Connected Markets through Global Real Estate Investments

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Abstract

One of the key features of the commercial real estate market of the late 1990s and the first decade of the twentieth century has been the rise of global private real estate investment. Private, institutional and listed real estate investors increasingly hold global real estate portfolios. This study focuses on the possibility of higher risk in the real estate markets due to the global investment network, which links the domestic and foreign markets by common real estate investors. The common holdings of properties in different local real estate markets forms the 'linked ownership' network. Based on transaction data from 2007 to 2016, our results show a significant co-movement in office market performance based on linked ownership between cities, even after controlling for rent and other office market performance drivers. The commonality in ownership outperforms other matrices constructed by geographic distance, openness, similarity, legal system, currency unit and even overlapping occupiers located in the cities. A one standard deviation negative office price shock in London is associated with an average of 0.94 percentage point decrease in each of the remaining 57 cities one quarter after that shock. The transmission mechanism is rapid and most pronounced during the global financial crisis period. Any adverse shocks to major office markets such as London could spread globally and be more serious than anticipated, certainly confounding diversification effects.

Keywords: Global Office Markets, Linked ownership, Co-movement.

JEL classification: R3, R12.

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I. Introduction

With financial globalization, international real estate investment has boomed. Private, institutional and listed real estate investors, such as occupational pension funds, insurance companies and sovereign wealth funds, increasingly hold global real estate portfolios by acquiring private real estate directly or through fund structures in multiple countries. For example, in 2015 over 10% of properties and over 30% of REITs held by CalPERS were international assets and over 50% of the properties held by TIAA Real Estate were located outside the U.S. Other large funds, such as CalSTRS and Blackstone, also held a significant proportion of their portfolios in global real estate. There has emerged a significant body of literature discussing the costs and benefits of investing internationally (Falkenback, 2009, Lizieri, 2009, Worzala and Sirmans, 2003, Lizieri et al., 2011, Lizieri and Pain, 2014, Newell et al., 2010).

This paper focuses on one specific network associated with global investment strategies – the network based on 'linked ownership' of properties. On the one hand, internationally diversified real estate investment strategies have become increasingly popular: Based on an MSCI survey, in 2013, 21% of US private commercial real estate investments were foreign investments (Aussant et al., 2014). In the City of London, foreign ownership rose from around 4% in the mid-1980s to 45% at 2006 and over 65% by 2014 (Lizieri and Kutsch, 2006, Lizieri and Mekic, 2017). On the other hand, those investments are dramatically concentrated in a small number of major cities and markets: RCA data shows that 67% of the value of major global office transactions 2007-2014 occurred in just 20 cities (Lizieri and Mekic, op cit.). As a result, the real estate in different cities and countries can be owned by the same investor or fund manager, forming a 'linked ownership' network. The 'linked ownership' network reflects the flow of international capital and creates invisible connections between cities, and may lead to co-movement in real estate markets, regardless of location for a number of reasons.

First, a large amount of capital inflow or outflow may destabilize the target markets and increase downside risk. Lizieri's (2009) Towers of Capital advances a model that suggests that there is an amplifying mechanism that comes from the intertwining of development markets, occupier markets, investment markets and financing markets but does not identify a clear transmission mechanism. Second, shocks between markets can be transmitted via those global real estate investments, as real estate portfolio holders in the market where the crisis initiates may undertake actions to liquidate their investments in other markets or face collateral write-downs, forcing down asset prices via contagion effects. This paper examines linked ownership as a mechanism for transmitting those shocks across markets: as far as we are aware, this is the first study to quantitatively investigate the co-movement of real estate markets due to the overlapping of property ownership

Focusing at the city level, we attempt to isolate the impact of this 'linked ownership' network on the commercial office markets of 58 global cities, while controlling for the different levels of rental growth, income growth, market transparency and economic structure. Our results show a significant co-movement in office market performance based on linked ownership between cities. The results remain robust when we control for the endogeneity by using instrumented weights. The commonality in ownership outperforms other matrices constructed by geographic distance, openness, similarity, legal system, currency unit and even the overlap of occupiers – for example, global firms located many of the cities. The ten most influential cites are London, Paris, New York, San Francisco, Los Angeles, Washington DC, Tokyo, Boston, Seattle and Seoul. A one standard deviation negative office price shock in London, for example, will generate a significant change in the remaining 57 cities by an average of 0.94 percentage point one quarter after the shock during the crisis period, with a maximum of 1.94 percent change in Dublin. The magnitude of the shock is determined by the extent of co-ownership. Given the large exposure of London to other cities in terms of commonality in ownership, any shock to London office market may have a global effect, reflecting the status of 'too-interconnected-to-fail' of London.

We believe this topic is important for investors who seek to hedge against market downturns and diversity risks in global markets. An in-depth understanding of the mechanisms driving co-movement can also help policy makers to limit the consequence during stressful periods. The rest of the paper is presented as follows: section 2 provides a discussion of theoretical underpinnings and a review of related research on this topic; section 3 describes the data; section 4 lays out the empirical strategy; the results are discussed section 5 followed by our concluding remarks in section 6.

II. Theoretical Context and Prior Literature

There are a number of theoretical and empirical grounds for investors to diversify their assets internationally. One important factor is that global property markets should not move in tandem, with spatially-fixed real estate prices being largely driven by local factors. Investing in a global portfolio, in theory, offers the ability to limit the impact of any property downturn in a specific country or region, improving ex ante risk adjusted returns. However, empirical evidence is mixed[1]. Some literature shows that an internationally diversified portfolio enables investors to achieve higher expected returns at lower risk (Del Casino, 1986, Sweeney, 1989, D'Arcy and Lee, 1998, Thomas and Lee, 2006). However, the benefits of diversification can be offset by higher risks, including currency risk (Worzala, 1994, Newell and Webb, 1996, Ziobrowski et al., 1997, Thomas and Lee, 2006); taxation risk (Newell and Worzala, 1995); barriers to international property investment (Lizieri and Finlay, 1995) and other costs (McAllister, 1999).

The trade-off between costs and benefits of diversification can be affected by the degree of interconnectedness or co-movement across international real estate markets. Although real estate markets, especially direct real estate investment markets, are generally more local and heterogeneous (Eichholtz, 1996, McAllister, 1999), co-movement may still occur across international real estate

[1] More evidence regarding the diversification benefits/costs are found in securitised real estate. For example, Eichholtz (1996), Conover et al. (2002), Liu and Mei (1998) and many others show that an internationally diversified portfolio of real estate securities enables investors to achieve higher expected returns at lower risk. However, Liu et al. (1997) and Stevenson (2000) find no significant gains from extending a REIT portfolio into international markets.

markets, both in private and public markets, due to global factors (Ling and Naranjo, 2002), international economic variables (Quan and Titman, 1999, Bardhan et al., 2008) the convergence and integration in (European) real estate markets (Lizieri et al., 2003), interconnectedness across market via factors that include migration (Holly et al., 2011), cross-border investing and capital flows (Zhu and Milcheva, 2016, Milcheva and Zhu, 2017, Milcheva and Zhu, 2016)

Lizieri utilises the concept of a ‘world city network’ in his book ‘Towers of Capital’ (Lizieri, 2009, Lizieri and Pain, 2014). Spatial clustering of global financial business occurs in a small number of major cities – the international financial centres (IFCs), acting as coordinating centres for an interlinked system of international financial flows (Firedmann, 1986, Lizieri and Pain, 2014). In these world cities, there exists an interlocking of occupation, ownership and finance: firms that occupy space are often the same firms that acquire offices as investment assets and which provide finance for the creation of new office space. Shocks in international financial markets are transmitted to occupier, investment and debt markets and can reinforce any tendency towards cyclical behaviour[2]. This potential volatility can further be transmitted internationally via the globalization of real estate ownership. Globalization of financial activity has led to increasing functional specialization in IFCs, with many domestic-focused firms squeezed out of the occupier market by international financial and linked business and professional services firms who together articulate global transactions and flows of finance.

Additionally, globalization of ownership also means that professional investors based in one IFC typically have exposure to real estate assets in other IFCs. Innovations in real estate investment make it easier to acquire a global real estate portfolio, with capital from a range of investors pooled to acquire

[2] IFCs satisfy Grenadier (1996) criteria for the existence of property cycles: an undiversified employment structure, long lags between starts and completions in development, and barriers to entry for developers due to scale of investment required.

prime real estate assets. Such interconnectedness built by the globalization of ownership – the 'linked ownership' network – connects different IFCs and can reinforce systemic risks across global real estate markets.

So far as are aware, there is no empirical study that explicitly investigates the overlapping of ownership across markets and its implication for real estate markets. However, previous literature does find evidence that external capital flows can affect local markets. For example, Stein (1995) and Cauley and Pavlov (2002) find a contemporaneous and self-reinforcing relationship between real estate price and trading volume in US housing markets. At aggregate national level, Fisher et al. (2009) show that institutional capital flows have a statistically and economically significant association with subsequent returns in U.S. markets, implying a 'price pressure channel'. However, such an effect is not found using UK data (Ling et al., 2009). Chervachidze and Wheaton (2013) focus on availability of debt (debt flow) as a driver of capitalization, finding that changes in debt availability at the national level have significant effects on capitalization rates, implying capital inflows can affect local real estate market performance.

Besides the aforementioned literature on capital flows to individual markets, prior studies on listed real estate securities also show that networks based on trade or foreign direct investment (FDI) can result in co-movement in asset prices across markets. For instance, Zhu and Milcheva (2016) investigate co-movement in the stock return index of real estate companies and find contagion triggered by aggregate FDI between countries during the financial crisis. Hoesli and Reka (2015) show that, in addition to portfolio rebalancing, investors' sentiment and liquidity correlation can also result in contagion between securitized real estate markets and financial markets internationally.

Most research on real estate market co-movement is, however, focused on public listed real estate markets and at the aggregate national level. The conclusions drawn by analyses of national public real estate markets may not be applicable to local, city-level private real estate markets. First, as local commercial real estate markets are relatively heterogeneous, the behavior of country level aggregate indices may not map onto the performance of urban real estate markets. Second, country level FDI flow is not a precise proxy of real estate capital flows. There has been limited work at city level examining concentration of flows, correlation and performance, but that has largely been confined to office markets and focused on global financial centers (e.g., Jackson et al. (2008); Lizieri and Pain (2014) which, as global investors seek new markets and sectors, needs to be extended. Third, as compared to public real estate markets, private real estate markets are less transparent and more illiquid with much higher transaction costs. Using city level office market performance data, pioneering work by Füss and Ruf (2017) shows that the co-movement of office market performance can be explained by commonality of banks that locates in those cities, weighted by the systemic capital shortfalls for those banks. This paper proposes a different channel to theirs, that is, the linkages built upon linked ownership of assets across markets.

