (I_{2002})^{9.5/12}}{(I_{2001})^{11.5/12} \times (I_{2000})^{0.5/12}} \times v_{4,Dec\ 2001,Mar\ 2003} \quad \textbf{(33)}$$

In effect, the exponents separate the contribution of the four index values straddling the time of both sales, and the multiplicative form assumes geometric interpolation of index values between each pair of sale-straddling periods.

It is also instructive to examine the third sale in Table 45 as this sale will have overlapping time-weights according to our specification. Reading from equation (32) row 3 we have;

$$\frac{P_{3,Sep\ 2003}}{P_{3,May\ 2002}} = \frac{(I_{2003})^{8.5/12}}{(I_{2002})^{1/12} \times (I_{2001})^{7.5/12}} \times v_{3,Sep\ 2003,May\ 2002}$$

Notice that the exponents on either side of the divisor sum to the same value: 8.5. If we reinstate the original I_{2002} terms between the divisor lost during cancelation, the right-hand side again becomes;

$$\frac{P_{3,Sep\ 2003}}{P_{3,May\ 2002}} = \frac{(I_{2003})^{8.5/12} \times (I_{2002})^{3.5/12}}{(I_{2002})^{4.5/12} \times (I_{2001})^{7.5/12}} \times v_{3,Sep\ 2003,May\ 2002}$$

Which we see is compositionally identical to the non-overlapping 4th sale-pair in equation (33) above.

Returning now to equation (19), this specification has generally been found to be heteroskedastic, with heteroskedasticity growing in proportion to the period between the first and second sales. Case and Shiller (1987) propose that this finding is due to properties possessing both a common and idiosyncratic variance, the latter of which causes the property's return to diverge from the index as a whole the longer the time period between sales. In order to correct for this bias, two weighted least squares estimation procedures have been proposed in the literature to underweight property-pairs in the regression estimation with long periods between first and second sales. The first is simply to run a weighted least squares (WLS) regression with the length between sales as weights[138]. We call this specification WLS1. The second method proposed by Case and Shiller (1989) is also a WLS procedure, but it proposes letting the data estimate the appropriate size of these weights with the following three-stage least squares process. We call this method WLS2. The three-step procedure is implemented by first running a standard OLS in order to estimate the model residuals;

$$\hat{\epsilon} = y - X\hat{\beta}$$

These residuals are then squared, and a second regression is run on these squared residuals, with a constant term and the length of time the property has been held as regressors.

$$\widehat{\epsilon_i}^2 = a + b(term\ held_i) + \theta_i$$

Where θ_i is an error term assumed to be i.i.d.

From this second stage, the estimates of a and b are used to predict the squared residuals in the third stage.

$$\widehat{\widehat{\epsilon_i}}^2 = \hat{a} + \hat{b}(term\ held_i)$$

And then these predicted squared residuals $\widehat{\widehat{\epsilon_i}}^2$ are used to weight the dependent and independent variables of the original first-stage regression[139], whose coefficients are then used to produce the heteroskedasticity-corrected index.

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[138] As is standard for WLS, this would entail multiplying both sides of the regression equation by $\sqrt{1/term\ held_i}$. Where $term\ held_i$ can be any period (annually, quarterly, daily) as long as it is consistently applied. Of course, the shorter the period the more accurate the correction for heteroskedasticity can be.

[139] The weights are now $\sqrt{1/\left[\hat{a} + \hat{b}(term\ held_i)\right]} = \sqrt{1/\left[\widehat{\widehat{\epsilon_i}}^2\right]}$.

Note that the WLS1 procedure is equivalent to WLS2 where the constant in the regression on the squared residuals has been set to 0 and the coefficient on the term held has been set to 1 arbitrarily. Since the WLS2 procedure allows the data to determine the appropriate magnitude of these coefficients, this is perhaps the more sophisticated procedure. Finally, it should also be borne in mind that homoscedasticity is a necessary assumption for the transformation-bias correction proposed by Kennedy (1981) and Giles (1982). Therefore, in order for the level-based fractional time weighting procedure outlined in the section above to be applicable for Kennedy's and Giles's standard transformation-bias correction, homoscedasticity must either be assumed or dealt with explicitly. For transformation-bias corrections consistent with heteroskedastic data see Manning and Mullahy (2001).

Repeat-sales are used extensively in the US to produce housing price indices for government and industry. The most prominent are the indices produced by the Federal National Mortgage Association, the Federal Home Loan Mortgage Corporation, and the S&P Case-Shiller house price index. The Case-Shiller index is also tradable, with options and futures contracts available for hedging. Although repeat-sales have been used to monitor housing prices in the US since the early 1990s, commercial repeat-sales price indices have been slower to gain acceptance. After an initial failed attempt in 2007, as of 2012 Moody's in association with Real Capital Analytics are again promoting a tradable repeat-sales index for US markets which covers the major commercial property types.

Like transaction-based indices in general, repeat-sales indices are demonstrably more volatile and contain less autocorrelation than valuation-based indices. Using tax records Gatzlaff and Geltner (1998) analyse the entire population of commercial repeat-sales occurring in the metropolitan areas of the state of Florida between 1981 and 1996 and compare the index produced with the corresponding NCREIF valuation-based index[140]. The repeat-sales index was shown to have comparable volatility (standard deviation=4.07% vs 3.86%) but markedly lower autocorrelation (-0.08 vs 0.61) Although the two indices do co-move to a considerable degree (correlation=0.59), the relative magnitudes of these

[140] Like the IPD in the UK, the NCREIF index is considered the US industry standard.

movements are significantly dissimilar, differing by as much as 20% per period and with noticeable lag. Analyzing house price movements Shimizu, Nishimura, and Watanabe (2010) find that repeat-sales indices lag hedonic indices due to sample selection issues. Also looking at housing, Meese and Wallace (1997) recommend hedonic indices to repeat-sales as this method is less sensitive to sample selection bias, and Clapham, et al (2004) shows that hedonic indexes appear to be substantially more stable than repeat-sales indexes, being less prone to substantial revision in light of new information. Not all studies find hedonics to be superior to repeat-sales however, as Crone and Voith (1992) find that repeat-sales are the most robust when it comes to reduced sample sizes, and Hansen (2006) finds no appreciable difference between repeat-sales and hedonic indices looking at Australian housing markets.

Although repeat-sales have been compared to hedonic indices in the context of housing, this paper may be the first comparison of hedonic and repeat-sales price indices in commercial property[141]. This housing/commercial distinction could prove important because commercial properties, especially in the case of offices, are fewer in number and generally more heterogeneous than housing. Therefore there may be important limitations of the hedonic method to accurately capture prices over time due to inadequate model specification, and for the repeat-sales method to gather sufficient and representative data.

Real Estate Securities

A further approach to analysing real estate price movements is to assemble an index of securities on the stock exchange which exclusively hold direct real estate assets. This type of index may differ markedly from the other transaction-based indices introduced above because real estate securities markets possess greater liquidity, publicly available information, low transaction costs, the ability to sell short, and a plenitude of small-scale buyers. As to whether the price movements of real estate securities are more similar to the performance of the broad stock market or their underlying properties, the evidence has been mixed. Early studies such as Giliberto (1990, Liu et al (1990), and Myer and Webb (1993)

[141] Perhaps the most similar extant paper in this regard is Chau et al. (2005), who only compares a commercial repeat-sales index of Hong Kong with valuation-based indices and a hybrid index.

noted similar return behaviour between real estate securities and stocks, but the results of later studies like Morawski, Rehkugler, and Fuss (2008) and Hoesli and Oikarinen (2012) have been more nuanced, finding that over the short-term securitized real estate resembles the stock market, whereas over the long-run the correspondence with direct real estate is stronger.

In terms of the price movements themselves, Mueller and Mueller (2003) and Brounen and Eichholtz (2003) show low contemporaneous correlation between securitized real estate and 'real' real estate. Moreover, relative to direct property, real estate securities certainly exhibit a higher high degree of negative autocorrelation, pronounced volatility[142], and lead the price movements of direct property[143]. This intuitively makes sense, as it is to be expected that price discovery take place in the most efficient market (Wang, Lizieri and Matysiak, 1997; Lizieri and Satchell, 1997).

However, the differences between real estate securities and direct property established in these studies may be have been confounded by lags inherent in the valuation process itself (Myers and Webb, 1993; Gyourko and Keim, 1992). With regard to studies which define direct property price movements in terms of a transaction-based index: Fisher, Geltner, and Webb, (1994) find evidence that public markets move sooner than private markets[144], while Boudry et al (2012) found either no such relationship or much shorter lags compared to previous literature, and Hoesli, Oikarinen, and Serrano (2012) find divergent results according to the property sector in question. Hoesli, Oikarinen, and Serrano also pioneer the examination of whether the presence of 'escrow lag[145]' in direct property can account for the apparent slower price adjustment relative to real estate securities found in many studies, and they conclude that this is indeed the case for some property sectors. Given the

[142] Phenomena which are indicative of the excessive 'noise' common to stock markets (Geltner, 1997; Black, 1985; and Lee, Schleifer and Thaler, 1991).
[143] For a negative result see Glascock, Liu and So (2000) and Boudry et al (2012). For a contrary result refer to Tuluca, Myer, Webb (2000).
[144] But a problem with their conclusion is that their time-dummies are not fractionally time-weighted, and therefore will be subject to artificial temporal lag bias by fault of their model specification (Geltner, 1997).
[145] As defined as the time interval between when buyers and sellers have arrived at a 'meeting of minds' on the sale price, and when the transaction is legally consummated.

dearth of transaction-based comparisons of real estate securities and the unsettled questions of its correspondence with direct property within the extant literature, this paper stands to make a meaningful contribution to our understanding of the linkages between public and private commercial real estate.

An important difference between real estate securities and direct property assets is that the magnitude of mean price movements and variance observed in real estate securities will also reflect the amount of leverage in the constituent companies (Lizieri and Satchell, 1997), whereas private real estate assets are sold at prices exclusive of contractual debt obligations against the property. Because of this difference, leveraged real estate securities will automatically register higher levels of risk than direct property, even when in point of fact the underlying assets may be no more volatile. However, if the real estate securities index contains debt both on the asset and liability side of the balance sheet, this will counteract debt-induced volatility to an extent, leaving the returns to equity as a reasonable reflection of changes in value of the properties held by the institution as a whole (Fisher, Geltner, and Webb, 1994). However this offsetting relationship is unlikely to be perfect at all points in time, and so securitized real estate returns are ideally corrected for leverage on both sides of the balance sheet when comparing the riskiness of returns to other indices[146]. The standard method to degearing securities is to assume a simple weighted average cost of capital (WACC) model, and use this to derive the returns of the underlying properties from the return to equity. Following Fisher, Geltner, and Webb (1994) our model begins by simplifying the composite balance sheet of all companies in the index to read;

$$P_t + M_t = D_t + E_t \tag{34}$$

Where;

P_t = Value of property assets held at time t

[146] Depending on the analysis in question unlevering real estate returns may not be strictly necessary. For instance, Yunus (2012) argues that questions of lagging and causality in price indices are unaffected by leverage.

