Beyond Location:

Value drivers of office space

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Executive summary

This report presents results from a statistical model that assesses the influence of amenities and technologies on rent levels in a sample of office buildings in London, UK. The empirical investigation is motivated by a discussion of major technological trends that have affected the real estate market in recent years.

The key results are:

1. There is empirical evidence of a trade-off between location, occupiers' freedom of choice, employee wellbeing, amenities, and rent levels. In addition, this is changing over time.
2. No single data source exists that would allow researchers to investigate the effect of individual amenities and technologies on rent levels in London or the UK. Instead, we have developed a manual data collection approach combining information from various web sources to derive a comprehensive dataset of office buildings in London, their location, basic hedonic building features, as well as more than 60 amenities and technologies.
3. The application of unsupervised and supervised statistical learning tools on this dataset enables us to identify a quantitative relationship between all these factors in London's current market for office space.
4. The analysis reveals several features that correlate positively or negatively with rent levels. For example, features related to a flexible fit-out (e. g. column-free offices) tend to achieve higher rent levels; amenities that limit flexibility (e. g. 'Plug & Play Fit-Out') have a negative correlation with rent levels.
5. Features related to sustainability and certificates (WELL, Fitwel, BREEAM etc.) are positively associated with rents.
6. Most amenities do not show a substantial correlation with rent levels. These amenities might not be perceived as relevant quality signals. It could also be that potential tenants do not know about these amenities because there is currently no established methodology to list amenities and alternative forms of data in an accessible and comparable way.
7. The findings identify data gaps as the bottleneck limiting transparency in the real estate market. Only if more and standardised data about individual amenities, technologies, and building features become available in a machine-readable and accessible format will the market correctly assign a premium to elements that are supposed to drive workplace productivity.

The data collection methodology presented in this report could help to overcome existing data limitations in real estate. It could serve as a prototype for an automatised approach to collect relevant building information from public web sources alone. To do so, the data collection methodology would need to be rolled out to a larger sample of office buildings in London or other locations and tracked over a longer period of time using data mining and machine learning to automatically identify and collect relevant data points. Then, the methodology would yield a granular and comprehensive data set on rents, building features, and amenities that could be used to conduct longitudinal studies. This could lead to a quantitative understanding of the evolving market value of workplace productivity and employee engagement technologies in the built environment.

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1. Introduction

A large share of the global population lives in cities. This trend is expected to continue. By 2050, likely, approximately 70% of the world's population will reside in urban areas [1]. With more than 80% of global GDP generated in cities, urbanisation plays a vital role for sustainable growth by increasing productivity, allowing innovation and new ideas to emerge. With over 50% of the total value of the world's assets [2], real estate forms one of the key sectors in the urban economy. However, real estate has only recently started to take concerted action to mitigate the impact of climate change and to embrace digital technologies. Cities, and in particular the built environment within cities, are responsible for approximately 75% of generated energy and produce 60–70% of greenhouse gas emissions [3], contributing to an increasingly negative image of the real estate sector.

In addition to environmental concerns, cities across the globe have been put to the test by the coronavirus COVID-19 pandemic, revealing severe problems in the ability of cities to provide a healthy and productive environment for people to live, commute and work. In this burdensome context, office markets have been severely impaired by the crisis, unveiling structural problems and exhibiting low resilience in comparison to other property types such as housing, warehouses and healthcare (which are collectively represented in the 'beds, sheds and meds' colloquialism). Consequentially, the pandemic has put the workplace, in particular the open-plan office, into the spotlight [4]. Stay-at-home polices and remote work question the need for large headquarter offices in the central business district, as well as many other pre-pandemic work practices.

As reported by a *McKinsey*[1] survey of 100 executives in large organisations, the future of work might be shaped by a hybrid combination of remote and on-site working – further increasing the possibility that people would choose to work from home instead of using workplaces that do not meet their needs. Moreover, according to a study by *Leesman*[2], the preference of people to work from home as an alternative to commuting to the office is linked to the quality of the workplace: over 90% of employees that work in offices within the 'outstanding workplace' category want to work in the office all week, whereas almost three out of four employees with a sub-optimal workplace (72 %) express the wish to work from home for the majority of the week rather than returning to the office. Employees working in the same organisation have contrasting perceptions depending on how highly they rate their overall workplace experience.

To revive offices and central business districts, improving the workplace experience and the quality of the office workplace appear to be critical. However, investing in the right amenities that drive employee engagement, workplace productivity, and sustainable rent levels requires a quantitative understanding of relevant building features and the market premium of such investments.