III. Methodology

A. The 'Linked Ownership' Network

Our office transaction data shows that 1) a significant proportion of office transactions are international; 2) most of the transactions are concentrated in a small number of cities in the world. Therefore, it is likely that there will be an overlap of ownership of offices between cities, even across countries. We define linked ownership as where a single real estate owner or fund manager owns real estate in two cities. The greater the extent of co-ownership in a pair of cities, the more they are "linked by ownership". This overlap in ownership creates interconnectedness between cities, in addition to traditional linkages such as distance and functional linkages through occupation and head office – branch office networks of the type investigated by the Globalisation and World Cities research network (GaWC).

Such a linked ownership network reflects the flow of capital and could potentially affect real estate market performance within and across markets. For example, if a real estate investor suffers losses in value in one city, this may lead to forced sales of their assets in another city, or lead to analysts marking down asset values in those cities due to concerns about asset quality or the validity of appraisals[3]. If that investor is leveraged at portfolio level, then the damage to collateral and loan to value ratios may lead to adverse action by lenders or asset liquidation, creating market and funding liquidity spiral effects of the type identified by Brunnermeier and Pedersen (2009). With a greater degree of ownership inter-connectedness between cities, there is a greater risk of contagion effects.

The concept of ownership is not without definitional problems. A global asset manager may be offering a number of real estate funds, each of which have multiple sources of equity. That asset manager would be defined as the building owner. It could be argued that if one such fund gets into difficulty, it is the end investors that suffer rather than the fund manager: and that other funds may be unaffected and not suffer sales pressure. It seems to us, however, that there are still likely to be spillover effects, for example on the ability to refinance or raise new debt and equity and on external valuations of fund value and performance benchmarking[4]. Joint ownership of properties, for example through limited partnerships, causes further issues, not least as shares of ownership and responsibilities are not always transparent. These are important nuances, but the general principle should still apply[5].

Another concern is that firms may purchase offices not for investment purpose, but use them as their headquarter or branches. Therefore, the revenue of the firm is unrelated to the office market performance. We argue that as offices are part of the tangible assets, the total asset value (especially for small firms) of the firm can still be affected by the performance of the underlying office market. The liquidity issue or the

[3] This has resonances in the arguments of Kaminsky *et al.* (2003) on financial contagion across markets.

[4] As an example, consider contagion effects across separate global funds offered by the same fund manager during the global financial crisis with debt and collateral write-downs in one fund triggered by problems in another, possibly with different investor base and market exposure.

[5] We are grateful for the helpful discussion with our RERI mentors on this point. We would note that the “fund manager” effect would reduce the likelihood of finding common patterns: if they were found, this would strengthen the result.

uncertainty in the office market may force firms to sale and leaseback their headquarters/branches. Nevertheless, we agree that large international firms may be not seriously affected. For this purpose, we checked those office transactions made by Fortune 500 firms in our sample (excluding CBRE and JLL). The average share of transaction in value is only 3.89%. In 2007, the share was 5.84%, but it dropped to only 0.67% in 2009. In 2015, the share rose to 5.06%. The weight matrix remains completely robust after we exclude transactions purchased by Fortune 500 companies.

We use the following rules to identify the 'linked ownership' network between city A and B. In general, the weight is based on the proportion of the properties located in the two cities that are owned by the same investors:

$$w_{i,j,t} = \frac{1}{L_t} \sum_{h=1}^{L_t} q_{i.l,j,h,t}, \quad (1)$$

with $l = 1,2,..L_t$ and L_t is the total number of properties in city i. $j = 1,2,..H_t$ and H_t is the total number of properties in city *j* at period t. $q_{i.l,j,t}$ is a dummy variable with value of 1 if property *l* in city *i* and property *h* in city *j* owned by the same investors, and 0 otherwise:

$$q_{i.l,j,h,t} = \begin{cases} 1 & if\ property\ l\ in\ city\ i\ and\ property\ h\ in\ city\ j\ owned\ by\ the\ same\ investor \\ 0 & otherwise \end{cases}, \quad (2)$$

A complete index would require a full ownership census for all the cities being assessed, which is not currently feasible. Instead we examine patterns of linked ownership from a time series of transactions in a wide range of global markets as a proxy for overall ownership.

Figure 1: Construction of the spatial weights between each pair of real estate companies

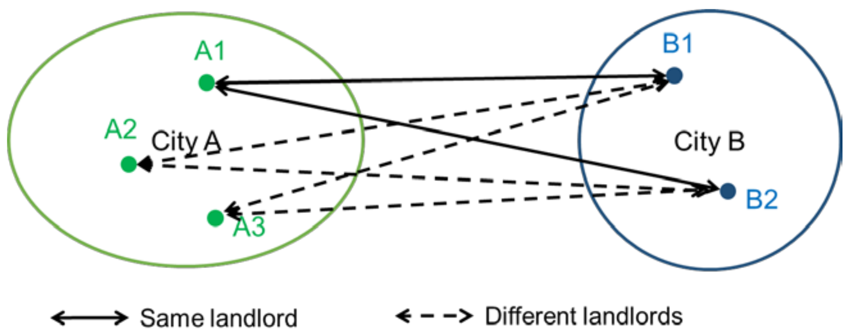


Figure 1 shows an example of how the overlap ratio between city A and B is calculated based on the individual ownership between a pair of properties from the distinct cities. Let us assume that three properties locate in city A, A1, A2 and A3, and two properties are in city B, B1 and B2. The solid lines denote that the pair of properties are owned by the same landlord, and dashed lines implies that they are owned by different investors. Among the six pairs of properties, A1 is acquired by the same investors as property B1 and B2, therefore there are two solid lines. So $\sum_{l=1}^{L_t} q_{i.l,j,h,t} = 1$. As $L_t = 3$, $w_{i,j,t} = \frac{1}{L_t} \sum_{l=1}^{L_t} q_{i.l,j,h,t} = \frac{1}{3}$. In the same way, $\sum_{h=1}^{H_t} q_{j,h,i,l,t} = 2$. As $H_t = 2$, we have $w_{j,i,t} = \frac{1}{H_t} \sum_{h=1}^{H_t} q_{j,h,i,l,t} = 1$. If the weight is 0, it implies that none of the properties between the two cities is owned by the same investor. If the weight is 1, it implies that all properties of one city are owned by the same investors as the corresponding counterparty[6]. As an intuitive interpretation, one third of the properties in city A are owned by investors with an interest in City B; all the properties in city B are owned by an investor with an interest in city A. Thus the measure is asymmetric between pairs of cities. In terms of cross-city transmission, a shock in city A is likely to have more of an impact in city B than a shock in city B is on city A (where two thirds of the properties are held by investors with no stake in B).

[6] We allow for turnover in portfolio holdings in our analysis, since the ownership linkage between cities is recalculated on a periodic basis. While private real estate holding periods tend to be relatively long, it is possible that finite life funds will enter a city and subsequently liquidate their holdings within our sample period.

B. Determinants of the 'Linked ownership Network'

We have a gravity model to explain the overlap in ownership between cities (*i* and *j*), which takes the form of

$$w_{i,j} = G\frac{M_i^{\beta_1} M_j^{\beta_2}}{D_{i,j}^{\beta_3}}, \tag{3}$$

where $w_{i,j}$ is overlap ratio between city i and j. G is a constant and M is a vector of the economic mass of each city. We consider city level GDP, unemployment rate, population yield and vacancy as well as national level exchange rate, stock market performance, CPI and interest rate. D is the distance between city i and j. We consider not only geographic distance, but also cultural affinity, legal system and currency unit, openness policy as well as commonality of occupiers – global firms. Equation (3) is solved by quasi-maximum likelihood estimate.

C. Impact of 'Linked ownership Network' on the Co-movement of Office Markets

In order to quantify the relationship between ownership overlap and co-movement in international office markets, we apply a spatial panel regression[7]:

$$y_t = \rho W_t y_t + \varphi y_{t-1} + X_t \gamma + Z_t \delta + D\alpha + u_t, \tag{4}$$

where y_t is the change in office price over time t for each the 58 cities in our sample. W_t is a time varying weight matrix, and ρ is the spatial dependence coefficient. We also consider a set of city-specific variables, such as vacancy rate, GDP, population, unemployment rate, and global financial status, a set of country specific variables, such as credit supply, interest rate, stock market performance and CPI. In order to control for global co-movement, we also include global variables, including oil price change and VIX change. D stands for city and year dummies. The spatial panel regression is solved using IV estimation for spatial models (Kelejian and Prucha; 1998)

[7] We also use Spatial Durbin model to measure the spatial dependence. The results in terms of impulse response and spatial dependence intensity are quite robust. Detailed results are in Appendix 1.

It should be noted that, in the above model, the parameters associated with the city and country specific variables (γ) capture only the average immediate effects of changes in the explanatory variables on the returns of that country, and do not account for direct and indirect spillover effects. The coefficients that capture those effects are called the marginal coefficients (Kelejian et al., 2006)[8]. The marginal effects thus need to be calculated. Assuming that the infinite sums are well-defined, by continuous substitution, Equation (4) can be represented as:

$$y_t = \sum_{p=0}^{\infty} A_{t-p}^{p} V_{t-p}(X_t\gamma + Z_t\delta + D\alpha + u_t), \tag{5}$$

where $V_t = (I - \rho W_t)^{-1}$, and $A_t = \varphi(I - \rho W_t)^{-1}$. Since $(I - \rho W_t)^{-1} = I + \rho W_t + \rho^2 W_t^2 + \rho^3 W_t^3 + \cdots$, Equation (4) implies a spatial multiplier effect (Anselin, 2006; LeSage and Pace, 2009). Any changes in the variables or unexpected shocks in one country will also affect the remaining countries through the spatial relationship among the countries. Not only do the first order 'neighbours', ρW_t, get affected (the direct spillover effect), but the 'neighbour's neighbours' are also impacted through that spatial multiplier effect through$\rho^2 W_t^2$, $\rho^3 W_t^3$, etc. (the indirect spillover effect). Ultimately, the change can create a feedback effect for the country of origin of the shock.

The average impulse response in the next P periods after the shock over the observation period is calculated as (following Pesaran and Shin, 1998):

$$\begin{bmatrix} \Psi_{1,1,P} \\ \vdots \\ \Psi_{1,1,P} \end{bmatrix} = \frac{1}{T} \sum_{t=1}^{T} \sum_{p=0}^{P} A_{t+p}^{P} V_{t+p} \Omega_e \begin{bmatrix} \sigma_1^{-1} \\ \vdots \\ 0 \end{bmatrix}, \tag{6}$$

where σ_1^{-1} is the standard deviation related to the error of the shock variable. $\Psi_{1,1,P}$is the response of the

[8] Similarly, the values of the parameter vector λ should be interpreted as immediate effects of changes in the foreign country variables on the returns in the domestic country.

office market in the jth country to the shock in the country 1. Since Ω_e is assumed to be a diagonal matrix – i.e. the error terms are independent from each other – the cross-border transmission of a country-specific shock entirely occurs through the spatial structure of V. Based on Equation (6), the average spillover effect of a one unit office market shock in the ith country in period P is:

$$\Psi_{i,P}^{imp} = \frac{1}{N-1} \sum_{j=1, j\neq i}^{N} \Psi_{i,j,P} \tag{7}$$

The average response of the ith country in period P to a foreign country shock is:

$$\Psi_{i,P}^{res} = \frac{1}{N-1} \sum_{j=1, j\neq i}^{N} \Psi_{j,i,P}. \tag{8}$$

IV. Data

A. Office Transactions Between 2007 and 2016

Data for major global office transactions were supplied by Real Capital Analytics (RCA). We collected 16,576 real estate transactions between 2007 and 2016, located over 210 cities and 57 countries. Over 80% of transactions are concentrated in the largest 58 cities, which are all included in our sample[9]. Figure 2 shows the location of these 58 cities along with their transaction volume. The value of the transactions in a city is illustrated by the radius of the circle: the larger the circle, the more acquisitions are made in the city. The largest circle is for London, with a share of 11.5% of the total value of major office transactions recorded by RCA. New York is the second largest market in terms of office transactions, with a 10% share. Tokyo is ranked as the third with a share of 6% (thus the three largest cities account for over a quarter of large commercial transactions, confirming the findings of Lizieri & Pain, 2014).