M_t= Value of mortgages and other debt-like securities held at time *t*

D_t = Value of outstanding liabilities (mortgages and other debt held against corporate assets) at time *t*

E_t = Value of shareholder equity at time *t*

Following this accounting identity and assuming capital structure irrelevance as outlined by Modigliani-Miller (1958), it follows that the returns to the equity index will be separately composed of;

$$r_t^E = r_t^P \frac{P_t}{E_t} + r_t^M \frac{M_t}{E_t} - r_t^D \frac{D_t}{E_t} \qquad \textbf{(35)}$$

Where;

r_t^E = return to equity (the naïve real estate securities series) iat time *t*

r_t^P = return to real estate property at time *t*

r_t^M = return to real estate debt at time *t*

r_t^D = cost of capital at time *t*

Assuming that the return to and cost of debt are approximately equal[147] $r_t^M \approx r_t^D\ \forall t$, equation (35) becomes;

$$r_t^E \approx r_t^P \frac{P_t}{E_t} + r_t^D \left(1 - \frac{P_t}{E_t}\right) \qquad \textbf{(36)}$$

[147] This assumption will naturally be most accurate where the debt held and issued is of similar riskiness and where efficient markets price risk uniformly.

With equation (36) holding as an approximation we can now estimate the return to the underlying properties in the portfolio of assets as;

$$r_t^P = r_t^E \frac{E_t}{P_t} + r_t^D \left(1 - \frac{E_t}{P_t}\right) \quad \textbf{(37)}$$

Invoking (34) simplifies (37) to;

$$r_t^P = r_t^E \frac{E_t}{P_t} + r_t^D \frac{D_t^n}{P_t} \quad \textbf{(38)}$$

Where D_t^n equals net debt, or $D_t - M_t$. Note that with algebraic manipulation (38) can be shown to be identical to the rather cumbrous and less intuitive expression more common in the literature;

$$r_t^P = \left(r_t^E + r_t^D \frac{D_t^n}{E_t}\right) \Big/ \left(1 + \frac{D_t^n}{E_t}\right)$$

Given that the cost of debt r_t^D will predominantly be lower than the return on equity[148], equation will progressively blunt the estimated index returns the greater the corporate debt, and by corollary the smaller the ratio of E_t/P_t.

Hybrid Indices

Transaction-linked Indices

A relatively recent addition to the universe of real estate index construction methods is the so-called transactions-linked or transactions-based valuation index now produced by NCREIF and IPD. This hybrid methodology combines property valuations with hedonic data on sales. Starting with the hedonic model in equation (15) this method recognizes that the vector of hedonic variables relating property characteristics to sale price, $\sum_{j=1}^{J} \beta_j X_{ij}$ can

[148] Or investors would otherwise altogether shun the contractually riskier equity.

be replaced with a single variable representing the property valuation price, in which case equation (15) becomes;

$$P_{it} = \gamma_0 + \alpha A_{it} + \sum_{t=1}^{T} I_t D_{it} + \epsilon_{it} \qquad \textbf{(39)}$$

Where;

α = the coefficient on valuations

A_{it} = the log of the valuation price of property *i* at time *t*

I_t = the systemic difference between valuations and transaction prices in period *t*

An important issue related to this estimation procedure is the question of how well appraised prices effectively represent differences in quality between properties. If the valuation itself contains error, then the relationship between appraised and market value is not direct. In particular, since the literature has often found both systemic and non-systemic components to these errors (Clapp, 1990; Kochin and Parks, 1982) this relationship can be modelled as;

$$A_{it} = \gamma_0 + \theta V_{it} + \mu_{it} \qquad \textbf{(40)}$$

Where;

A_{it} = appraised price of property *i* at time *t*

γ_0 = constant factor in the systemic error in valuations

θ = scaling factor in the systemic error in valuations

V_{it} = the unobservable true market value of property *i* at time *t*

μ_{it} = the idiosyncratic error in the valuation of property *i* at time *t*

In most studies comparing real estate valuations with sales it has been found that γ_0 is either zero or positive and θ is less than one (Brown, 1985; Matysiak and Wang, 1995; Blundell and Ward, 2008). The net effect of these two coefficients indicates that valuers are systemically biased in underestimating the sale price of properties. Rearranging (40) we see that with respect to actual market value V_{it}, equation (39) is more accurately depicted by;

$$P_{it} = \gamma_0 + \alpha\left(\frac{A_{it} - \gamma_0 - \mu_{it}}{\theta}\right) + \sum_{t=1}^{T} I_t D_{it} + \epsilon_{it}$$

Which with further rearrangement yields;

$$P_{it} = \gamma_0 + \alpha\left(\frac{A_{it} - \gamma_0}{\theta}\right) + \sum_{t=1}^{T} I_t D_{it} + \left[\epsilon_{it} - \frac{\alpha}{\theta}\mu_{it}\right] \qquad \textbf{(41)}$$

We can now see the consequence of errors in the use of assessed values to model market values in a hedonic price model. The compound error term of equation (41) is now $\left[\epsilon_{it} - \frac{\alpha}{\theta}\mu_{it}\right]$, making it negatively correlated by construction with α, which means that α is now biased under standard OLS assumptions. To resolve this issue one approach is to adopt an instrumental variables (IV) technique: finding an instrument which is both correlated with A_{it} but not with μ_{it}. Once an acceptable instrument for A_{it} is found it can replace A_{it} in equation (39) and this will allow for consistent estimation of the parameters in the model. In the seminal paper on using assessed values as a proxy for hedonic controls, this instrumental variable technique was adopted by Clapp (1990) to analyse land prices. However, subsequent studies on the assessed value method which compare the results of OLS and IV specifications found them to be virtually identical in large samples (Clapp and

Giacotto, 1992; Devaney and Diaz, 2011). As a result, in both empirical work and in industry the effect of the valuation error on assessed value estimates is now routinely ignored.

Once equation (39) has been estimated the coefficients so derived are used to correct the appraised value of the rest of the properties which did not transact for each time period, as shown below in equation (42).

$$\widehat{P_{it}} = \widehat{\gamma_0} + \hat{\alpha}A_{it} + \sum_{t=1}^{T} \widehat{I_t}D_{it} \quad \textbf{(42)}$$

In this way the appraised values A_{it} can be econometrically corrected to more accurately reflect current price movements $\widehat{P_{it}}$. In order to derive average capital returns, the estimated value of each $\widehat{P_{it}}$ is then exponentiated and divided by the exponentiated previous return $\widehat{P_{it-1}}$, and the resulting returns across all properties can be either equal-weighted or value-weighted to produce an average capital return and construct a price index[149].

A possible accoutrement to this model is the use of a Heckman (1979) procedure to control for unobserved sample selection bias in the transactions which are observed. Theoretically the Heckman procedure has the potential to correct the model coefficients for the fact that the properties which sell every period may not be representative of the total population of properties appraised that period. This method is carried out by first defining a selection equation which identifies the effect of property and environmental characteristic on the probability of sale by running a probit regression, as in equation (43) below.

$$\left. S_{it}^{*} = \gamma_0 + \alpha A + \sum_{t}^{T} \gamma_t Z_{it} + v_{it} \right\} S_{it} = 1 \; if \; S_{it}^{*} \geq 0, \text{ and 0 otherwise} \quad \textbf{(43)}$$

Which can then be estimated as a probit model;

[149] Equal-weights apply to indices viewed as statistical samples and value-weights to indices which are a population census. Indices used for research are best viewed as a statistical sample (Geltner and Ling, 2007).

$$\Pr[S_{it} = 1] = \Phi\left(\gamma_0 + \alpha A + \sum_{t}^{T} \gamma_t Z_{it}\right) \quad \textbf{(44)}$$

Where;

S_i^* = threshold value of property *i* being transacted

S_{it} = an indicator variable for whether property *i* sold in time *t*

$\Phi(\cdot)$ = the cumulative density function (cdf) of the normal distribution

γ_t = coefficient on Z_t

Z_{it} = characteristic of office *i* at time *t* which influences the probability of sale

v_{it} = normally distributed error term on property *i* at time *t*

In the next step is to use the estimated coefficients in equation (44) to construct the inverse Mills ratio;

$$\lambda_{it} = \frac{\phi(\widehat{\gamma_0} + \widehat{\alpha} A_{it} + \sum_t^T \widehat{\gamma_t} Z_{it})}{\Phi(\widehat{\gamma_0} + \widehat{\alpha} A_{it} + \sum_t^T \widehat{\gamma_t} Z_{it})}$$

Where;

$\phi(\cdot)$ = the probability density function (pdf) of the normal distribution

In the presence of unobserved sample selection bias the correct specification of equation (39) will now be;

$$P_{it}|S_{it} = \gamma_0 + \alpha A_{it} + \sum_{t=1}^{T} I_t D_{it} + [\epsilon_{it}|S_{it}]$$

With the error term likely leading to bias in the estimated index coefficients I_t. But with our estimates from the selection equation (44) the biasing effect of the error term can now be modelled with the inverse Mills-ratio.

$$P_{it}|S_{it} = \gamma_0 + \alpha A_{it} + \sum_{t=1}^{T} I_t D_{it} + \delta_t \lambda_{it} + \eta_{it} \tag{45}$$

Where;

δ_t = the estimated coefficient on the Mills-ratio for period *t*

η_{it} = the new unbiased error term for property *i* in period *t*

However the standard errors in equation (45) are now heteroskedastic and must be corrected according to Greene (1981). Coefficient estimates from the following equation can now be used to update valuations and produce an average capital return corrected for unobserved sample selection bias.

$$\widehat{P_{it}|S_{it}} = \widehat{\gamma_0} + \hat{\alpha} A_{it} + \sum_{t=1}^{T} \widehat{I_t} D_{it} + \widehat{\delta_t} \lambda_{it}$$

Although the Heckman procedure is currently used in academic work, neither the NCREIF in the US nor the IPD in the UK use it in their transaction-linked indices produced for industry. IPD states that the reason that they do not use the Heckman procedure in their models is because they found that it to be generally unstable, and highly sensitive to small samples of sales common when liquidity is low (IPD, 2012). Furthermore, in analyzing NCREIF data Fisher, Geltner, Pollakowski (2007) found that the influence of unobserved sample selection bias was not significant on the estimated price series. These objections are common to the use of the Heckman procedure across many areas of economics in general, and the question of whether this method will be adopted by industry in future is still open.

Data

Valuation-based

Valuations

As a comparable benchmark to the transaction-based indices produced by this paper, the valuation-based office property capital-growth index for Inner London produced by Investment Property Databank (IPD) is used. The IPD commercial property indices are generally considered to be the 'gold standard' in the UK, and the 'Inner London' geography series used here is the closest geographic analogue to our transaction data available from IPD. As a 'capital growth' series it also excludes income from estimated returns in order to be directly comparable to the transaction-based hedonic and repeat-sales indices.

Desmoothed Valuations

The desmoothed index is derived directly from the IPD Inner London Office capital growth index. Although there are currently more sophisticated desmoothing models in existence, we feel that given its simplicity, ease of interpretation, and widespread historical use, the first-order autoregressive filter used by Geltner (1993b) is the most general choice for an expository comparison of indices. This desmoothing procedure was applied to the UK market by Barkham and Geltner (1994) and more recently by Booth and Marcato (2004b). Following these papers we assume;

$$r_t = (r_t^* - a r_{t-1}^*)/(1-a) \tag{46}$$

r_t^* = rate of return on the valuation-based index in period t

r_t = true market rate of return in period t

a = first-order autoregressive parameter between 0 and 1

According to Geltner (1993b) the optimal value for α in equation (14) is approximated by;

$$\alpha = \frac{\sigma_M^2}{\sigma_M^2 + \sigma_V^2} \tag{47}$$

Where;

σ_M^2 = the true variance of real estate returns in the market

σ_V^2 = the variance of valuations with respect to the true market price

As we can see from the descriptive statistics of the hedonic and repeat-sales transaction-based Table 49 below, a reasonable approximation for the standard deviation of the market rate of return over the duration of our dataset is 20%, and from the discussion of valuation variance in the valuation-based indices section above a realistic approximation of the standard deviation of valuations is also 20%. Via equation (47) these two assumptions imply a value for α in our dataset of 0.5, which Geltner (1993b) states suggests a value for a in equation (46) of 0.6[150]. In our desmoothed valuation-based series this is also the value for a which we use.