In this research, we seek to reveal the prospects of technological and environmental trends in the office sector in quantitative terms. The results build on empirical research on value drivers in real estate, but they offer new insights into how more detailed amenity and technology data can help to identify influential factors of real estate rents other than location and basic hedonic features. This study focuses on the London, UK office market, one of the most eminent commercial real estate markets. Even though the UK real estate market is considered transparent [5], we have identified data limitations as an important

[1] https://www.mckinsey.com/business-functions/people-and-organizational-performance/our-insights/ what-executives-are-saying-about-the-future-of-hybrid-work

[2] https://www.leesmanindex.com/measure-remote-working/

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bottleneck in identifying the potential market value of amenities and technologies in the built environment. In having developed a manual data collection approach gathering information from various web sources, we could, nonetheless, create a comprehensive dataset of amenities and office features for more than 200 office buildings in London.

Our results suggest that, in addition to location, specific amenities – particularly those related to flexibility of the fit-out and environmental sustainability – matter when predicting rent levels. However, many features that are supposed to drive employee engagement or workplace productivity do not correlate with rent levels. Instead, features related to the occupiers' flexibility in fitting out office space as they wish appear to be associated with higher rent levels. From the empirical findings, we draw the conclusion that the current real estate market in London values flexibility, and to some extent, sustainability. Location is still a key driver of commercial rents, but building features are becoming a more relevant determinant of rents. Standard building features (such as height or age), however, do not seem to play a major role in predicting rent levels. Only if more and standardised data about individual amenities, technologies, and building features become available in machine-readable and accessible format will the market be able to correctly assign a premium to features that are supposed to drive the productivity of the workplace.

The remainder of this report is organised as follows. In the next two chapters, we review the impact of the mega-trends and ESG criteria in the office sector. Chapter 4 presents the results of the quantitative analysis – the main contribution of this report. The last chapter summarises the findings, concludes and offers suggestions for future research.

2. Changing work patterns and their influence on office space

The future of office-based work is changing due to several megatrends. The most relevant ones playing out in real estate are the COVID-19 pandemic [4] (and the workplace implications related to it), climate change [6], and digitalisation [7].

In this chapter, we discuss how these trends influence the office sector, present findings from the academic literature, and showcase some empirical research on the topic. The baseline is that the commercial real estate sector is simultaneously highly affected by all three trends. More empirical research that creatively combines available data is needed to understand better how these processes influence each other and to disentangle how the trends towards workplace productivity, environmental concerns, and the platformisation of real estate affect how and where we will work in the future.

2.1 The pandemic's impact on the office sector

The stay-at-home policies and remote working routines induced by the COVID-19 pandemic have changed how knowledge work is organised [4], leading to questions about the future of the office in the post-COVID-19 era. Before the pandemic, the majority of employees in central business districts commuted daily to the office to work, to interact with colleagues and to coordinate tasks in face-to-face meetings. The lockdown made it suddenly necessary to work remotely, to apply video-conferencing software for meetings, and to use cloud platforms for document sharing and collaboration.

The rapid adoption of technologies and novel work routines in 2020 allowed for a more efficient organisation of distributed knowledge work, and it will most likely change the demand for office space in central business districts [8–11]. This process will not only affect the magnitude of office space demanded by companies, but it will also influence workplace design [12] and the location of offices. These trends might have long-term repercussions for owners and users of real estate, city centres and the work routines of employees.

Additionally, due to practical considerations [13], tenants in the post-pandemic office will most likely have requirements that are different from the pre-COVID-19 work environment. As social distancing is likely to stay in place at least for the medium term, tenants will require more space to keep the distance from others, they will also want more privacy and personal space – not only because the office is now competing with the desk in the living room for the best work environment. This will potentially lead to a re-evaluation of the open-plan office as the default workplace design model chosen by many organisations [12] and extensive hot-desking, which have been under scrutiny already before COVID-19. Additionally, because of hybrid work models and more flexible work settings, more sophisticated teleconferencing tools, more and better equipped meeting rooms, and reliable internet infrastructure are probably needed to allow for the coordination of office-based work at a distance.

Figure 1 visualises some of the most likely trends in the office sector influenced by the pandemic. The post-pandemic office will most likely need to better allow for collaboration – both on-site and via video-conferencing; the central business district headquarter office is challenged from a decentralised network of offices, combining co-working spaces, satellite offices in sub-urban areas, work from home, and public workplaces; in the mid-term future, the office could be *platformised*, that is KPIs as well as automatised capacity control technologies could spark an on-demand platform market for office space to utilise spare capacity [2].

A decentralised office network

The COVID-19 pandemic has introduced many challenges but also a few key opportunities for office workers, including less commuting, less traffic, and more flexibility. The success of remote working questions the need for centralised headquarter offices [8]. Instead, a 'network of different organisational spaces' [14] is conceivable, with the headquarter office in the central business district being supplemented by smaller satellite offices in sub-urban or rural areas.