[9] We note that since our data has a minimum size constraint, this will somewhat bias our sample towards larger markets (and larger, professional, investors). However, the concentration figures reported here are consistent with those of other authors. Appendix 1 reports the name, country and the share of the share of transactions by value for each city.

Figure 3 shows the share of transactions by value of the ten largest markets over the period between 2007 and 2016: two European cities (London and Paris), four Asian cities (Tokyo, Shanghai, Seoul and Singapore) and four US cities (New York, San Francisco, Washington DC and Los Angeles). These ten markets account for over 51% of total major transactions recorded in RCA. The two biggest markets in terms of office building transactions in North American are New York Metro and San Francisco Metro; the two largest in Europe are London and Paris; Tokyo and Shanghai are the two biggest markets in Asia.

Figure 2: Transaction volume of 58 Cities, average over 2007 to 2016.

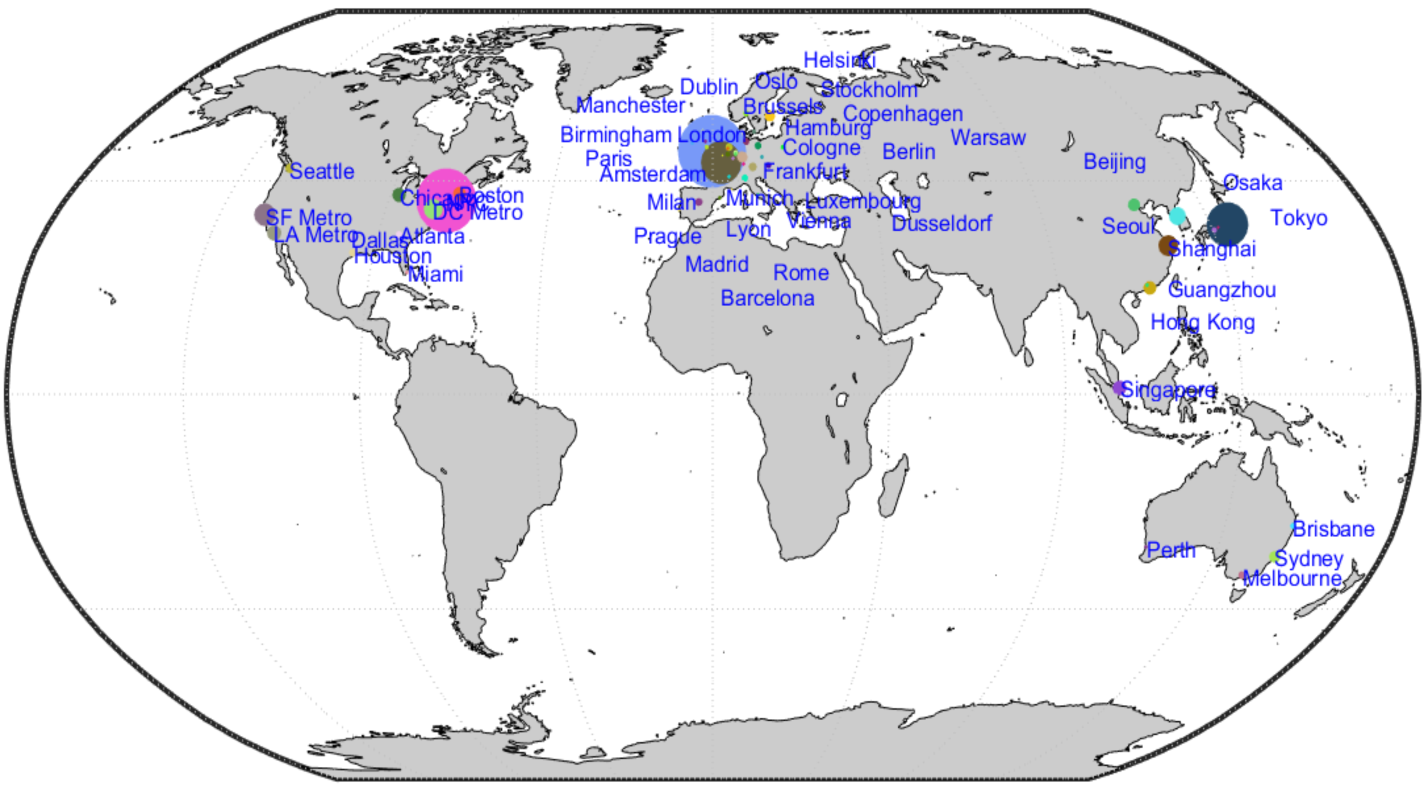
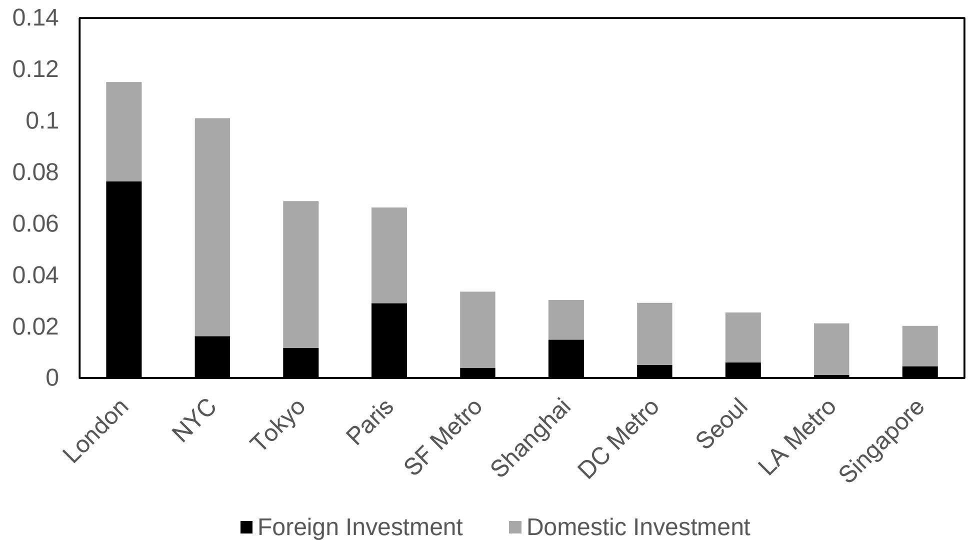


Figure 3: Share of Transactions in Value in Ten Largest Office Markets (mean activity over 2007 to 2016)
Source: © Real Capital Analytics Inc.



Among those transactions, foreign capital plays a remarkable role. On average, for the 58 cities, 38% of the transactions are acquisitions by foreign investors. In the ten largest cities by activity, foreign investors contributed up to 35% of the capital. With such significant foreign capital inflows into their office markets, it is likely that there will be properties in any two cities in different countries that are owned by the same investor. Figure 3 additionally splits the acquisition value between domestic and foreign investors. London has the largest foreign investment share, amounting to 66% (consistent with the findings of Lizieri and Mekic, 2018), followed by Shanghai (49%) and Paris (42%). By contrast the four largest U.S. cities by transaction value, LA metro, Boston Area, SF metro and DC metro, show a low share of foreign investment. In LA, only 5% of the RCA office transactions were purchased by foreigners over the period of 2007 to 2016.

Of the 16,576 office transactions, U.S. investors are the largest buyer, acquiring over 30% of the properties in the database. Investors from two Asian countries, Japan and China (mainland, excluding Hong Kong SAR), are the next two most active buyers. They own 5% and 3% of the transacted offices, respectively. As shown in Figure 4, American investors were more focussed on domestic deals. 75% of their office acquisitions were located in the United States (only partially a function of size of market). Japanese investors are even more domestic oriented, with 90% of their investments within their own country. Chinese (mainland, excluding Hong Kong SAR) investors also mainly focused their domestic market, with 75% of domestic investment, perhaps due to constraints on export of capital and the action of state-owned enterprises as investors. Singapore, Hong Kong and German investors have a greater propensity to acquire outside their own markets with over 55% of their investments located internationally. Overall, a significant proportion of transactions in the database are global in nature, with the effects of the global financial crisis receding as cross-border investment returns to pre-crash levels.

Figure 4: Share of transactions in value recorded by RCA by largest ten countries (average over 2007 to 2016)

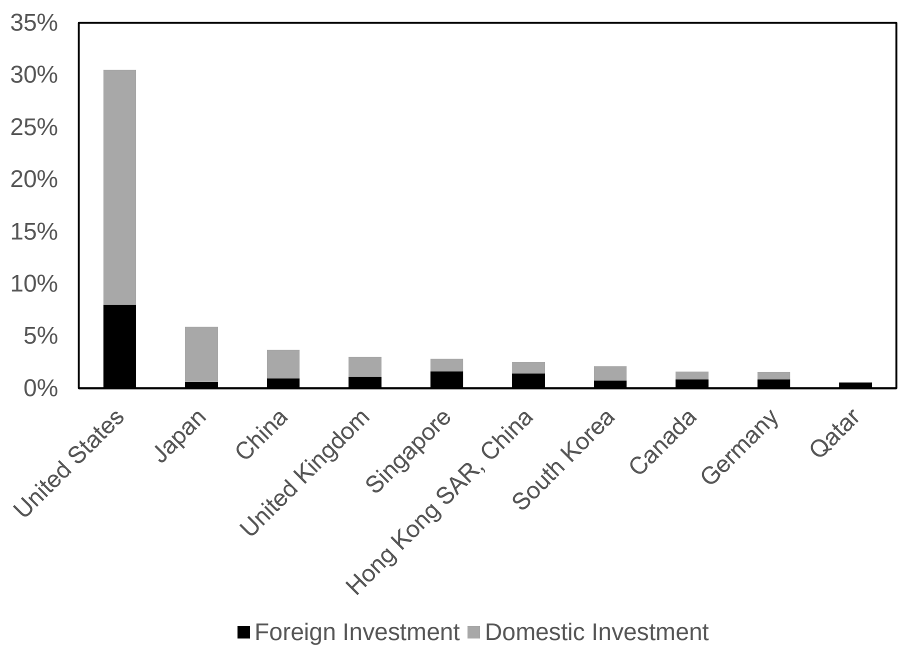


Figure 5 visualises the average overlap of ownership across the 58 cities over the period 2007 to 2016. The overlap ratio is between 0 and 1. The higher the overlap ratio, the darker the cell is. Nearly all cities are connected to *some* other cities, implying that there is obvious ownership interconnection between cities all over the world. There are two obvious clusters in terms of ownership overlapping. One is within the U.S. (LA metro, DC metro, NYC, Boston, SF metro) and the other is in Europe (London, Pairs, Frankfurt, Munich cluster). Besides, there is also significant cross-border overlap in ownership. Some are across countries, such as from London to Marseille (90.6%), from London to Lyon (69%), from Pairs to Düsseldorf (67.4%), from Paris to Frankfurt (67.1%), from Paris to Luxembourg (50.4%), from London to Rotterdam (51.2%), and some are even across continents, such as from Düsseldorf to Sydney (64.3%) , from New York to Sydney (62.4%), from New York to Hamburg (53.2%), from Huston to Melbourne (53%).