Transaction-based

Hedonic and Repeat-sales

The index samples were constructed with 3,351 unique sale instances in central and outer London between 1978 and 2010 using databases from Estates Gazette and Real Capital Analytics. However, there were insufficient repeat-sales prior to 1998 to viably estimate an annual return series index, so values for years prior to 1998 are not constructed. The remaining observations were then culled with the following methodology.

---

[150] In point of fact, the value Geltner's (1993b) uses for his α is 0.4. However, since his analog of equation (46) is actually, $r_t = [r_t^* - (1 - a)r_{t-1}^*]/(a)$, the equivalent value of a in equation (46)is 0.6.

1. Removed non-central London building sales, as defined by EG and RCA.
2. Removed all portfolio sales.
3. Removed all predominantly non-office space building sales.
4. Removed sales of buildings which had been rebuilt, refurbished, or otherwise altered between transactions.
5. Removed sales which occurred less than 12 months after the previous sale[151].
6. Removed sales in the hedonic estimation for which complete data on relevant controls could not be identified.
7. Removed repeat-sales which exhibited annualized price movements greater than 50% of the previous sale price.

This data culling yielded 529 hedonic sales and 354 repeat sale-pairs. 173 of the hedonic sales are also present in at least one of the repeat-sales pairs. We have slightly more hedonic observations in this dataset than in chapter 1 (513) because we have sufficient observations to estimate an annual series for 1998 and 1999 at the annual frequency, but not the quarterly frequency which is used in chapter 1. For the hedonic sample, as complete a set of hedonic controls as possible is included in the regressions. In the interest of brevity the interested reader is referred to a full description of these variables in chapter 1 of this thesis, and the results of the regression and the full specification used to construct the hedonic index are displayed in Figure 32 below This comprehensive suite of controls combined with the use of a fractional time-weight specification outlined in 'Appendix B: FTW level-based index time-weights' represents a sophisticated hedonic model of the London office market.

[151] Rapidly resold properties have been shown to have a distorting effect on repeat-sales price indices (Clapp and Giacotto, 1999).

Figure 32: Hedonic index model specification and results

VARIABLES	Ln(Price/Sqm)
Within Conservation Area	0.0537
	(0.0347)
Listed	0.00153
	(0.0480)
Ln(Office Refusal Rate 9yr Moving Average)	0.0275*
	(0.0140)
Built 1950s	-0.0884
	(0.0750)
Built 1960s	-0.146**
	(0.0648)
Built 1970s	-0.202***
	(0.0658)
Built 1980s	-0.0471
	(0.0471)
Built 1990s	0.0423
	(0.0441)
Built 2000s	0.116**
	(0.0496)
Built 2010s	0.351
	(0.227)
Sold 1999	0.213
	(0.209)
Sold 2000	0.208
	(0.159)
Sold 2001	0.378**
	(0.159)
Sold 2002	0.394**
	(0.162)
Sold 2003	0.271*
	(0.151)
Sold 2004	0.492***
	(0.154)
Sold 2005	0.466***
	(0.148)
Sold 2006	0.773***
	(0.149)
Sold 2007	0.720***
	(0.150)
Sold 2008	0.276*
	(0.155)
Sold 2009	0.383**
	(0.149)
Sold 2010	0.541***
	(0.154)
City Fringe	-0.281***
	(0.0734)
Docklands	0.205
	(0.205)
Midtown	0.0164

	(0.0562)
North Central	0.104
	(0.135)
South Central	-0.0536
	(0.109)
Southern Fringe	0.0687
	(0.0988)
West Central	0.330***
	(0.124)
West End	0.400***
	(0.0662)
Ln(Employment 600m)	0.172***
	(0.0322)
Ln(Conservation Area Density 300m)	0.00653
	(0.00834)
Ln(Listed Building Density 300m)	0.0169
	(0.0137)
Ln(Parks and Gardens Density 300m)	0.00772***
	(0.00251)
Adjacent to Park or Garden	0.122***
	(0.0425)
Ln(Nearest Station Distance)	-0.0377
	(0.0252)
Ln(Floors)	0.0854
	(0.0538)
Ln(Depreciation Age)	-0.00646
	(0.00664)
Ln(Basements/Floors)	-0.0156**
	(0.00786)
A/C	0.203***
	(0.0750)
EG Office Grade A/B	0.0133
	(0.0416)
EG Office Grade A	0.0529
	(0.0375)
Ln(Percent Occupied)	0.0299***
	(0.00770)
Multiple Tenants	-0.0797**
	(0.0335)
Ln(Parking Spaces)	0.000455
	(0.00330)
Constant	5.843***
	(0.450)
Observations	529
R-squared	0.631

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Naturally the repeat-sales index is likewise fractionally time-weighted according to ‘Appendix B: FTW level-based index time-weights’. The result of this repeat-sales regression is shown below for the unweighted OLS and weighted WLS1 and WLS2 homoskedasticity corrections.

Table 46: Repeat-sales price index heteroskedasticity correction comparison

VARIABLES	(1) RSPI OLS	(2) RSPI WLS 1 (1/yrs held)	(3) RSPI WLS 2 (3SLS) [1/(a+b*yrs held)]
1998	0.128	-0.00312	0.107
	(0.130)	(0.140)	(0.132)
1999	-0.00959	0.0419	-0.00168
	(0.108)	(0.117)	(0.110)
2000	0.195**	0.178**	0.192**
	(0.0814)	(0.0897)	(0.0825)
2001	0.000469	0.0867	0.00787
	(0.0723)	(0.0724)	(0.0726)
2002	-0.00906	-0.0502	-0.00954
	(0.0804)	(0.0775)	(0.0800)
2003	0.00463	-0.0148	0.000528
	(0.0730)	(0.0665)	(0.0720)
2004	0.0660	0.116**	0.0710
	(0.0622)	(0.0528)	(0.0610)
2005	0.142**	0.112**	0.140**
	(0.0551)	(0.0476)	(0.0541)
2006	0.228***	0.228***	0.226***
	(0.0523)	(0.0465)	(0.0517)
2007	-0.121**	-0.0889*	-0.118**
	(0.0582)	(0.0505)	(0.0575)
2008	-0.371***	-0.353***	-0.368***
	(0.0713)	(0.0616)	(0.0701)
2009	0.249***	0.209***	0.243***
	(0.0747)	(0.0689)	(0.0741)
2010	0.0688	0.138*	0.0764
	(0.0824)	(0.0790)	(0.0825)
Observations	354	354	354
R-squared	0.589	0.526	0.575

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The second stage regression used to calibrate the WLS2 procedure in Table 46 specification 3 is shown in Table 47 below.

Table 47: Repeat-sales price index WLS2 2nd stage

VARIABLES	(1) Residuals-squared
Years Held	0.00338**
	(0.00171)
Constant	0.0344***
	(0.00806)
Observations	354
R-squared	0.011

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Real Estate Securities

The three real estate securities that were considered for this paper are outlined in Table 48 below. Although the ideal index would have been the FTSE UK Office Property Index since it is only comprised of office properties, its base date only begins in 2006 limiting its usefulness as a comparison with our other indices. The next index, the FTSE EPRA/NAREIT Index has an earlier start date of 1989, but is composed of six property sectors including retail, public storage, and healthcare (FTSE Group, 2012). This is problematic because different property sectors will tend to move idiosyncratically relative to the office-only indices we intend to compare them with (Hamelink et al, 2000). The Datastream Office and Industrial REITs UK (DS REITs) series on the other hand begins early enough and is composed only of securities which invest primarily in office and industrial properties. Because this index corresponds most closely to the other indices analysed here, the DS REITs index is used as this paper's real estate securities comparison.

Table 48: UK Real Estate Securities

	Levered	Base Date	Sectoral Composition
FTSE UK Office Property Index	NO	2006	Office
FTSE EPRA/NAREIT Index	YES	1989	All
Datastream Office and Industrial REITs UK Index	YES	1965	Office, Industrial

Booth and Marcato (2004b) also use the DS REITSs series as their preferred real estate securities index in their analysis of real estate price indices. Naturally we use the pure price index of this series which excludes dividends. As the DS REITs series is also levered, we unlever it following equation (37) using; annual balance sheet data on all the index's constituents to construct the ratio of equity to assets, and annual average UK bank's base interest rates provided by the Bank of England for the cost of capital. Roughly following Booth and Marcato (2004a)[152], we add 150 basis points to this interest rate as an approximation for the spread to real estate assets. Although a more accurate method may be to adjust spreads annually according to, say, De Montfort numbers[153], the choice of interest rate is of second order of magnitude, and therefore the precise choice of interest rate is unimportant (Booth and Marcato, 2004a). Index values are then taken at year-end to correspond to the price-capture dates of the valuation and transaction-based indices.

As Crosby and McAllister (2004) find that the median duration of escrow lag for office property in the UK is only 50 days, and our indices are only reported at the annual frequency, we do not attempt to follow Hoesli, Oikarinen, and Serrano (2012) and correct for 'escrow lag'. This decision is reinforced by the fact that even at a quarterly frequency Hoesli, Oikarinen, and Serrano do not universally find evidence that 'escrow lag' affects indices across all real estate sectors.

In addition to the real estate securities series, we also compare the performance of the FTSE All Shares price index. The index we use is the pure price index which excludes dividends and consists of a capitalisation-weighted basket of 602 of the roughly 2,000 stocks listed on the London Stock Exchange. This index comprises approximately 98% of the UK stock market's capitalisation (FTSE Group, 2012). Since he FTSE All Shares Index consists of financially levered equities, to increase comparability we also unlever the FTSE All Shares Index in the same manner as the DS REITs series.

Hybrid Indices

The transaction-linked index utilized in this paper is produced by IPD. Unfortunately the only transaction-linked index they current report for the UK is for the entire country and covers office, industrial, retail, residential, hotel, and healthcare property types. Because

[152] They add 12.5 basis points per month to the benchmark yield for five year gilts.
[153] The author was unable to acquire their commercial lending reports.