It should be noted that this graph is asymmetric by nature. For instance, the overlap ratio of London with Lyon is 7.52%, which means, 7.52% of the offices in London are owned by investors who also have asset exposure to Lyon. However, the overlap ratio of Lyon with London is 63.48%, which implies that 63.48% of offices in Lyon are acquired by investors who are also represented in the London office market. Although the total number of properties with linked owners is the same for the two pairs, given different market size of the two cities, the ratio is not the same.

As shown in Table 1, on average, 10% of office buildings have owners with interests in offices in the other cities. The maximum overlap ratio is 97%, which runs between San Francisco and Seattle. Second, cities within the same country tends to have higher overlap ratios, emphasising that geography and proximity still matter. The overlap ratio for cities within the same country is 38.7%, which is much higher than the overlap ratio for cross-border cities, which is just 8.6%. Third, larger cities tend to show higher overlap ratios. In Table 1, for the 10 largest office markets in terms of their transaction volume, the average overlap ratio is 11.8%; while for the 10 smallest markets, the average overlap ratio is only 6.7%. If we group the cities according to their GDP, the 10 cities with highest GDP have an average overlap ratio of 12.5% while the 10 cities with lowest GDP have a ratio of only 4.6%. Forth, cities with stronger competitiveness of financial centres exhibit slightly higher overlap ratios. If we sort the cities according to the Global Financial Centres Index (GFCI)[10], top financial centres have a higher overlap ratio than those ranked at the bottom.

[10] The GFCI index represents the global city index rank. The Global Financial Centres Index (GFCI) is a ranking of the competitiveness of financial centres published each year since 2007 by Z/Yen Group and based on over 29,000

Figure 5: Overlap ratio of ownership, average from 2007 to 2016

financial centre assessments from an online questionnaire together with over 100 indices from a variable database (The Long Finance Report).

Table 1: Ownership Overlap Ratio

	Mean	Std	Max	Min	75%	50%	25%
Average of 58 Cities	0.104	0.144	0.924	0	0.145	0.047	0
Within the same country	0.387	0.209	0.924	0	0.531	0.394	0.233
Cross border	0.086	0.118	0.903	0	0.123	0.041	0.000
10 cities with highest transaction volume	0.118	0.176	0.930	0	0.161	0.043	0
10 cities with lowest transaction volume	0.067	0.151	1.000	0	0.049	0	0
10 cities with highest GDP	0.125	0.192	0.924	0	0.176	0.030	0
10 cities with lowest GDP	0.046	0.127	1.000	0	0.023	0	0
10 cities with highest GFCI ranking	0.110	0.174	1.000	0	0.138	0.031	0
10 cities with lowest GFCI ranking	0.104	0.180	0.924	0	0.128	0	0
10 largest office markets							
Overlap ratio of other 57 cities with the following cities							
London	0.232	0.201	0.907	0	0.364	0.182	0
New York	0.232	0.264	0.907	0	0.418	0.121	0
Tokyo	0.135	0.153	0.567	0	0.202	0.074	0
Paris	0.294	0.215	0.930	0	0.398	0.297	0
San Francisco	0.210	0.253	0.924	0	0.354	0.109	0
Shanghai	0.017	0.045	0.249	0	0.011	0.000	0
Washington	0.146	0.225	0.907	0	0.135	0.047	0
Seoul	0.080	0.126	0.447	0	0.081	0.017	0
Los Angeles	0.204	0.247	0.907	0	0.313	0.092	0
Singapore	0.057	0.078	0.295	0	0.088	0.021	0
Overlap ratio of the following cities with other 57 cities							
London	0.057	0.064	0.354	0	0.084	0.042	0
New York	0.053	0.079	0.323	0	0.079	0.018	0
Tokyo	0.052	0.063	0.355	0	0.073	0.042	0
Paris	0.080	0.083	0.409	0	0.107	0.057	0
San Francisco	0.142	0.192	0.676	0	0.174	0.050	0
Shanghai	0.038	0.080	0.461	0	0.069	0.000	0
Washington	0.097	0.183	0.730	0	0.068	0.015	0
Seoul	0.083	0.098	0.321	0	0.173	0.019	0
Los Angeles	0.072	0.131	0.476	0	0.045	0.008	0
Singapore	0.073	0.083	0.278	0	0.128	0.023	0

Table 1 also reports the overlap ratio for 10 biggest office markets in terms of transaction volumes. London, New York, Paris, San Francisco and Los Angeles have an overlap ratio over 20%. Paris has an average overlap ratio of 29%, which means, on average, in each of the remaining 57 cities, 29% of the properties have owners who also own at least one property in Paris. London has an overlap ratio of 23%, which means, 23% of the properties in each of the other 57 cities have owners with interest in London. It should be noted that although the average overlap ratio of other cities with Paris and London is higher than 20%, less than 10% of properties in Paris and London have owners with interest in other cities. This could be due to the large market size and high total transaction volume in London and Paris. Besides, cities like Paris and London are well diversified in terms of property owners and have significant domestic players headquartered there. They attract many investors from all over the world. So cities like London and Paris have a relatively low overlap ratio with other cities, but other cities have a high overlap ratio with them. By definition, then, the matrix is not symmetric.

Table 2: Degree of Centrality of the Cities

Note: the numbers reported are computed as $c_i = \frac{1}{N-1}\sum_{j=1, j\neq i}^{N} w_{i,j}$, *where* $w_{i,j}$ *is the proportion of properties in city i which are owned by investors who also invest in city j. For example, an average of 29.33% of the properties in the other 57 cities are owned by the investors who also own property in Paris.*

City	Centrality	City	Centrality	City	Centrality	City	Centrality
Paris	29.33%	Tokyo	13.70%	Prague	7.73%	Vienna	2.27%
London	23.62%	Boston	13.42%	Milan	7.60%	Lille	2.03%
NYC	23.61%	Chicago	13.30%	Madrid	6.13%	Copenhagen	1.85%
SF Metro	21.35%	Seattle	13.25%	Singapore	5.79%	Shanghai	1.70%
LA Metro	20.73%	Atlanta	13.02%	Stockholm	5.25%	Marseille	1.63%
Frankfurt	20.31%	Miami	12.55%	Rotterdam	4.40%	Oslo	1.45%
Dusseldorf	20.04%	Osaka	11.94%	Warsaw	4.37%	Budapest	0.73%
Munich	19.46%	Cologne	11.80%	Luxembourg	4.10%	Beijing	0.71%
Hamburg	19.30%	Sydney	10.67%	Birmingham	4.09%	Hong Kong	0.26%
Amsterdam	18.98%	Perth	9.28%	Edinburgh	4.08%	Rome	0.20%
Berlin	17.34%	Helsinki	8.87%	Barcelona	3.34%	Dublin	0.19%
Brussels	15.13%	Brisbane	8.76%	Manchester	3.28%	Nagoya	0.07%
Stuttgart	15.03%	Houston	8.70%	Glasgow	2.91%	Guangzhou	0.00%
DC Metro	14.84%	Melbourne	8.62%	Lisbon	2.82%		
Dallas	14.62%	Seoul	8.18%	Lyon	2.28%		

Table 2 reports the degree of centrality for the 58 cities. Paris has the highest level of overlap to other cities. An average of 29.33% of the properties in the other 57 cities are owned by the investors who are also invested in properties in Paris. New York and London are the second and third most highly connected cities.

Three U.S. cities (New York, San Francisco and Los Angeles) and four European cities (Paris, London, Frankfurt and Dusseldorf) have overlap ratios of over 20%. Asian cities, such as Beijing, Hong Kong, Shanghai and Guangzhou have a much lower connectivity.

B. **Office Market Data**

Our office market performance data come from Property Market Analysis LLP (PMA), which reports the performance of office market in 61 cities globally. After we removed missing data, 58 cities are left for analysis. Over the period 2007 to 2016, PMA report average annual price returns[11] of 2.8%, with a standard deviation of 20.8%. Rental growth rates average 2.1% annually, with a lower standard deviation. The average yield is 5.5% and the mean vacancy rate is 10.7%, reflecting the post-GFC difficulties.

The explanatory variables were collected from a variety of sources. The cultural index relies on Hofstede Scores which are obtained from Geert Hofstede's website and are designed to measure affinity across six distinct cultural dimensions[12]. The legal system is classified based on the following categories: Napoleonic, Germanic, Nordic, Anglo-American, Social, and Islamic law. Transparency is measured by use of JLL global real estate transparency ranking[13]. JLL ranks countries based on real estate transparency every two years. The transparency is quantified based on 139 variables relating to transaction processes, regulatory & legal frameworks, corporate governance, performance measurement and data availability. Higher ranking implies higher transparency, which is associated with stronger investors and corporate real estate activities.

[11] PMA's prime capital value estimates are based on transaction data on rents and cap rates which are used to value a representative synthetic building and are used for investment strategy and performance benchmarking by many large professional investors.

[12] These factors include assessments of a society's attitudes and responses with respect to issues of: 1) Power Distance, 2) Individualism versus Collectivism, 3) Masculinity versus Femininity, 4) Uncertainty Avoidance, 5) Long Term versus Short Term Orientation, and 6) Indulgence versus Restraint.

[13] Alternatively, we also use a measure of openness from the Heritage Foundation accounting for both trade and investment openness. Trade freedom is defined as "the absence of tariff and non-tariff barriers that affect imports and exports of goods and services" (The Heritage Foundation, 2014). Investment freedom is determined by the number of restrictions on foreign investment, such as restrictions on real estate purchases, foreign exchange and capital controls, different national treatment of foreign investment, bureaucracy, expropriation of investment, etc. The results remain robust.

We also collect the location of 100 global service firms (accountancy, advertising, banking/finance, insurance, law, and management consultancy) for each city. The data are from the GaWC database. Other city level variables such as GDP, unemployment rate, and population are from the World Bank database, for consistency and comparability. National level variables, such as interest rates, and exchange rates, are extracted from DataStream. Table 3 shows summary statistics.

Table 3: Summary Statistics of Variables

	Mean	Std	Max	Min	75%	50%	25%
Office Market Performance							
Price Growth (per quarter)	0.007	0.052	0.229	-0.404	0.030	0.003	-0.002
Rent Growth (per quarter)	0.003	0.031	0.189	-0.284	0.012	0.000	0.000
Yield	0.055	0.011	0.087	0.028	0.061	0.054	0.048
Vacancy Rate	10.704	4.728	23.325	0.575	14.125	10.325	7.050
Economic Fundamentals							
City Level							
Unemployment Rate	6.829	3.372	23.1	1.63	8.51	6.03	4.39
Log of Population	15.128	0.889	17.397	13.082	15.676	14.913	14.476
Log of GDP	10.752	0.438	11.491	8.894	10.983	10.800	10.588
Offices of 100 Global Firms	124	74	368	0	164	116	67
GFCI score	4.817	2.805	10	1	7	5	2
Country Level							
Log of CPI	4.761	0.331	5.481	4.377	4.776	4.605	4.567
Exchange Rate	25.839	145.196	1271	0.501	1.723	0.898	0.735
Log of Stock	6.845	0.972	9.537	3.880	7.358	6.967	6.547
Long-term rate	3.046	1.580	11.177	-0.0265	4.13	2.929	1.815
Transparency Rank	12.30	10.38	49	1	18	10	3
Geographic Location							
Log of Distance	8.232	1.241	9.837	3.550	9.140	8.881	7.122
Same Country	0.059	0.235	1	0	0	0	0
Cultural Index	7.214	6.170	31.833	0	11.833	5.333	2
Same Legal system	0.261	0.439	1	0	1	0	0

V. Results

A. Determinants of Linked Ownership

In the first stage of our analysis, we run a gravity model to explain the drivers of the overlap in ownership. The ownership overlap ratio is the dependent variable. The results are reported in Table 4. The signs of the significant parameters seem reasonable and intuitive. The ownership overlap ratio increases significantly with a drop in the geographic distance between pairs of cities. Being in the same country increases the likelihood of linked ownership. Apart from that, cultural similarity and similarity in investment and financial freedoms play a significant role in investors' locational investment decisions. Cities with stronger commonality in cultural and investment and finance policies tend to have higher overlap in the ownership of properties. The degree of overlap in the global firms established in the pair of cities is also highly related to commonality in ownership of properties, which provides support for the 'Towers of Capital' thesis (Lizieri, 2009, Lizieri and Pain, 2014). The spatial clustering of global financial business acts to create coordinating centres for an interlinked system of international financial flows (Friedmann, 1986, Lizieri and Pain, 2014).

Regarding push and pull factors, we find that cities with higher GDP, more population, lower interest rates and lower inflation tend to be more attractive to investors. Additionally, the exchange rate of local currency to US dollar also seems to affect ownership overlap. When the relative exchange rate decreases, the local market seems more attractive to the investors.

Table 4: Gravity Model

*Note: This table reports the gravity model estimated by quasi-maximum likelihood estimation. The dependent variable is the ownership overlap ratio. Independent variables include dummy variables for same country, same currency, same legal system, and difference in cultural, transparency rank for the countries of the two cities, city level GDP, unemployment rate and population. We report the standard error in brackets. ***, ** and * denotes 1%, 5% and 10% significance level, respectively.*

	Model 1: Gravity Model	
Constant	-21.77***	(1.252)
Log of Distance $_{i,j}$	-0.2462***	(0.0216)
Same Country $_{i,j}$	0.4820***	(0.0659)
Cultural Distance $_{i,j}$	-0.0482***	(0.0038)
Same Legal System $_{i,j}$	-0.0039	(0.0474)
Same Currency Unit	0.1010	(0.0626)
Overlap in Firms	0.8033***	(0.1313)
Transparency Distance	-7.7540***	(1.9765)
GFCI distance	-1.7692	(1.1190)
Yield $_{i,t}$	17.61***	(2.713)
Yield $_{j,t}$	-1.035	(2.774)
Vacancy $_{i,t}$	-0.0296***	(0.0047)
Vacancy $_{j,t}$	0.0009	(0.0052)
Unemployment $_{i,t}$	0.0014	(0.0060)
Unemployment $_{j,t}$	-0.0174**	(0.0064)
Log PoP $_{i,t}$	-0.0087	(0.0306)
Log PoP$_{j,t}$	0.5175***	(0.0265)
Log GDP $_{i,t}$	0.4229***	(0.0729)
Log GDP $_{j,t}$	1.1689***	(0.0802)
Exchange $_{i,t}$	-0.0002	(0.0002)
Exchange $_{j,t}$	-0.0001	(0.0001)
CPI $_{i,t}$	0.0845	(0.0876)
CPI $_{j,t}$	-0.5261***	(0.0816)
ir $_{i,t}$	0.0291	(0.0277)
ir $_{j,t}$	-0.0958***	(0.0301)
Log stock $_{i,t}$	-0.0197	(0.0177)
Log stock $_{j,t}$	-0.0316	(0.0191)
Year dummies	Yes	
Ave. no. of City	58	
No. of Period	10	
No. of Observations (Pair of Cities * Period)	33060	
Quasi-LL	-9928	

B. The Impact of Linked Ownership on Co-movement

In this section, we seek to explain the co-movement in capital returns across cities[14]. Model 2 is a panel model without a spatial term, while Models 3, 4 and 5 regress real estate capital returns on the change in returns of 'connected' cities. The weights capture the spatial linkages between each pair of office returns using the ratio of properties owned by the same landlord in each pair of cities. Model 3 includes only one matrix. In Model 4, we use three weight matrices. Matrix one includes only cities with overlap ratios larger than 15%. That means, each weight between a pair of cities has at least 15% of properties that are owned by the same owner. If the overlap ratio is below 15%, the weights are set as zero. Matrix two is defined in the same way as matrix one. The only difference is that the weight includes cities with overlap ratio between 15% and 4%. If the overlap ratio is above 15% or below 4%, the weight between the two cities is set as zero. In the same way, we define matrix three as before but with the overlap ratio less than 5%. In other words, if the overlap ratio is less than 5%, the weight is defined according to the overlap ratio; otherwise, the weight is set as zero.

We see that the spatial coefficient is significantly positive and takes the value of 0.56 in model 3. It means that spatial linkages in the ownership of properties across cities significantly drive the co-movement in real estate performance, controlling for global factors, national factors as well as city-specific characteristics. Model 3 also achieves higher adjusted R^2 and lower BIC than the model without spatial consideration (Model 2), confirming significant spatial dependence in the office market performance.

In Model 4, the matrix based on ownership overlap ratios higher than 15% has the highest coefficient, which is 0.31. When the overlap ratio is lower than 15%, the spatial dependence coefficient drops to 0.091, which

[14] We also used total return as an alternative measure of office market performance, as shown in Appendix 2. The results are quite robust. When the income return is also accounted for, the spatial dependence coefficient becomes larger. The reason could be co-movement in rental demand from common occupation. Given the fact that capital value moves explain a very high proportion of volatility in total returns, our baseline models still use appreciation return as the dependent variable.

is statistically significantly smaller than the weight with a higher overlap ratio. The decrease in the spatial dependence intensity with different overlap ratios implies that the co-movement in the office market performance declines with decreasing overlap ratio. From an investment perspective, this implies that diversification benefits will be greater in markets with lower levels of linked ownership.

In all these models, we control for drivers of office market performance at city, national and global levels. The control variables have the expected signs, but not all of them are significant. In Model 2, we can see that lagged capital returns have a significant effect on current performance, confirming the stickiness of property prices. A one percentage point increase in the previous return would lead to an increase in the price in the next period by 0.13 percentage points, economically as well as statistically significant. As expected, office returns are significantly positively related to rent growth. At the city level, the unemployment rate has a significant negative impact on price changes[15]. The return in office markets also increases with local stock market performance, demonstrating common movement between different asset classes, as might be expected given the cyclical events experienced over the time-span of the dataset employed.

In this paper, we also investigate whether the spatial dependence changes during times of market distress. During the GFC, co-movement may increase due to the drying up of the liquidity, resulting in contagion effects. Because of the relatively short crisis period, we decided not to split the data and not to run the model separately in each phase. Instead, we allow for time-varying spatial linkages. It should be noted that we have allowed the spatial weights to change over time; therefore, the increase in the coefficient is purely due to the increase in the intensity, rather than to change in the weight itself. Specifically, we use a logit nonlinear smooth transition process (van Dijk et al., 2002) to analyse whether the spatial coefficient changes

[15] We would note that these are short-run impacts and there is limited empirical evidence that economic growth variables have a long run effect on real estate rents and values.

significantly during the 2007–2009 financial crisis[16]. Compared with the simple dummy variable approach, the smooth transition process allows for more efficient regime switches from one phase to another. Incorporating these modifications, Equation (4) becomes:

$$y_t = \rho_t W_t y_t + \varphi y_{t-1} + X_t\gamma + Z_t\delta + D\alpha + u_t,$$

$$\rho_t = \rho + \rho_p\left(1 - \frac{\exp(t-p)}{1+\exp(t-p)}\right), \tag{9}$$

where ρ is the coefficient of spatial dependence in the normal period and ρ_p captures the change of the coefficient in the crisis period from 2007Q1 to 2009Q2. The results are shown in Model 6 Table 4. During the crisis period, the spatial coefficient rises from 0,12 to 0.70. The increase is both statistically and economically significant, implying the contagion effect during the crisis. The results confirm that the spillover effect becomes more serious over the period with low market liquidity and strong capital shortfall.

[16] It was suggested to us that real estate reacted more slowly to the GFC and that the crisis phase should be pushed backwards to as late as 2010. While some markets (notably the US) did fall late, some of this was an appraisal effect masking earlier falls, alongside possible client pressure (Crosby et al., 2018). In the UK, the IPD (valuation-based) capital value index peaked in July 2007 and fell 11% by year end and a further 10% in H1 2008; by Q3 2010 it was recovering. IPD/MSCI appraisal-based figures show falls in many countries (including the US, contrasting with NCREIF) in 2008. REIT indices around the world fell very substantially in 2008, given further confirmation to our periodization.