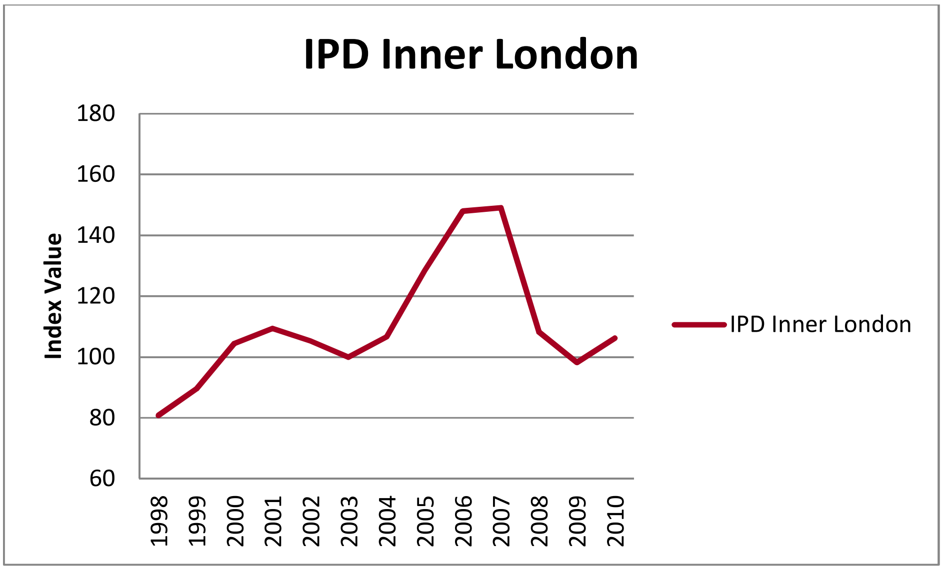
this geographic extent and inclusion of other property types differs from all the other indices examined here, the transaction-linked index is not directly comparable to them. To date, no other transaction-linked index is produced in the UK, and due to these dissimilarities its inclusion in the analysis is for expository purposes only. Like the other indices presented here, the IPD transaction-linked index is however also a capital return index.

Empirical comparison of alternative indices

The time period analysed here (1998-2010) encompasses two boom and bust phases. The first real-estate boom phase stems from the so-called Dot-com bubble which peaked sometime around the beginning of 2000 and then continued falling through 2003. From this point the big real estate boom of the middle 2000s begins and continues apace until sometime around 2006-07, at which point the market stalls and then falls precipitously, bottoming out around late 2008 or early 2009. We can see these events clearly unfolding in the IPD Inner London series in Figure 33. Since the IPD indices are currently the *de facto* industry standard in the UK, we superimpose this index on the other indices in this paper as the benchmark comparison.

IPD Inner London

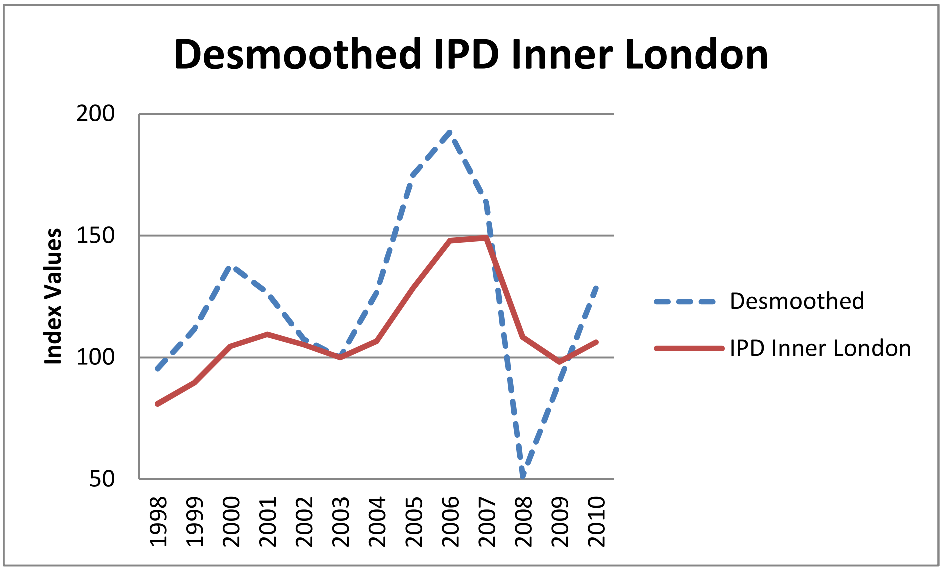
Figure 33: IPD Inner London Index



Base year is 2003 with index values = 100.

Desmoothed IPD Inner London

Figure 34: Desmoothed IPD Inner London Index



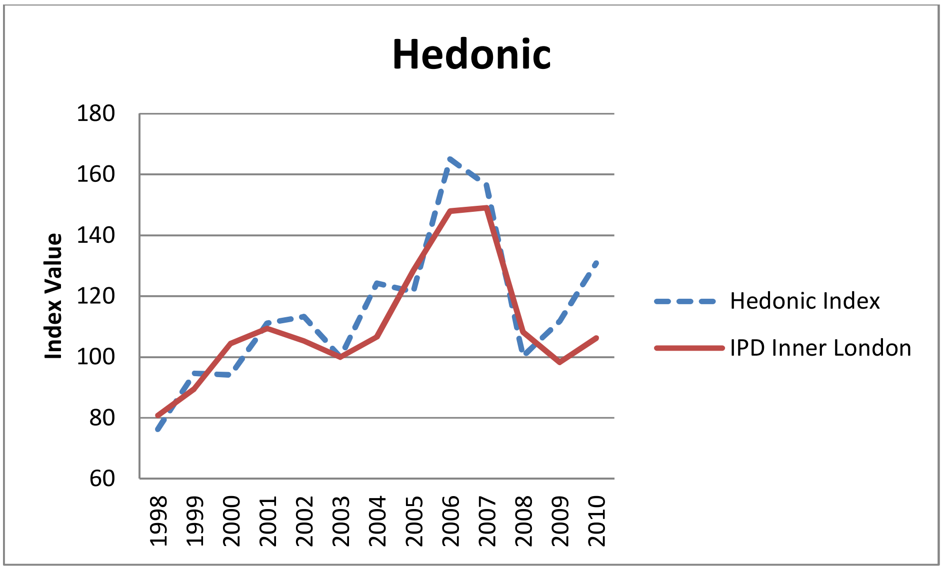
Base year is 2003 with index values = 100. First-order autoregressive parameter is 0.6.

As we see in Figure 34 the desmoothed IPD series has a greatly more pronounced variance than the uncorrected version[154], with higher peaks and lower troughs in three out of the four market turning points. The two indices are equivalent by construction at the 2003 trough, as this is the year selected as the index base. This year was chosen as it maximizes the comparability of the hedonic and repeat-sales series, for reasons we will see shortly. Although a more formal investigation into the existence of lead-lag relationships would invoke tests of Granger causality, the length of the annual dataset used here is not adequate to produce a test of sufficient statistical power. Therefore, similar to Fisher, Geltner, and Webb (1994), in analysing lead-lag and other relationships we restrict ourselves to visual comparisons of the data. It is clear from visual inspection that the desmoothed series also leads the uncorrected index by about a year at those same 3 market turning points. Along a similar vein, it would be ideal to be able to test whether the desmoothed series is actually statistically different in general from its benchmark: IPD inner London. Previous literature such as Clapp and Giacotto (1999) utilize Wilcoxon's signed rank test (Conover 1980, p. 280) for equality of means and Run Tests (Lindgren 1976, p. 498) for consistent positive or negative divergence in a time series for this purpose. However, none of the indices produced here are statistically different from their respective benchmark according to these tests, and again this is likely due to the fact that these annual series are of insufficient duration to register differences statistically. From Table 49 we also see that the desmoothing procedure has successfully reduced the degree of autocorrelation present in the data. However, given the extreme fluctuations of this series relative to the others below, it would appear as though the value of $a = 0.6$ used in equation (46) to desmooth the IPD series here is excessive. However, since it is not clear *a priori* what lower value of a would be appropriate, this analysis retains the more objective value of 0.6.

[154] See Table 49 for quantification of this difference.

Hedonic

Figure 35: Hedonic Index



Base year is 2003 with index values = 100.

In general, the hedonic index is comparable to the IPD valuation index, though there are some obvious differences. The lead-lag relationship of the hedonic series appears similar to the desmoothed series: turning about a year in advance of IPD valuations. Moreover the 2002 and 2006 peak occurs at a more extreme value than the IPD valuation index, though unlike the desmoothed index, the 2008 turning point is less extreme than the IPD valuation series. The hedonic index marginally falls between 2004-05, and this is the only index studied here which exhibits this behaviour. Given this and the appearance of more 'jagged' returns compared to the repeat-sales series exhibited below it may be reasonable to assume that this idiosyncratic fall is a result of mere noise manifesting itself in the form of excessive negative autocorrelation. However as we will show subsequently, the jagged appearance of this series is in fact a result of sample selection and not estimation error emanating from the relatively smaller sample of sales observations in the hedonic methodology. Another notable feature of the hedonic, and indeed the repeat-sales series below, is the low degree of persistence in these indices, as evident from the negative first-order autocorrelation in Table 49 and Table 50 which follow.

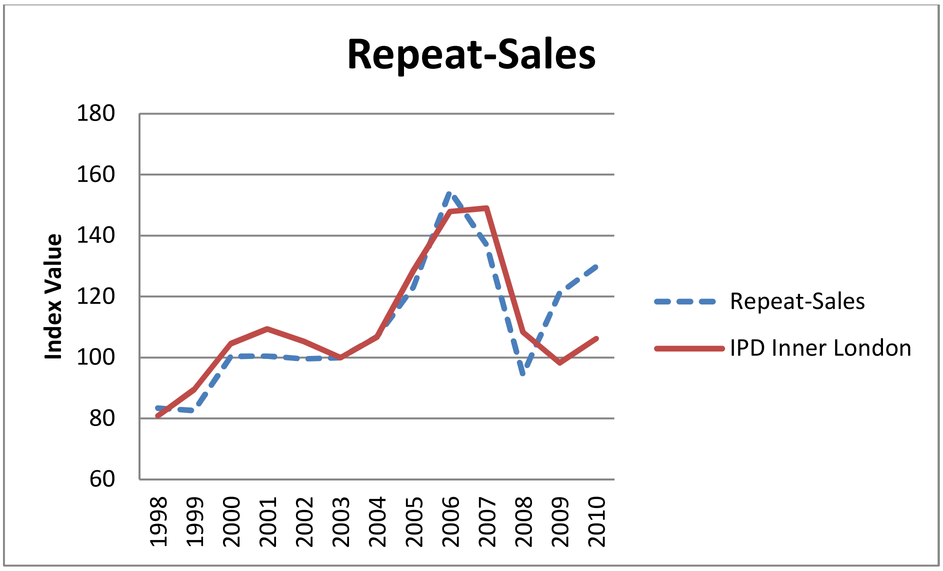
Repeat-sales

Figure 36: Repeat-sales price index heteroskedasticity corrections comparison

Base year is 2003 with index values =100.

Although the second-stage regression of the WLS2 procedure in Table 47 finds statistically significant linear heteroskedasticity present in the OLS return series, as we can see from Figure 36 the resulting WLS2 index calibrated for this observed heteroskedasticity is not noticeably altered by this correction. On the other hand, the more arbitrarily applied WLS1 specification does exhibit a noticeable divergence from the OLS series, tracking secularly higher. Interestingly, although it would superficially appear that the inverse weighting WLS1 procedure increases the volatility of the repeat-sales series, both the WLS1 and WLS2 series have slightly smaller standard deviations at 15.65% and 16.36% respectively, relative to the OLS index at 16.61%. Given the close correspondence between the heteroskedasticity calibrated WLS2 procedure and OLS, and since the WLS2 procedure is the only heteroskedasticity correction utilized by industry, it was decided to use the computationally simpler OLS series instead of WLS1 and WLS2 as the basis for the comparison with other indices. This OLS series is illustrated in Figure 37 below.