Table 5: Spatial Panel Regressions

	Model 2: Panel Model	Model 3: Spatial Panel Model	Model 4: Spatial Panel Model + Distance Decay Model	Model 5: Spatial Panel Model + Phase Dependent Co-movement
ρ		0.4777***		
		(0.0561)		
ρ (overlap > 15%)			0.3136***	
			(0.0376)	
ρ (15% >overlap > 4%)			0.0942*	
			(0.0528)	
ρ (overlap < 4%)			0.0931*	
			(0.0481)	
ρ_tranquil				0.1235*
				(0.0693)
ρ_crisis				0.5761***
				(0.0792)
Δ Log Price t-1	0.1850***	0.1299***	0.1271***	0.1328***
	(0.0181)	(0.0187)	(0.0186)	(0.0187)
Δ Log Rent	0.8302***	0.8321***	0.8453***	0.8090***
	(0.0289)	(0.0284)	(0.0286)	(0.0284)
Δ Log Population	0.0409	0.0370	0.1179	0.0782
	(0.1949)	(0.1910)	(0.1914)	(0.1898)
Δ Unemployment rate	-0.0029***	-0.0037***	-0.0039***	-0.0043***
	(0.0009)	(0.0009)	(0.0009)	(0.0009)
Δ Log GDP	0.0144	0.0273	0.0311	0.0382
	(0.0321)	(0.0315)	(0.0315)	(0.0313)
Δ Vacancy	-0.0011*	-0.0005	-0.0004	-0.0004
	(0.0006)	(0.0006)	(0.0006)	(0.0006)
GICS	0.0040	0.0048	0.0055	0.0052
	(0.0043)	(0.0043)	(0.0043)	(0.0042)
Δ Long-term Rate	0.0002	0.0020	0.0018	-0.0001
	(0.0017)	(0.0017)	(0.0017)	(0.0017)
Δ log CPI	-0.0860	0.0244	0.0074	-0.0634
	(0.1481)	(0.1456)	(0.1454)	(0.1450)
Δ exchange rate	-0.0001	-0.0001	-0.0001	-0.0001
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Δ Log stock	0.0614***	0.0235**	0.0282***	0.0218*
	(0.0106)	(0.0111)	(0.0109)	(0.0112)
Δ oil	0.0047	0.0055	0.0062	0.0006
	(0.0078)	(0.0076)	(0.0076)	(0.0076)
Δ VIX	0.0006	0.0004	0.0028	-0.0028
	(0.0077)	(0.0075)	(0.0075)	(0.0075)
City dummies	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes
Ave. no. of City	58	58	58	58
No. of Period	39	39	39	39
No. of Observations (Pair of Cities * Period)	2204	2204	2204	2204
Adj. R^2	0.5769	0.5936	0.5958	0.5988

Note: This table reports the spatial panel model using IV estimation using the instruments proposed by (Kelejian and Prucha 1998). The dependent variable in model 2, 3, 4 and 5 is the return of office price. Model 6 uses total return as the dependent variable. ρ is the spatial dependence coefficient. W is constructed using the linked ownership ratio.

*Control variables include change in lagged return, change in population, change in unemployment rate, change in GDP, change in long-term interest rate, change in CPI, change in credit supply, global financial center rank, vacancy rate, change in exchange rate, global oil price change and change in VIX index. Population, unemployment rate, GDP, global financial center score, vacancy rate are at city level. Interest rate, CPI, credit supply, exchange rate are at national level. Oil price and VIX are at the global level. We report standard errors in brackets. ***, ** and * denotes 1%, 5% and 10% significance level, respectively.*

C. Robustness Analyses

In order to make sure that physical distance is the best way to capture the relationships in the companies and that the spatial weight matrix does not capture other linkages or global co-movements, we add into our spatial panel model an alternative weight matrix. We construct additional weight matrices based on distance; on cultural similarity; whether the two cities are in the same country, whether the two cities have the same legal system as well as similarity in investment and financial policy. As Lizieri and Pain (2014) and Füss and Ruf (2017) show, the performance of office markets can also be connected via their ‘common occupiers’. Cities can also be connected by global firms that have affiliates all over the world. Therefore, we also consider the network based on the overlap of financial firms between each pair of cities. In the spirit of GaWC, but using the location of 100 leading firms in accounting, banking, financial, advertisement and other firms, we construct a weight matrix according to the proportion of same bank or the same financial insurance company between pairs of cities. In this way, we control for the inter-connectedness by global financial firms. Thus, Equation (4) becomes:

$$y_t = \rho W_t y_t + \rho_{alternative} W_t^{alternative} y_t + \varphi y_{t-1} + X_t \gamma + Z_t \delta + D\alpha + u_t, \tag{10}$$

The results are reported in Table 5. In all cases, the spatial dependence coefficient triggered by linked ownership remains significant, ranging from 0.3444 to 0.5032. With the exception of the weight matrix constructed based on distance, all other coefficients are insignificant. This shows that the linked ownership is not simply capturing other linkages between the cities such as similarity in culture or similarity in investment and financial regulations. Our measure of the ownership network between cities does a good job in capturing co-movements when compared to more commonly used spatial measures. Importantly, the network effects driven by linked ownership of office buildings plays a more important role in explaining co-movement of office market performance than those networks built on the occupiers of the buildings – the global firms occupying space in world cities. By implication, contagion effects from capital pressures on owners of buildings in multiple cities can affect the office market performance in a more direct way than effects that come from common performance drivers affecting the business of tenants of buildings across cities.

Table 5: Spatial Panel Regression with Alternative Matrix

*Note: This table reports results from the spatial panel model using IV estimate. The dependent variable is the return on office prices. ρ is the spatial dependence coefficient. The first W(ρ) is constructed using the linked ownership ratio. The alternative weight matrix is constructed based on distance (model 7), similar in culture (model 8), same legal system (Model 9), same currency unit (Model 10), similarity in real estate transparency (Model 11) and overlap in 100 global firms (Model 12). Control variables include change in lagged return, change in population, change in unemployment rate, change in GDP, change in long-term interest rate, change in CPI, change in credit supply, global financial center rank, vacancy rate, change in exchange rate, global oil price change and change in VIX index. Population, unemployment rate, GDP, global financial center score, vacancy rate are at city level. Interest rate, CPI, credit supply, and exchange rates are at national level. Oil price and VIX are at global level. We report standard error in brackets. ***, ** and * denotes 1%, 5% and 10% significance level, respectively.*

	Model 6: Distance	Model 7: Same Country	Model 8: Similar Cultural	Model 9: Same Legal system	Model 10: Same Currency Unit	Model 11: Similar Transparency	Model 12: Overlap in 100 Global Firms
ρ	0.3674***	0.3782***	0.4236***	0.5032***	0.4587***	0.3444***	0.4358***
	(0.0741)	(0.0633)	(0.0781)	(0.0620)	(0.0703)	(0.0861)	(0.0815)
ρ_distance	0.1598*						
	(0.0938)						
ρ_country		-0.0272					
		(0.0604)					
ρ_cultural			0.0454				
			(0.1031)				
ρ_currency				-0.1020			
				(0.1539)			
ρ_legal					-0.0228		
					(0.0770)		
ρ_open						0.1741	
						(0.1128)	
ρ_same firm							0.0197
							(0.1074)
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes
City dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adj. R^2	0.5909	0.5922	0.5902	0.5972	0.5902	0.5893	0.5903
Adj. R^2_alternative	0.5890	0.5901	0.5827	0.5817	0.5768	0.5856	0.5847

The above models are estimated using an IV estimation, which is the standard way to deal with the inefficiency of the coefficients resulting from the inclusion of a spatial term. Other estimators proposed in the literature are OLS estimators, ML and Bayesian estimator with heteroscedastic errors. In order to see whether the choice of the estimation will affect the baseline results, we solve Equation (4) using those alternative estimations. The results are reported in Table 6. The results are robust.

Table 6: Spatial Panel Regression with Alternative Estimate
*Note: This table reports the spatial panel model using maximum likelihood estimate. The dependent variable is the return on office prices. ρ is the spatial dependence coefficient. W is constructed using the linked ownership ratio. Control variables include change in lagged return, change in population, change in unemployment rate, change in GDP, change in long-term interest rate, change in CPI, change in credit supply, global financial center rank, vacancy rate, change in exchange rate, global oil price change and change in VIX index. Population, unemployment rate, GDP, global financial center score, vacancy rate are at city level. Interest rate, CPI, credit supply, exchange rate are at national level. Oil price and VIX are at the global level. We report the standard error in brackets. ***, ** and * denotes 1%, 5% and 10% significance level, respectively.*

	Model 13: OLS	Model 14: ML	Model 15: Bayesian	Model 16: Instrumented Weights (Piras and Kelejian, 2014)
ρ	0.6289***	0.5336***	0.5330***	0.5047**
	(0.0638)	(0.0343)	(0.0246)	(0.2492)
Control Variables	Yes	Yes	Yes	Yes
City dummies	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes
Adj. R2	0.6201	0.6200	0.6193	0.5775

Another concern is about potentially endogenous weights. As investors may strategically select which cities to invest, real estate market performance and the ownership overlap ratio can be endogenously-related. In other words, we assume that the ownership overlap affects office market performance, but the impact could be vice versa, which means, the ownership overlap may essentially be affected by market performance. For instance, opportunistic funds may be attracted by cities with higher investment yields, such as cities in some emerging countries, but other risk averse investors may be interested in well-developed real estate markets, such as London. As a result, different types of investors may cluster in some cities due to the real estate market performance of these cities. This bilateral relationship may result in endogeneity and lead to biased results.

Piras and Kelejian (2014) proposed estimates for spatial panel models with lagged dependent variables in terms of endogenous weights. We follow their method and use instruments to estimate the weights. The instruments include geographic distance, being in the same country, cultural distance, being in the same legal system, being in the same currency unit, the overlap ratio of international firms, a distance measure of real estate investment transparency, the log of population of the two cities, log of GDP of the two cities and year dummies. We argue that these instruments are (largely) exogenous to the real estate market. In the next step, we perform a 2SLS based on the estimated weights. The results are reported in Model 16, Table 6. The spatial coefficient remains significant. However, the standard error becomes much larger, which might be improved when more valid instruments are included. Overall, we can conclude that the concern about endogenous weights do not change the main finding of this paper: linked ownership has a direct impact on the correlation.

D. Impulse Response Analysis

The advantage of a spatial model is that it allows us to investigate how a change in the dependent variable in one country transmits throughout the spatial system to the other countries. Due to the dynamic nature of the spatial framework, applied return variations in one country will affect the returns in countries with a high overlap in the property ownership. The resulting movements in those markets will, in turn, affect their 'neighbouring' markets, and so on. For transmission of spatial shocks, we calculate the impulse responses that follow a one standard deviation city-specific foreign shock. Figure 6 shows the average spatial effect of a one standard deviation shock to the office market globally. The impulse response is based on model 4, which reports the overall spatial dependence during the entire observation period. London appears to be the dominant driver, as a shock to London office market generates the strongest impact A one standard deviation shock to the London office market will change the office capital returns in each of the remaining cities on average by an accumulative 0.77 of a percentage point impact ten quarters after the shock. Tokyo and New York are also important drivers, with an average cumulative impact of 0.34 percent and 0.45

percent, respectively These results are determined by our ownership spatial matrix – the overlap ratios – hence, they are unsurprising given that the cities above have high overlap ratios with other markets. The ten most influential cities based on their impact are London, Paris, New York, San Francisco, Los Angeles, Washington DC, Tokyo, Boston, Seattle and Seoul.

Figure 6 Average Cumulative Response of Global Office Markets to a One Standard Deviation City-Specific Shock 10 Quarters After the Shock

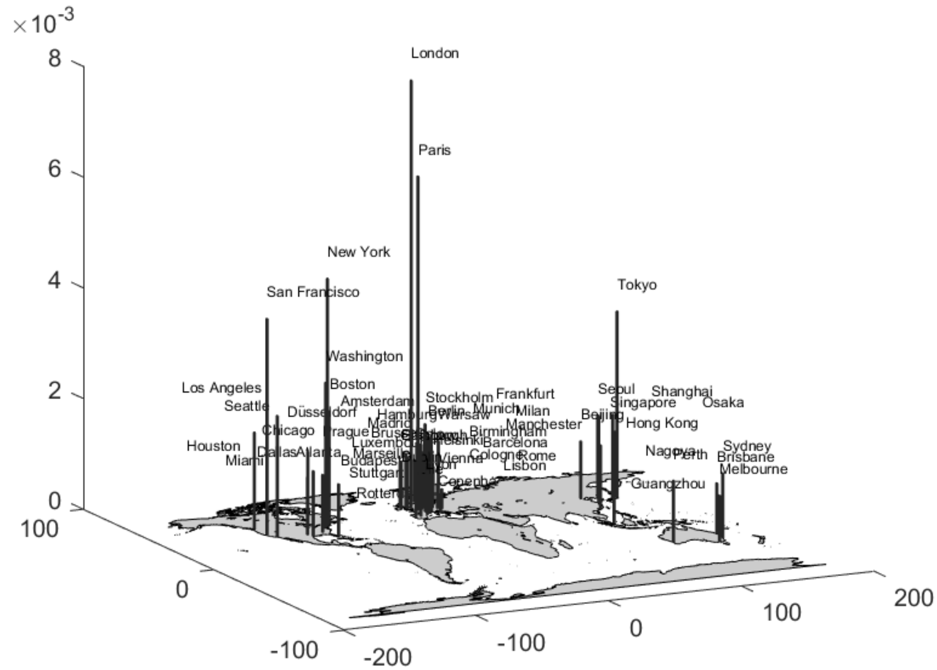
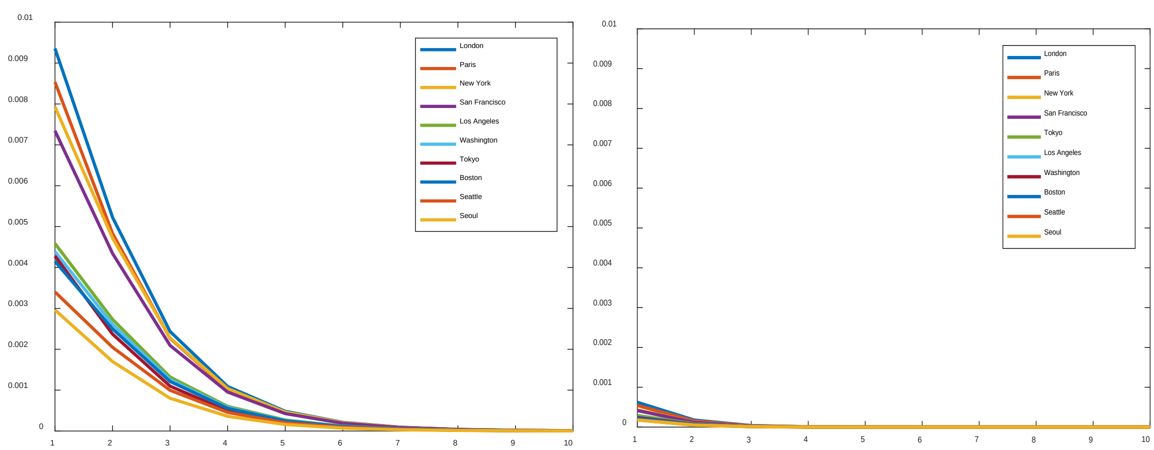


Figure 7 distinguishes the co-movement during the crisis phase and more tranquil periods. It illustrates the average response of the remaining countries to a shock in those ten cities that yield the strongest impact. The coefficient is based on Model 4. In both crisis and tranquil periods, the effect is highest in the first quarter and lasts for one year. Thus the effect is strong only in the relatively short term and then dissipates. The co-movement is most pronounced during the crisis period. During the crisis period, a one standard deviation office price shock in London will generate an average of 0.94 percentage point change on each of the rest of the other cities one quarter after the shock.

It should be noted that the mean quarterly price appreciation is only 0.7 percent, as shown in the summary statistics. We argue that the transmission of shocks is economically significant. Besides, the 0.94 percentage point change is the average for each of the 57 cities. The total transmitted shock is 53.58 percentage points, which is 7.65 times of the size of the original shock to the London market. The shock is amplified and yields an oversized impact on the global market. We also show the impact during the tranquil period (Figure 7-b). The transmission of the shocks is marginal. A one standard deviation shock to the London office market will result in only an average 0.06 percentage points increase in each foreign city. During the crisis period, the interdependence increased dramatically, which may be explained by the price pressure generated by the fire sale of institutional investors due to their liquidity problem. This asymmetric impact suggests that downside risks from contagion effects are most pronounced in inter-connected markets, with implications for investment strategy.

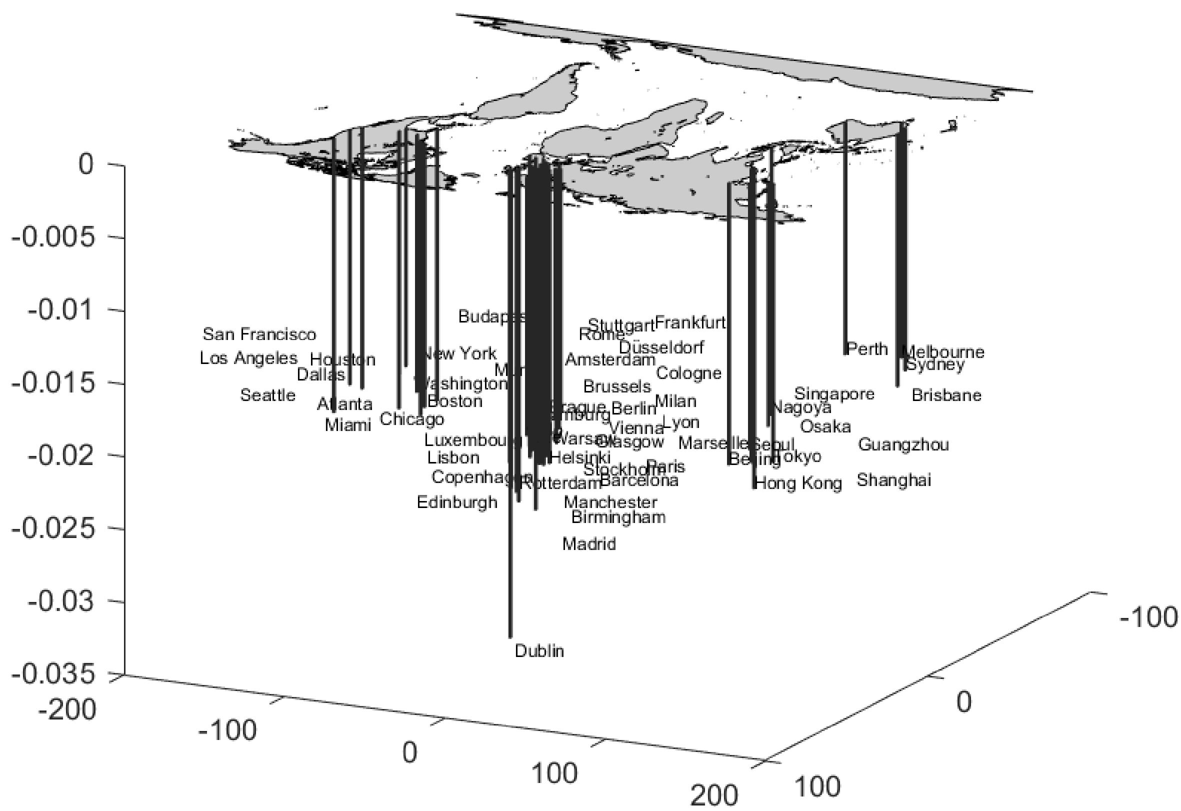
Figure 7 Average Response of Global Office Markets to a One Standard Deviation City-Specific Shock in Ten Dominant Cities During Crisis and Tranquil Periods



Panel A: Crisis Period *Panel B: During Post-crisis Period*

Figure 8, 9 and 10 show the cumulative impact of a one standard deviation decrease in office prices in, respectively, the London, Tokyo and New York markets on the remaining cities for up to ten quarters after the shock during the crisis period. The strongest response to a London office market shock occurs in Dublin, with office capital returns dropping by about 1.94 percent. This can be explained by the high overlap in ownership between Dublin and London. Also, we see strong joint exposure with Birmingham and with Madrid and hence, strong spillover effects of between 1.23 percent and 1.33 percent. Tokyo also have a distinct response, amounting to 0.95 percent. Overall, European cities have the strongest response, followed by Asian cities, while US cities seems to be least affected, confirming regional effects found in other studies.

Figure 8 Cumulative Response of Global Office Markets to a One Standard Deviation Decrease in London Office Capital Returns Ten Quarters after the Shock During Crisis Period



As shown in Figure 9, the impact of Tokyo office market mainly focuses on Asian cities, with domestic cities Nagoya and Osaka showing the strongest decrease, amounting to 1.95 percent and 1.18 percent, respectively. The weakest effect is observed for North American cites. Regarding the response to a one percent shock in New York office market, Washington office market reacts strongest, driven by the high linked ownership of space in the two cities. North American cities respond more pronouncedly and European cities react least to the shock in New York. This illustrates the continued importance of regional factors despite the growth of pan-continental investment strategies.