Figure 37: Repeat-Sales Index

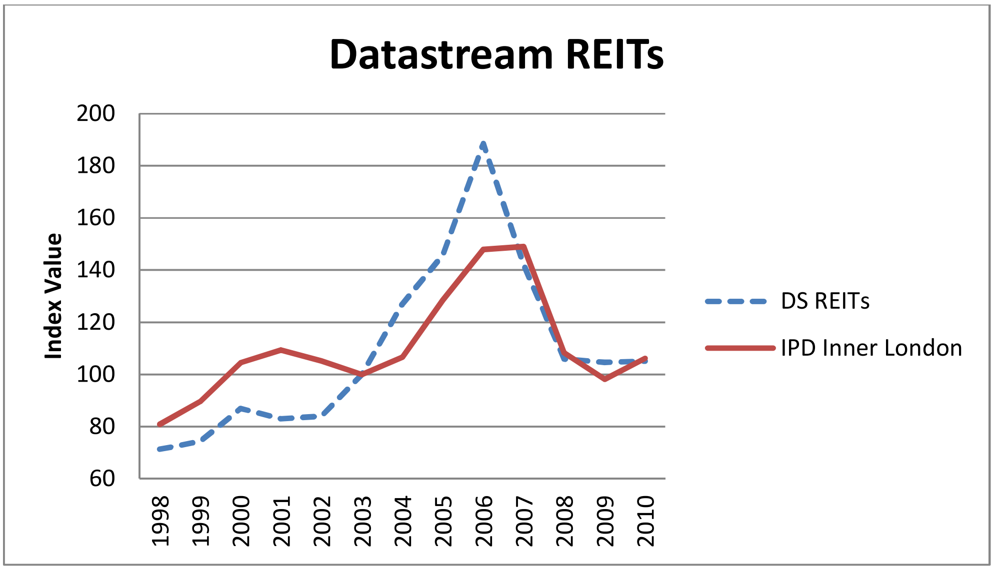


Base year is 2003 with index values = 100.

The correspondence between the repeat-sales and IPD series in estimated index levels in Figure 37 is striking. Aside from more muted price movements in the early 2000s, the only major difference between the repeat sale and IPD indices occurs in 2009 when the repeat-sales index tracks sharply higher as the IPD index continues to fall. That said, the repeat-sales series clearly leads the IPD series in the late 2000s in much the same way as the desmoothed and hedonic series; registering a fall in 2007 rather than 2008, and recovering in 2009 rather than 2010. Note as well that the excessive negative autocorrelation apparent in the hedonic series is now absent. Of all the transaction-based indices studied here, the repeat-sales index is the most similar to the IPD.

Real Estate Securities

Figure 38: Datastream REITs



Base year is 2003 with index values = 100.

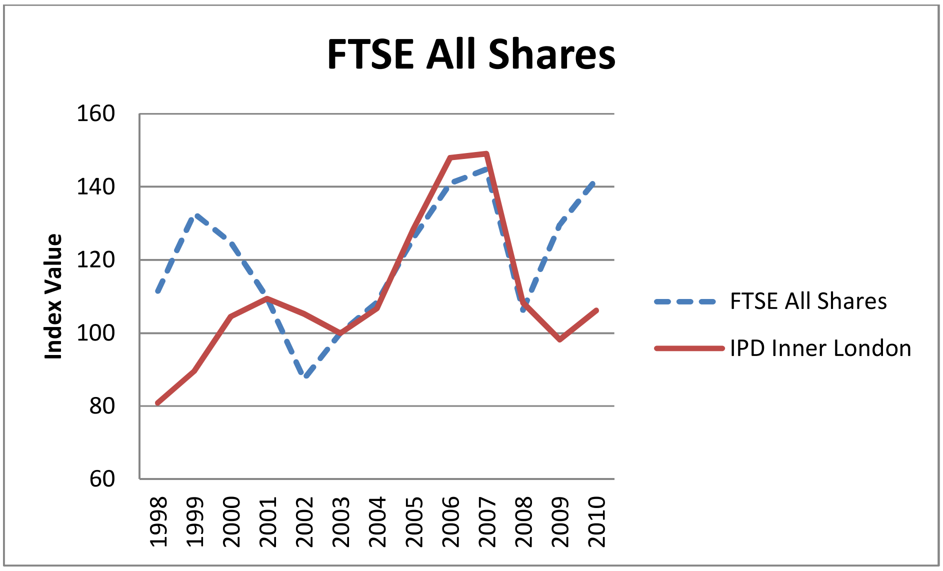
Like the repeat-sales series, the DS REITs index moves only slightly in the early 2000s, with a mild peak occurring in 2000, perhaps reflective of the 'so-called' dot-com bubble occurring at the time[155]. After treading water for several years it then exhibits the most extreme rise of any index examined here during the middle and late 2000s real estate boom[156]. Furthermore, this uptick in the real estate market begins earlier (2002) than any other index in this series, perhaps indicative of price discovery. However, contrary to the private-market real estate indices, the DS REIT series does not experience any sort of rebound in prices in either 2009 or 2010. At first blush one might expect this to be due to downward pressure from the stock market in general. But as Figure 39 shows, the stock market, as represented by the FTSE All Share Index, rebounded strongly in both 2009 and 2010. A possible explanation for this is that, while London rebounded quickly from the last recession, the rest of the country did not, and as the constituents of the DS REITs series do not operate exclusively in London, this index does not see a similar uptick for this period.

[155] The very modest growth occurring during this period is in stark contrast to the precipitous rise of internet stocks and the broad stock market at the time (see Figure 39). However, this is hardly surprising given that value sectors including real estate greatly under-performed internet stocks during this period.
[156] Note the larger variation in the y-axis values than in the other graphs need to accommodate this rise.

Overall, the index price-path appears relatively smooth for a transaction-based index, with levels of autocorrelation similar to the IPD index[157]. This finding is surprising, and perhaps again may be due to the geographic diversification of the index constituents, reducing 'noise' at the local London level[158].

Stock Exchange

Figure 39: FTSE All Shares Index



Base year is 2003 with index values = 100.

The FTSE All Share Index shows some interesting variation from the IPD Inner London and real estate securities series. The early years of the FTSE series experience the most massive fall in values beginning in 2000 in the wake of the Dot-com bubble. This large reversal in prices in the late 1990s and early 2000s is unlike any of the real estate indices studied here. The series then begins to recover in 2003, but unlike all other indices except IPD Inner London, the FTSE index continues to rise through 2007. Like the other transaction-based indices it then recovers quickly in 2009. Given the results of the other securities-based index in Figure 38, the evidence for a lead-lag relationship with respect to the private real estate market, at least at the annual frequency, is mixed.

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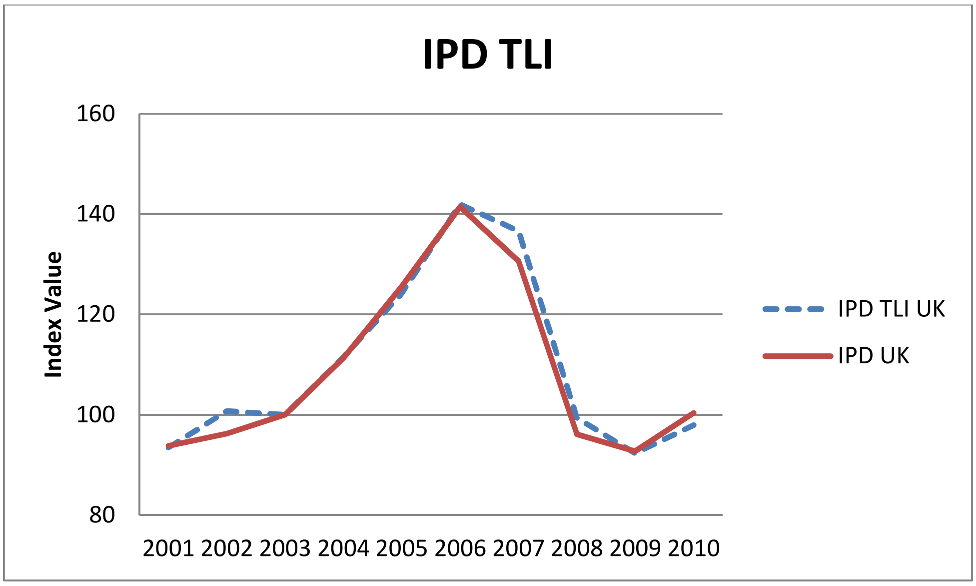
[157] See Table 49 and Table 50 below.
[158] Always avoid alliteration.

IPD Transaction-Linked

Figure 40: IPD Transaction-Linked Index



Base year is 2003 with index values = 100.

To date, the transaction-linked UK index has only been published for the years 2001-2010, and this is reflected in Figure 38. In addition, the TLI series covers the universe of IPD office properties in the UK, and therefore the comparison used in Figure 38 is the IPD UK All Property valuation series, rather than IPD Inner London offices. The TLI series is very similar to the pure valuation-based series except for the fact that it tracks marginally higher for much of the period. This upward adjustment is consistent with the findings of Blundell and Ward (2008), Matysiak and Wang (1995), and Cullen (1994) that pure valuations systemically underestimate market values. On the main, however, the two indices do not appear to possess substantial differences.

The four tables below outline the descriptive statistics and contemporaneous cross-correlations of the indices illustrated above. These tables separately cover the period 1998-2010 and 2001-2010. The reason for this dual coverage is to be able compare the IPD Transaction-Linked series which only extends back to 2001 with the other indices, while at the same time also showing the entire time period available for the other indices' data. For the 1998-2010 series, the IPD TLI index is replaced by the IPD UK All Property capital return index, which is identical to the uncorrected IPD TLI index: also covering all property types (office, industrial, retail, residential, hotel, and healthcare) across the entire UK. The seven indices compared in these tables are organised into two column groups indicating those indices which cover only office property in inner London (Inner London Offices) and indices which cover additional asset types throughout all the UK (UK All Property).

Table 49: Index Descriptive Statistics 1998-2010, all indices are unlevered

	Inner London Offices				UK All Property		
	IPD Inner London	Desmoothed IPD	Hedonic	Repeat-Sales	DS REITs	FTSE	IPD UK ALL†
Mean	3.15%	9.99%	6.43%	5.07%	4.76%	3.27%	2.06%
Median	5.67%	13.36%	6.67%	3.65%	2.76%	9.01%	3.71%
Standard Deviation	13.24%	36.64%	19.47%	16.61%	17.78%	15.95%	10.96%
First-order Autocorrelation*	0.41	0.21	-0.24	-0.15	0.30	-0.04	0.41
Kurtosis	1.31	1.22	0.72	0.78	-0.46	-0.62	3.54
Minimum Annual Return	-27.33%	-68.69%	-35.92%	-31.03%	-25.53%	-26.61%	-26.33%
Maximum Annual Return	20.40%	76.01%	35.88%	28.31%	29.25%	21.97%	12.77%
First Peak	2001	2000	2002	2001	2000	1999	-
Fall 1st Peak to Trough	-8.59%	--27.50%	-11.71%	-0.01%	-4.59%	-34.12%	-
First Trough	2003	2003	2003	2002	2001	2002	-
Rise 1nd Trough to Peak	49.04%	63.63%	64.98%	55.32%	127.15%	65.61%	-
Second Peak	2007	2006	2006	2006	2006	2007	2006
Fall 2nd Peak to Trough	-34.11%	-68.69%	-39.20%	-38.90%	-44.50%	-26.61%	-34.48%
Second Trough	2009	2008	2008	2008	2009	2008	2009

*First order autocorrelation refers to the correlation of the rate of return in the present period with the rate of return in the prior period. Thus it is an indicator of the degree to which prior information (just the first lag in this case) explains the present state of affairs.

†The IPD UK ALL property index increases monotonically from 1998-2007, and therefore unlike the other indices it cannot be said to possess either a first peak or trough in the early 2000s.

Table 50: Index Descriptive Statistics with TLI 2001-2010, all indices are unlevered

	Inner London Offices				UK All Property		
	IPD Inner London	Desmoothed IPD	Hedonic	Repeat-Sales	DS REITs	FTSE	IPD TLI UK
Mean	0.64%	9.70%	3.95%	4.47%	4.50%	4.26%	1.35%
Median	0.75%	9.98%	1.96%	6.83%	1.29%	9.61%	6.14%
Standard Deviation	14.26%	42.13%	21.27%	18.37%	20.13%	16.65%	13.02%
First-order Autocorrelation	0.38	0.37	-0.21	-0.11	0.34	-0.25	0.36
Kurtosis	0.77	0.51	0.45	0.57	-0.95	0.31	2.20
Minimum Annual Return	-27.34%	-68.69%	-35.92%	-31.03%	-25.53%	-26.61%	-27.25%
Maximum Annual Return	20.40%	76.01%	35.88%	28.31%	29.25%	21.97%	14.23%
First Peak	2001	2000	2002	2001	2000	1999	2002
Fall 1st Peak to Trough	-8.59%	--27.50%	-11.71%	-0.01%	-4.59%	-34.12%	-0.72%
First Trough	2003	2003	2003	2002	2001	2002	2003
Rise 1nd Trough to Peak	49.04%	63.63%	64.98%	55.32%	127.15%	65.61%	41.94%
Second Peak	2007	2006	2006	2006	2006	2007	2006
Fall 2nd Peak to Trough	-34.11%	-68.69%	-39.20%	-38.90%	-44.50%	-26.61%	-34.99%
Second Trough	2009	2008	2008	2008	2009	2008	2009

Table 51: Contemporaneous Cross-Correlation of Returns IPD UK All 1998-2010

	Inner London Office				UK All Property		
	IPD Inner London	Desmoothed IPD	Hedonic	Repeat-Sales	DS REITs	FTSE	IPD UK ALL
IPD Inner London	1	0.54	0.64	0.64	0.65	0.47	0.86
Desmoothed IPD	0.54	1	0.58	0.85	0.52	0.76	0.64
Hedonic	0.64	0.58	1	0.63	0.58	0.50	0.75
Repeat-Sales	0.64	0.85	0.63	1	0.71	0.61	0.70
DS REITs	0.65	0.48	0.58	0.71	1	0.50	0.86
FTSE	0.47	0.76	0.50	0.61	0.50	1	0.60
IPD UK ALL	0.86	0.64	0.75	0.70	0.86	0.60	1
Average Correlations							
Full Sample	0.63	0.64	0.61	0.69	0.64	0.57	0.74
Inner London Office	0.61	0.66	0.62	0.71	0.62	0.59	0.74
UK All Property	0.66	0.63	0.61	0.67	0.68	0.55	0.73
Valuation-Based (+UK ALL)	0.70	0.59	0.61	0.73	0.68	0.61	0.75
Transaction-Based (-UK ALL)	0.60	0.67	0.57	0.65	0.60	0.54	0.73

Valuation-based (+UK ALL) consists of IPD Inner London, Desmoothed IPD, and IPD UK ALL.
Transaction-based (-UK ALL) consists of Hedonic, Repeat-Sales, DS REITs, and FTSE.

Table 52: Contemporaneous Cross Correlation of Returns TLI 2001-2010

	Inner London Office				UK All Property		
	IPD Inner London	Desmoothed IPD	Hedonic	Repeat-Sales	DS REITs	FTSE	IPD TLI UK
IPD Inner London	1	0.55	0.70	0.65	0.65	0.61	0.91
Desmoothed IPD	0.55	1	0.66	0.87	0.45	0.83	0.52
Hedonic	0.70	0.66	1	0.80	0.68	0.56	0.80
Repeat-Sales	0.65	0.87	0.80	1	0.68	0.79	0.67
DS REITs	0.65	0.46	0.68	0.68	1	0.55	0.78
FTSE	0.61	0.83	0.56	0.79	0.55	1	0.49
IPD TLI UK	0.91	0.52	0.80	0.67	0.78	0.49	1
Average Correlations							
Full Sample	0.68	0.65	0.70	0.74	0.63	0.64	0.70
Inner London Office	0.63	0.69	0.72	0.77	0.62	0.70	0.73
UK All Property	0.72	0.60	0.68	0.71	0.67	0.52	0.64
Valuation-Based (+TLI)	0.73	0.54	0.72	0.73	0.63	0.64	0.72
Transaction-Based (-TLI)	0.65	0.71	0.68	0.76	0.64	0.63	0.69

Valuation-based (+TLI) consists of IPD Inner London, Desmoothed IPD, and IPD TLI UK.
Transaction-based (-TLI) consists of Hedonic, Repeat-Sales, DS REITs, and FTSE

Discussion

Referring to Table 49, all the indices' first moments are uniformly low and positive, but consistent with prior empirics, the valuation-based real estate indices' first moments are somewhat lower than the transaction-based indices'. The volatility of the valuation-based index as defined by its standard deviation appears to be roughly 50% higher for transaction-based indices (securities included) compared to their valuation counterparts[159]. This greater volatility was expected[160]. First-order auto-correlation is also markedly different between the valuation and transaction-based indices. In the pure valuation-based indices the autocorrelation is decidedly positive, and with the exception of the DS REITs series, the autocorrelation in the transaction-based indices are slightly negative or zero. The positive autocorrelation in the valuation-based indices may be indicative of smoothing problems, whereas the negative autocorrelation in the transaction-based indices may suggest excessive 'noise' in the data[161]. Consistent with expectations, the lead-lag relationships exhibited in Table 49 appear to follow a pattern where valuation-based indices either move contemporaneously or with a one-year lag relative to transaction-based indices. This is most clearly evident in the timing of the 2006-07 peak and the 2008-09 trough, although the securitized series contradict this trend slightly. Given that our indices only indicate prices annually, the universality of this lead-lag effect may be somewhat subdued relative to an index with more frequent price reporting. For instance in a similar analysis using annual data Gelter, Fisher, and Webb (1994) found that, contrary to expectations, valuations did not lag transaction-based indices.

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[159] The standard deviation of the uncorrected *levered* FTSE All Shares Index between 1998-2010 is 19%. The standard assumption made by investment practitioners is that the levered stock market indices have roughly double the volatility of the corresponding "true volatility" valuation-based real estate series in the US (Fisher, Geltner, and Webb, 1994). For the case of the FTSE All Shares Index the comparable index is the IPD UK All Property index. As we can see from the standard deviation in of the IPD UK All Property index in Table 49 (10.96%), this assumption may understate the true volatility of commercial UK property.

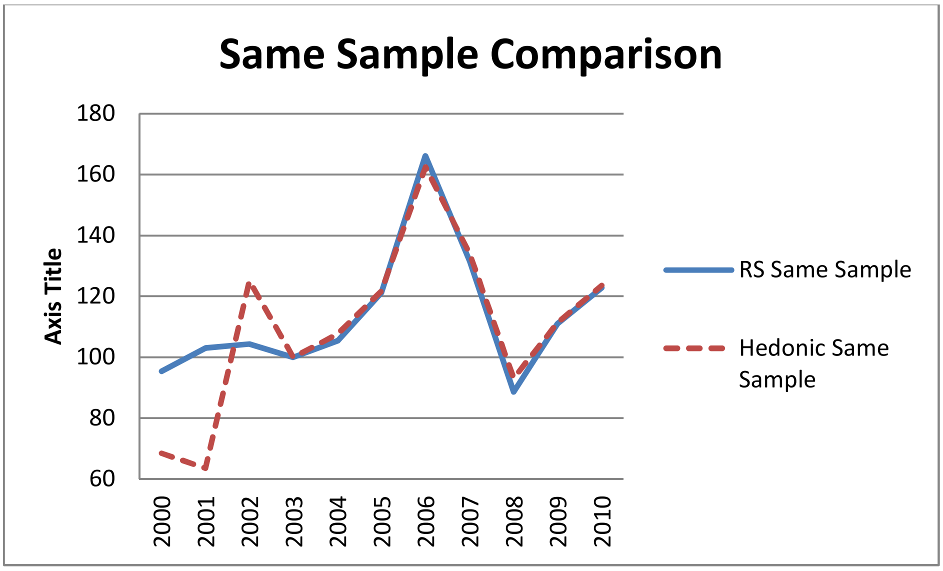
[160] Note that the lower standard deviation present in the IPD TLI UK index compared to the IPD Inner London series in Table 50 is not necessarily anomalous since they comprise different geographical consituents.

[161] Efficient markets imply autocorrelations with all past index values of zero. However, this may be too strong an assumption here, as various research such as Case and Shiller (1989); and Lee, Devaney, and Young (2003) have shown some persistence (positive autocorrelation) in real estate market returns. Therefore the observance of negative autocorrelation can be considered robust evidence for superfluous 'noise', whereas positive autocorrelation may simply reflect underlying tendencies of the market.

Comparing the various indices it is interesting to note that the mechanical desmoothing technique outlined in equation (46) exhibits lead-lag relationships in Table 49 that more closely resemble those of the transaction-based series, but the descriptive statistics, in particular the standard deviation, are clearly exaggerated. In this respect we may consider the desmoothed series to be somewhat of an improvement on naïve valuations, and may in fact be a reasonable proxy for transaction-based data so long as the magnitude of the desmoothing parameter is not excessive: as it appears to be in this case.

As was already evident in Figure 35 and Figure 37, the hedonic index is more volatile than the repeat-sales series and exhibits a greater degree of negative autocorrelation. In response to this finding, Occam's razor might suggest that these differences are likely due to inadequate model specification generating spurious 'noise' in the index. Whereas, since repeat-sales automatically control for all constant property characteristics, in the face of heterogeneous properties, model specification problems in repeat-sale indices are relatively immaterial. However, an alternative interpretation could also be that since the samples of properties used to construct these indices are not identical, the average rates of return of these different properties at each time-period may also be divergent. In order to test which of these two assumptions may be true, we rerun the hedonic and repeat-sales models throwing out all hedonic sales which are not also in the full repeat-sales sample and likewise the repeat-sales pairs which do not have at least one sale in the hedonic sample. The resulting sample of sold properties used for the hedonic and repeat-sales indices is similar but not strictly identical, as we also retain observations in the repeat-sales pair which have a either a first or a second sale in the full hedonic sample but whose other paired sale is not. This is done in order to preserve a reasonably large comparison sample size. The resulting sample consists of 173 hedonic and repeat-sales pairs between 2000-2010: years prior to 2000 have no observations in this sample. The price indices derived from this sample are exhibited in Figure 41 below.

Figure 41: Repeat-sales and Hedonic indices same sample comparison



Base year is 2003 with index values = 100.