Figure 9 Cumulative Response of Global Office Markets to a One Standard Deviation Decrease in Tokyo Office Capital Returns Ten Quarters after the Shock During Crisis Period

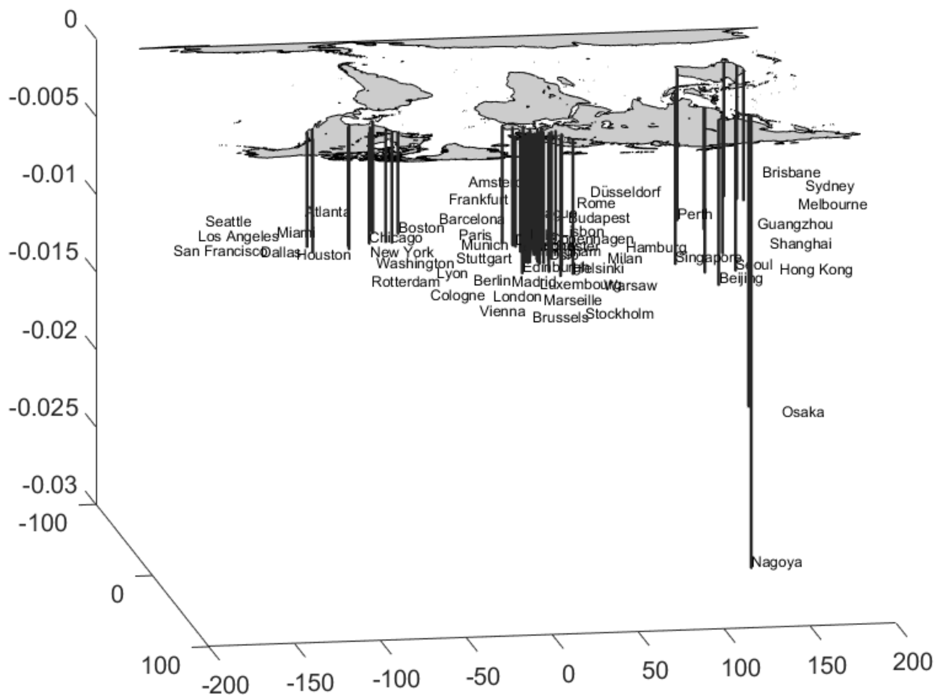
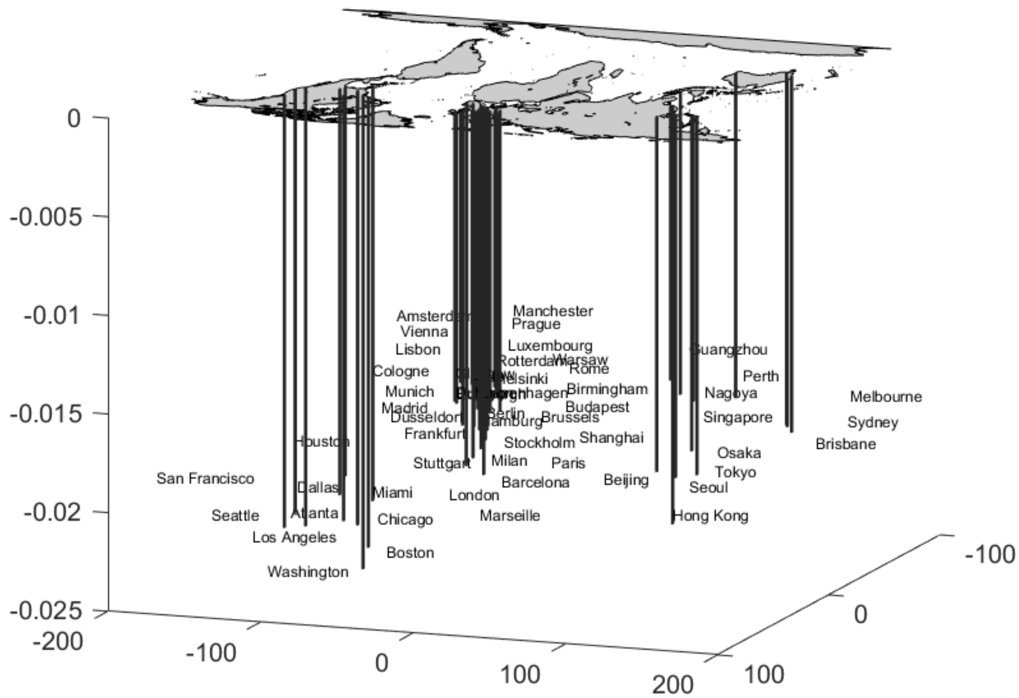


Figure 10 Cumulative Response of Global Office Markets to a One Standard Deviation Increase in New York Office Capital Returns Ten Quarters after the Shock During Crisis Period



VII. Conclusions

In this paper, we have assessed how commonality in property ownership can capture the co-movements across 58 global office markets over the period of 2007 to 2016 using a dynamic spatial panel model. Office market shocks can have spillover effects on other cities through the channel of the global investment of real estate investors, over and above standard return drivers: an invisible network coming from commonality in ownership, which reflects the flow of international capital. While controlling for city level, country-level and global factors, we find that commonality of ownership can significantly capture co-movement of office market returns. Markets with a larger proportion of properties owned by the same investors show stronger office market return linkages. For instance, give the large exposure of investors to London and to other cities, when London office market are adversely affected, investors may have to liquidate their investments in other markets, and thereby affect the demand and supply in those other cities.

We show that a one standard deviation shock to the office return in London will generate a significant shift in prices in the other cities one quarter after the shock, amounting to 0.94 percent during the crisis period, with a maximum impact of 1.94 percent in Dublin. We also show that commonality of property owners adds additional information next to other spatial linkages – such as geographic distance, similarity in cultural and transparency, and even the overlap in occupiers (global firms). The results remain robust after we use instrumented weights to deal with issue of endogenous weights.

These results have potentially important policy implications for real estate investors seeking global diversification in their property strategies. The strong clustering of investment in a relatively small set of cities contributes to the pattern of shared ownership we identify. Our results show that it is these markets that are most prone to near-simultaneous shocks transmitted from one market to another. By implication, there will be contagion effects and stronger co-movements in those cities, reducing diversification gains, with movements most pronounced in the tails of the distribution. To minimize such downside risks, investors should consider seeking less connected markets, subject to liquidity and scale constraints.

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Appendix 1: Cities, Countries and Share of Transactions by Value

City	Country	Share	City	Country	Share
London	United Kingdom	11.51%	Osaka	Japan	0.58%
NYC	United States	10.11%	Dallas	United States	0.58%
Tokyo	Japan	6.88%	Brussels	Belgium	0.50%
Paris	France	6.64%	Dusseldorf	Germany	0.50%
SF Metro	United States	3.35%	Warsaw	Poland	0.45%
Shanghai	China	3.03%	Birmingham	United Kingdom	0.36%
DC Metro	United States	2.92%	Copenhagen	Denmark	0.34%
Seoul	South Korea	2.55%	Prague	Czech Republic	0.30%
LA Metro	United States	2.13%	Dublin	Ireland	0.30%
Singapore	Singapore	2.02%	Miami	United States	0.29%
Chicago	United States	1.95%	Guangzhou	China	0.27%
Hong Kong	Hong Kong, China	1.86%	Cologne	Germany	0.26%
Boston	United States	1.85%	Rome	Italy	0.26%
Beijing	China	1.73%	Barcelona	Spain	0.26%
Sydney	Australia	1.56%	Manchester	United Kingdom	0.25%
Frankfurt	Germany	1.47%	Perth	Australia	0.24%
Stockholm	Sweden	1.43%	Lyon	France	0.23%
Seattle	United States	1.20%	Helsinki	Finland	0.21%
Munich	Germany	1.02%	Luxembourg	Luxembourg	0.21%
Houston	United States	0.97%	Rotterdam	Netherlands	0.21%
Madrid	Spain	0.92%	Stuttgart	Germany	0.20%
Amsterdam	Netherlands	0.90%	Nagoya	Japan	0.15%
Melbourne	Australia	0.89%	Lisbon	Portugal	0.13%
Berlin	Germany	0.82%	Edinburgh	United Kingdom	0.12%
Milan	Italy	0.76%	Glasgow	United Kingdom	0.11%
Hamburg	Germany	0.75%	Budapest	Hungary	0.08%
Atlanta	United States	0.74%	Marseille	France	0.06%
Brisbane	Australia	0.68%	Lille	France	0.02%
Oslo	Norway	0.64%			
Vienna	Austria	0.61%			

Appendix 2: Alternative Specification of Spatial Panel Models

*Note: This table reports the spatial panel model using IV estimation using the instrument proposed by (Kelejian and Prucha 1998). The dependent variable in model 2, 3, 4 and 5 is the return of office price. Model 6 uses total return as the dependent variable. ρ is the spatial dependence coefficient. W is constructed using the linked ownership ratio. Control variables include change in lagged return, change in population, change in unemployment rate, change in GDP, change in long-term interest rate, change in CPI, change in credit supply, global financial center rank, vacancy rate, change in exchange rate, global oil price change and change in VIX index. Population, unemployment rate, GDP, global financial center score, vacancy rate are at city level. Interest rate, CPI, credit supply, exchange rate are at national level. Oil price and VIX are at the global level. We report standard errors in brackets. ***, ** and * denotes 1%, 5% and 10% significance level, respectively.*

	Model 5: Spatial Panel Model, Domestic and Foreign Cities	Model 6: Spatial Panel Model_ Total Return	Model: Spatial Durbin Model
ρ			
ρ (domestic cities)	0.7633***		
	(0.0784)		
ρ (foreign cities)	0.4158***		
	(0.0706)		
		0.6093***	
		(0.0753)	
ρ			0.6591***
			(0.0378)
Δ Log Price t-1	0.1198***		0.1263***
	(0.0185)		(0.0172)
Δ Log Rent	0.8429***		0.8397***
	(0.0282)		(0.0269)
Total Return t-1		0.2972***	
		(0.0209)	
Δ Log Population	-0.0084	-0.0921	-0.0130
	(0.1890)	(0.2272)	(0.1805)
Δ Unemployment rate	-0.0029***	-0.0048***	-0.0037***
	(0.0009)	(0.0010)	(0.0009)
Δ Log GDP	0.0167	0.0523	0.0184
	(0.0312)	(0.0375)	(0.0307)
Δ Vacancy	-0.0004	-0.0016**	-0.0007
	(0.0006)	(0.0007)	(0.0006)
GICS	0.0069	-0.0018	0.0059
	(0.0042)	(0.0051)	(0.0040)
Δ Long-term Rate	0.0019	0.0011	0.0007
	(0.0016)	(0.0020)	(0.0021)
Δ log CPI	-0.1121	-0.0558	-0.1257
	(0.1448)	(0.1731)	(0.1639)
Δ exchange rate	-0.0001	-0.0000	-0.0001
	(0.0001)	(0.0001)	(0.0001)
Δ Log stock	0.0216*	0.0467***	0.0283***
	(0.0111)	(0.0128)	(0.0131)
Δ Log Price t-1			-0.6647***
			(0.1108)
Δ Log Rent			0.4078

			(0.8657)
Δ Log Population			-0.0013
			(0.0035)
Δ Unemployment rate			-0.1551
			(0.1469)
Δ Log GDP			-0.0099***
			(0.0040)
Δ Vacancy			0.0014
			(0.0075)
GICS			-0.0027
			(0.0034)
Δ Long-term Rate			0.0014
			(0.0072)
Δ log CPI			0.6591***
			(0.0378)
Δ exchange rate			0.1263***
			(0.0172)
Δ Log stock			0.8397***
			(0.0269)
Δ oil	0.0038	-0.0001	-0.0130
	(0.0075)	(0.0088)	(0.1805)
Δ VIX	0.0001	-0.0014	-0.0037***
	(0.0074)	(0.0087)	(0.0009)
City dummies	Yes	Yes	
Year dummies	Yes	Yes	
Ave. no. of City	58	58	
No. of Period	39	39	
No. of Observations (Pair of Cities * Period)	2204	2204	
Adj. R2	0.6030	0.4643	