Immediately we notice that both price series tracks very closely indeed except for years prior to 2003. However, if we look at the distribution of observations in the hedonic model sample according to year in Table 53 we see that there are precious few observations per year prior to 2004. So if in fact the two series are, for all practical purposes, identical with their similar samples, it is not surprising that we see substantial deviation in these early years[162].

Table 53: Hedonic observations by year

2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	*Total*
1	0*	5	6	11	21	31	25	14	25	34	*173*

*The 2001 time-dummy can still be estimated even though there are no observations in this year due to the fractional-time weighting of sales in 2002.

With the new sample the repeat-sales series now exhibits a distinctive hump in the early 2000s which it lacked previously, and which is characteristic of most of the other indices

[162] The nonparametric Wilcoxon's Signed Ranks Test for equality of means (Conover 1980, p. 280) and Run Tests for consistent positive or negative divergence in a time series (Lindgren 1976, p. 498) also do not register significant differences between the hedonic and repeat-sales indices in Figure 41. But again, the short duration of the sample impinges upon the power of statistical tests to detect significant differences.

including the hedonic index. It is interesting that unlike the hedonic index, the repeat-sales series does not appear appreciably more volatile in the early 2000s even though the sample size during this period is minimal. As noted earlier, the result that repeat-sales indices are more robust than hedonic indices with respect to small sample sizes was also found by Crone and Voith (1992). The repeat-sales index also takes on the higher 2003-06 rise apparent in the hedonic index in Figure 35 and the hedonic index in Figure 41 now has the more precipitous 2006 peak of the repeat-sales index in Figure 37. Thus with a more similar sample it appears that the two indices are now collectively taking on their distinctive features in Figure 35 and Figure 37 which previously made them different.

The repeat-sales index in Figure 41 is actually based off of almost twice (316) the number of total observations (including second *and* first sales) as the hedonic index alongside it, and yet the hedonic series performs almost identically to when it uses the same sample of properties. Although the test in Figure 41 is not perfect due to the fact that the hedonic and repeat-sales samples are not completely identical (they do contain the same sample of properties however), the available evidence suggests that the extra volatility observed in the full sample hedonic index in Figure 35 compared to the repeat-sales index in Figure 37 is a result of the different (and larger 529 vs 354) sample of observations, and not a flaw with the specification of our model, or difficulties to do with modelling commercial property markets with hedonic methods in general.

The finding that the particular sample studied is significant in determining the outcomes of hedonic and repeat-sales indices was also identified by Shimizu, Nishimura, and Watanabe (2010), who noted that the differences observed between the their hedonic and repeat-sales indices were due to sample selection issues. As mentioned earlier, a major critique of the repeat-sales index is inefficient use of data. The result that repeat-sold properties are not representative of more numerous hedonic sales is also consistent with the conclusion of chapter 2, that repeat-sold properties differ from the market as whole in ways that interfere with the construction of accurate indices. As we have also seen in the present chapter, sample selection can compromise the representativeness of repeat-sales indices relative to hedonic indices, and therefore if a working hedonic model can be constructed it will likely be superior to a repeat-sales index. Furthermore, because hedonic indices only observe prices when properties sell, future research may indicate that even hedonic indices may also be less representative of the market than valuation indices which at least observe proxies for prices every period.

According to IPD the stated purpose of their Transaction-Linked valuation index correction is to better identify the true volatility present in the market. Table 50 compares the 2001-2010 transaction-linked series to the other indices constructed in this paper. As we can see, in spite of the transactions-based correction, the standard deviation of the underlying valuation index only marginally increases from 12.68%[163] to 13.02%. This level of risk is markedly below the other transaction-based and desmoothed indices which have standard deviations closer to 20%. Of course, this is not quite a one-for-one comparison because the TLI index covers all property-types across all the UK, whereas the other indices mentioned only cover offices in inner London. But since the difference between the standard deviations of the IPD UK All Property Index and the IPD Inner London in Table 49 is only about 2%, it may be the case that the TLI index does not increase valuation volatilities to levels commensurate with the actual market. However, in order address this question with greater rigour, further research into the validity of the TLI procedure is needed.

From Table 51 we also see that the performance of real estate securities appears to be more similar to that of the other real estate indices than the stock market in general. The source of this difference would primarily appear to be the expansive Dot-com boom in the early 2000s evidenced in Figure 39, which has no equal in any of the other indices. This result differs from most studies that compare real estate securities with private real estate indices and broad-based stock market indices, such as Liu, et al (1990), Webb and Myer (1993), and Giliberto (1990) who found that REITs are predominately integrated with the stock market compared to private commercial real estate. The low correlation of the FTSE All Shares Index relative to the property-based indices is indicative of divergent market

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[163] 12.68% is the standard deviation of the IPD UK All Property Index between 2001-2010 which is not reported in Table 49 or Table 50.

movements between the two asset types, and has been previously reflected in the distinct grouping of these two assets in factor analyses by Lee and Lizieri (1999).

Conclusion

This paper compares commercial property valuation, desmoothed valuation, hedonic, repeat-sale, transaction-linked, and real estate securities indices within the context of the London office market during the period 1998-2010. As these indices have been developed using different data and different methodologies, the common themes and patterns we observe can be considered a relatively robust indicator of the actual price movements experienced during this period. These price movements are of interest as they coincide with some of the most dramatic market booms and busts experienced in several decades. The evidence from a comparison of these indices in Table 49 suggests that the London office market increased through the late 1990s until 2000 or perhaps 2001, and then proceeded marginally downward by about 10% until 2003. From this point the market experienced a large sustained boom in prices of around 55% peaking in 2006. From here the market fell markedly in 2007 and then precipitously in 2008 by a total of approximately 40%. In the following two years the market then quickly recovered by a total of about 30% off its 2008 nadir. The major differences between the sequence of events outlined by these various indices and the IPD inner London index are the earlier market corrections in both 2006 and 2008, and the slightly more extreme fluctuations around these years.

Given the dearth of transaction-based comparisons of commercial real estate and problems with the literature that exists[164], this paper is able to expand and improve upon previous studies to produce results which are novel to the literature. In agreement with previous research, this paper finds that, in general, valuation indices suffer from problems of smoothing: lagging transaction-based indices with higher autocorrelations and approximately 33% lower standard deviations. In terms of original results, this paper finds that although the magnitude of the desmoothing, parameter chosen was in line with previous empirical estimates, overall it produced a mixed approximation of transaction-

[164] Such as excessively parsimonious and aggregated hedonic models and comparisons of fractionally time weighted and non-fractionally time weighted indices.

based indices. Although the unsmoothed series more closely matched the timing of the transaction-based indices, many descriptive statistics, in particular variance, appeared to be well out-of-line. Although not currently used in industry, desmoothed indices whose parameters have been calibrated by transaction-based indices may prove popular in future.

Turning to transaction-based indices, real estate has tended to shy away from hedonic indices in commercial real estate often on the grounds that hedonic specification is too difficult and unreliable. Moreover, many industry professionals have a vested interest in valuations and most operators would neither understand nor be able to construct a hedonic model. This study has demonstrated that hedonic models of commercial real estate markets can not only be adequately specified, but if done so, hedonics performs no worse than repeat-sales indices, and if anything is superior due to the sample sensitivity underlying both methods and the greater inclusivity of sales observations made possible by the hedonic methodology. On that note, transaction-based indices are indeed found to be extremely sensitive to the sample of properties used, even when using sample sizes which would normally be considered ample. In order to improve the representativeness of transaction-based indices of London offices in future, assuming adequate data, future research may consider a Heckman's correction for unobserved sample selection bias on both hedonic and repeat-sales indices. However this method must be used with caution as previous research has tended to find these corrections to be unstable.

Since London may be unique among other markets in that high quality disaggregated data is available on relevant hedonic variables, it is an open question as to whether this method can be extended to other localities that may necessitate a different mix of variables or where such variables are unavailable or not measured with sufficient accuracy. However, this paper has introduced a technique for testing the acceptability of hedonic models of real estate prices by simultaneously producing a repeat-sales index with as similar a sample of properties to the hedonic index as is possible. The two indices are then compared to see whether the two time-series they produce are identical. In future this method could be used to test the validity of proposed hedonic models in other cities or as a robustness check for whether the hedonic models employed in other research are indeed valid.

Additional results from the other indices include noting that the 3SLS procedure, conventionally used to correct for heteroskedasticity in repeat-sales regressions of housing produces a time-series for commercial offices which is indistinguishable from uncorrected OLS. Therefore it may be the case that repeat-sale regressions of commercial offices do not exhibit the same problems of heteroskedasticity that are generally encountered in housing. In addition, this paper introduces an original fractional-time weighting procedure for repeat-sales that allows for simpler calculation of transformation-bias while maintaining a minimum of temporal aggregation bias. Other notable findings include the fact that, contrary to previous research, real estate securities in the UK follow the movements of London office property more closely than the stock market as a whole, and that the annual transaction-linked index is extremely similar to its underlying uncorrected valuation index.

Given the material variation in the price indices produced above and their relative strengths and weaknesses, it is clear that researchers and investors should not rely on any single index methodology to provide them with the correct picture of market movements. Rather, by comparing and contrasting several indices in concert while recognising the specific strengths and weaknesses of each, the most accurate impression of historical price movements can be obtained. Although it is doubtless preferable to arrive at these conclusions with statistical rigour, in the world of commercial real estate were data is scarce, for the time being informal tests remain an important check upon the validity of return series.

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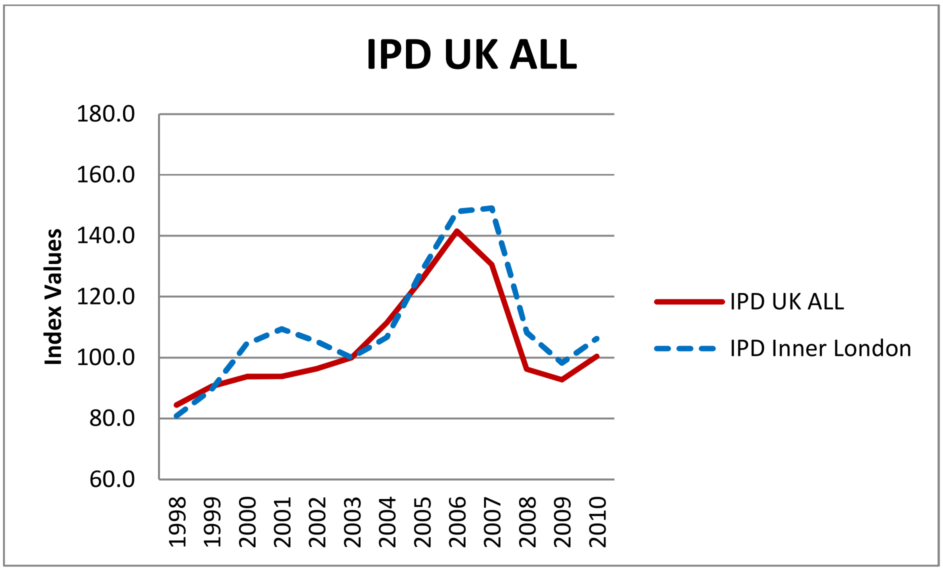
Appendix A: IPD UK ALL Annual

Figure 42: IPD UK All



Base year is 2003 with index values =100.

As a comparison for the TLI index, the IPD UK All series contains valuation data on all the UK geographies and property types covered by IPD. These sectors comprise office, industrial, retail, residential, hotel, and healthcare properties.

Appendix B: FTW level-based index time-weights

Table 54: Hedonic regression fractional time-weightings

	Month of Sale											
Sale	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
(Previous year weight) (Current year weight	(11.5/12) (0.5/12)	(10.5/12) (1.5/12)	(9.5/12) (2.5/12)	(8.5/12) (3.5/12)	(7.5/12) (4.5/12)	(6.5/12) (5.5/12)	(5.5/12) (6.5/12)	(4.5/12) (7.5/12)	(3.5/12) (8.5/12)	(2.5/12) (9.5/12)	(1.5/12) (10.5/12)	(0.5/12) (11.5/12)

Table 55: Repeat-sales regression fractional time-weightings

	Month of Sale											
Sale Order	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
First Sale (Previous year weight) (Current year weight	-(11.5/12) -(0.5/12)	-(10.5/12) -(1.5/12)	-(9.5/12) -(2.5/12)	-(8.5/12) -(3.5/12)	-(7.5/12) -(4.5/12)	-(6.5/12) -(5.5/12)	-(5.5/12) -(6.5/12)	-(4.5/12) -(7.5/12)	-(3.5/12) -(8.5/12)	-(2.5/12) -(9.5/12)	-(1.5/12) -(10.5/12)	-(0.5/12) -(11.5/12)
Second Sale (Previous year weight) (Current year weight	(11.5/12) (0.5/12)	(10.5/12) (1.5/12)	(9.5/12) (2.5/12)	(8.5/12) (3.5/12)	(7.5/12) (4.5/12)	(6.5/12) (5.5/12)	(5.5/12) (6.5/12)	(4.5/12) (7.5/12)	(3.5/12) (8.5/12)	(2.5/12) (9.5/12)	(1.5/12) (10.5/12)	(0.5/12) (11.5/12)

Thesis Conclusion

This thesis has developed three chapters which extend our understanding of asset performance within the London office market. These analyses collectively investigated the determinants of capital returns and issues which affect their accurate measurement. It was found that rent seeking through eminent building design, changes in local employment density, and the planning restrictiveness of local authority areas are important drivers for realised capital returns in the London office market, and that these effects can have important ramifications for price index construction. It was also shown that commercial real estate price indices in London are sensitive to the particular method used for their assembly, with marked differences not only between valuation and transaction-based indices, but also within them.

The first chapter began by examining whether star architects are able to convince city planners to allow bigger projects within the tightly regulated London property market, and therefore to earn economic rents relative to developments which are not so favoured. Although any decision criterion used to define 'star' architects is naturally subjective, peer recognition is perhaps the least contentious. Therefore, it was decided that architects which had won awards from at least one of the three most prestigious architectural bodies were to be considered famous for the purposes of this paper. Outside of conservation areas it was found that planners allow famous architects to build on average 20 stories taller than their less celebrated peers. Using cost data from Gardiner & Theobald it was estimated that these additional floors allowed developers to increase total revenues and profits on a given land plot by roughly 100%. This figure is inherently somewhat inflated however because these returns do not account for the additional expense and uncertainty associated with attempting to flex the planning system. Although Kruger (1974) famously demonstrated that competitive rent-seeking in a regulated economy exacts dead-weights losses over and above those caused purely by the regulations themselves, in the case of architecture this competitive process may yet yield some ancillary benefits in the form of improved public aesthetics. If this is the case, then London's flexibly enforced development restrictions may be responsible for much of its critically acclaimed modern architecture.

In contrast to previous research, this paper also found that modern famous architects exert no net effect upon the sale price of their space. Apparently, it is only the fact that famous architects are allowed to build tall which makes their services at all valuable to developers in London. This finding can be explained by considering the extra maintenance costs which may be involved in the upkeep of such buildings, and the fact that planning authorities may eye these properties with designs for historic designation in future, thus reducing the present value of future redevelopment options. Moreover, it was found that buildings built by pre-modern famous architects (built previous to 1925 in our sample) sold for a marked discount. If famous architects cannot in fact increase the per area-unit sale price of office buildings in the current regulatory environment, then this implies that the divide between the sale price of buildings with good architecture and the total subjective benefits such buildings provide to the public may be large. This value gap may lead to a situation where good architecture is underprovided by way of private incentives. If this is the case, then in order to generate efficient levels of good architecture threats of historic designation for new buildings would either have to be lessened or public subsidies to good design would have to be provided. The current concession to developers who hire famous architects to build tall appears to be one such subsidy which can overcome this price-gap and deliver more efficient quantities of good architecture to the city.

Given the degree to which land markets in London are regulated it is not surprising that there are economic rents to be earned from obtaining special exemptions to them. What is of greater concern however is the magnitude of these rents, as this is indicative of the degree to which these planning regulations cause market distortions. Although not the primary aim of this paper, the data corroborates the controversial conclusion of Cheshire and Hilber (2008) that the regulatory restrictiveness of the London office market may exert significant economic costs, though the estimated magnitudes of these effects were not found to be as large as in their paper[165]. Nevertheless the size of the regulatory distortions estimated here are still substantial and cause for concern. Of course, as in previous studies

[165] This discrepancy is likely due to methodological conflicts between the two papers rather than material differences in measured regulatory tax levels.

these gross costs are presented without a comparison of the estimated benefits potentially also delivered by these regulations.

Regulatory restrictions on building development which arbitrarily limit employment density may also have important consequences for the productivity of the economy as a whole. Employment density has long been regarded as fundamental for increasing opportunities to conceive and exchange the ideas which drive economic growth. Therefore regulations which affect the land market may have direct consequences for other areas of the economy and economic welfare generally. For this reason it is imperative that researchers extend this investigation in future to ascertain the full complement of costs and benefits of the current land-use planning system, and use this information to inform the public and politicians of the economically efficient course of action. Until such time as these questions are answered, our current knowledge of the substantial costs of the planning system would logically preclude any further entrenchment or expansion of existing regulations.

Like Cheshire and Hilber (2008), the first chapter also found that the estimated regulatory taxes varied considerably across London submarkets due to differences in the price of office space. As was shown in the second paper, this intra-city price variation seems to be at least partially due to differences in the restrictiveness of development control across local administrative boundaries, which roughly correspond to the recognised extent of London submarkets. Furthermore, this very same submarket price variability has significant implications for the accuracy of repeat-sales price indices in practice, because the sale-multiples required for these indices are unrepresentative of the market as a whole. While the primary advantage of repeat-sales indices is that their construction requires no more information than; sale prices, sale dates, and sale locations, the assumptions that allow this procedure to produce a viable price index may be violated in practice with important repercussions. In particular, it was found that repeat-sales of office properties in London are over-weighted by their specific temporal and locational attributes relative to the office stock as a whole. The factors contributing to this bias were found to be employment density changes and the restrictiveness of office supply in the corresponding local authority area.

These biases arise because of the effect of employment density and supply restrictions on prices and the fact that repeat-sales occur disproportionately in areas where these attributes differ compared to the office stock as a whole. The correlation between planning restrictiveness by submarket and the realized returns of office properties within that submarket, if causal, has important implications. As argued by Cheshire (2005), to a large extent the current level of office prices in the United Kingdom is a product of the system of planning controls currently in force which effectively restrict supply.

Although other factors not examined here may be simultaneously causing bias in the repeat-sales index, when employment density changes and planning restrictiveness are controlled for, a Heckman's correction for unobserved sample heterogeneity loses its ability to explain index levels. These findings are consistent with the conjecture that employment density changes and development restrictiveness are the key external drivers of sample heterogeneity and bias. A further methodological contribution to this paper is that it may be enough to run a standard Heckman's correction when unrepresentative sample selection is only occurring in the second-sale. Although selection bias in employment density changes and planning restrictiveness were found to be statistically significant, the resulting price indices derived from them were not statistically different from the naïve repeat-sales index. Given their limited statistical power, even though these indices were not found to be statistically different, the absolute differences between them may still be practically important. Where these indices are used as performance benchmarks or in order to assess the cross-correlation of returns with respect to other assets for diversification purposes, accurate indices are essential to informed decision-making. If in future market actors attempt to produce a commercially viable repeat-sales index for the London office market, these findings may prove useful in informing market participants of its inherent limitations and in identifying fruitful directions that it may be improved.

The third paper expands upon the analysis of repeat-sales in the second by comparing seven different price index methodologies within the context of the London office market during the period 1998-2010. Given the dearth of transaction-based comparisons of commercial real estate and problems with the examples that do exist, this paper is able to expand and improve upon these previous investigations. In accord with previous research this paper finds that, in general, valuation indices suffer from problems of smoothing: lagging transaction-based indices with higher autocorrelations and lower standard deviations. This paper also finds that the desmoothing technique of Geltner (1993b) produces lead-lag relationships that are a surprisingly close analogue to transaction-based series but which appear to exaggerate actual price movements.

Real estate markets have been reluctant to adopt hedonic indices in commercial property often on the grounds that hedonic specification is too difficult and unreliable. However, this study has demonstrated that hedonic models of commercial real estate markets can not only be adequately specified, but if done so hedonics performs no worse than repeat-sales indices, and if anything is superior due to the sample sensitivity underlying both methods and the greater inclusivity of sales observations allowed by the hedonic methodology. On that note, both hedonic and repeat-sales indices are indeed found to be extremely sensitive to the sample of properties used, even when using sample sizes which would normally be considered sufficient. Although other markets may be more difficult to model with hedonics, this paper has introduced a technique for testing the acceptability of hedonic models of real estate prices by simultaneously comparing them with a repeat-sales index produced with a similar sample of properties. If the two indices so constructed are not essentially identical, one can justifiably infer that the hedonic model suffers from misspecification, and that any differences between the full sample results of these indices is due to sample selection bias.

Additional results from this paper include noting that the 3SLS procedure, conventionally used to correct for heteroskedasticity in repeat-sales regressions of housing produces a time-series for commercial offices which is indistinguishable from uncorrected OLS. Therefore it may be the case that repeat-sales indices of commercial offices do not exhibit the same degree of heteroskedasticity that is generally encountered in housing. In addition, this paper introduces an original fractional-time weighting procedure for repeat-sales that allows for simpler calculation of transformation-bias while maintaining a minimum of temporal aggregation bias. Other notable findings include the fact that, contrary to previous research, real estate securities in the UK follow the movements of London office property more closely than the stock market as a whole, and that the annual transaction-linked index is extremely similar to its underlying uncorrected valuation index. Given the material variation in the price-paths of the indices identified in this chapter, it is clear that researchers and investors should not rely on any single index methodology to provide them with a complete picture of market movements. Rather by comparing and contrasting several indices in concert the most accurate impression of historical market movements can be obtained.

The London office market is a fertile environment for studying empirical and practical issues of urban economics. Not only is it one of the world's most important property markets, but its rich history and array of market interventions suffuse research initiatives with intrigue and import. Until recently data limitations in this relatively private and closed market had precluded many such analyses. However thanks to a unique dataset assembled from several leading property firms and primary sources, this thesis was able to successfully address issues centred around asset performance within the London office market across three papers. Although by no means comprehensive, this foray into the London office market has at least shown potential for fruitful new discovery and it is hoped that subsequent research can benefit from and expand upon these preliminary findings.

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