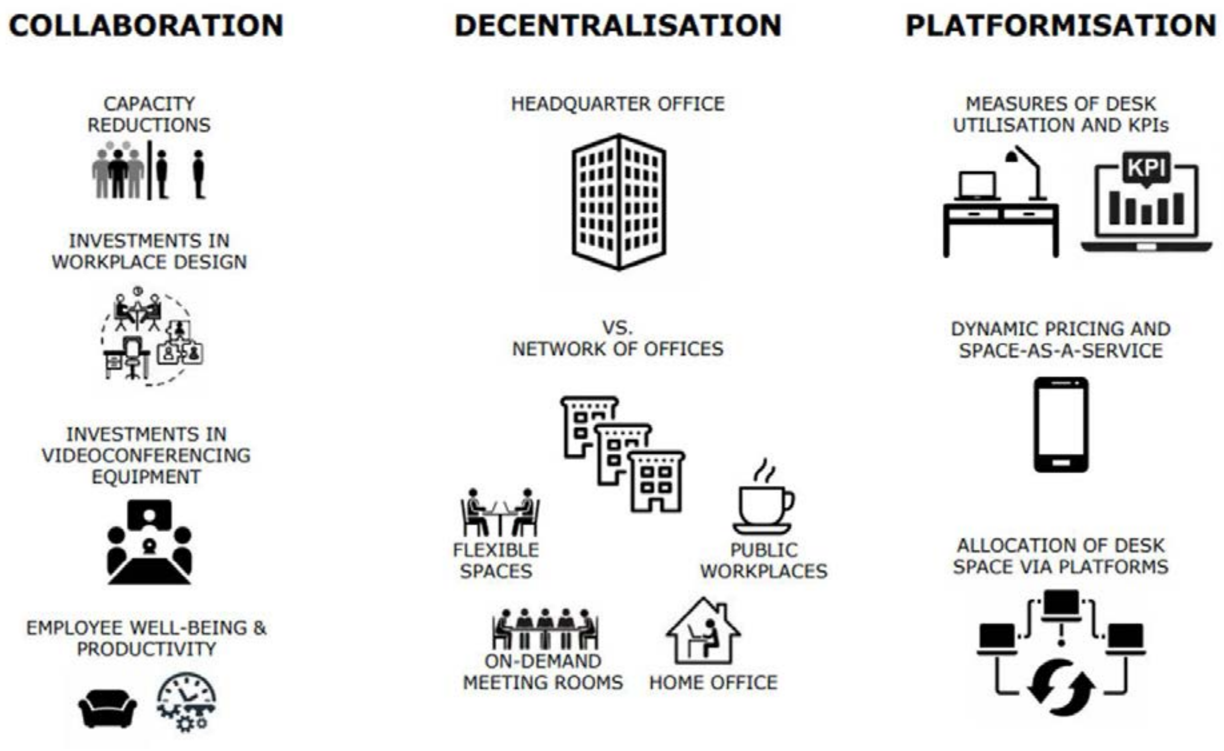

Figure 1 Potential developments affecting the post-pandemic design, location, and economics of office space.

Organisations might use this multiple-hub solution to co-locate with customers or talent pools. Employees could choose their workplace more freely, including to work from home, and coworking spaces might play a key role in satisfying the increased demand for offices outside of city centres.

For example, Bacevice et al. (2020) argue in favour of a distributed network of offices. They say that a network of office locations could translate into a workplace that increases productivity and that generates more well-being for employees if the right conditions are met [14]. To meet such requirements, workplaces need to be designed to bring together employee needs for privacy and connectivity – both are often not met in today's centralised large-scale open-plan offices. Distributed and networked offices could leverage existing infrastructure such as coworking spaces of public workplaces (such as libraries or cafés). These alternative workplaces are often located in different city areas, allowing the workforce to enjoy shorter commutes and interact more with their local community.

The decentralised office network allows for a reduced capacity in the headquarter office. Associated cost savings [8] need to be contrasted with higher coordination costs, necessary investments in videoconferencing equipment [10, 14], and additional costs of maintaining satellite offices, renting coworking spaces, or financial support for employees' home offices. The extent to which organisations might use multiple hubs will be subject to an industry- and location-specific optimisation process (see Fig. 2). Such an optimisation process would need to take the real estate costs in the headquarter location, the costs for third party spaces, transport, and housing costs into account.

Collaboration and workplace productivity

As the number of white-collar workers has grown steadily in recent decades, open-plan offices increasingly replaced private offices as the main form of workplace design. This process was partly motivated by potential real estate cost-savings, but it was also meant to drive interaction and collaboration among employees [15]. This perspective, however, was challenged by the rise of shared spaces and collaborative amenities in the recent hype around coworking [16].

As employees return to their offices in the post-COVID-19 era, they will demand some of the amenities they got used to during remote work. Accordingly, it is to be expected that property managers will be keen to introduce workplace design elements that give employees a 'feel-good' experience, which fosters knowledge exchange and interaction. In doing so, the office could become 'a destination with purpose', offering a collaborative experience that is not available in the home office.

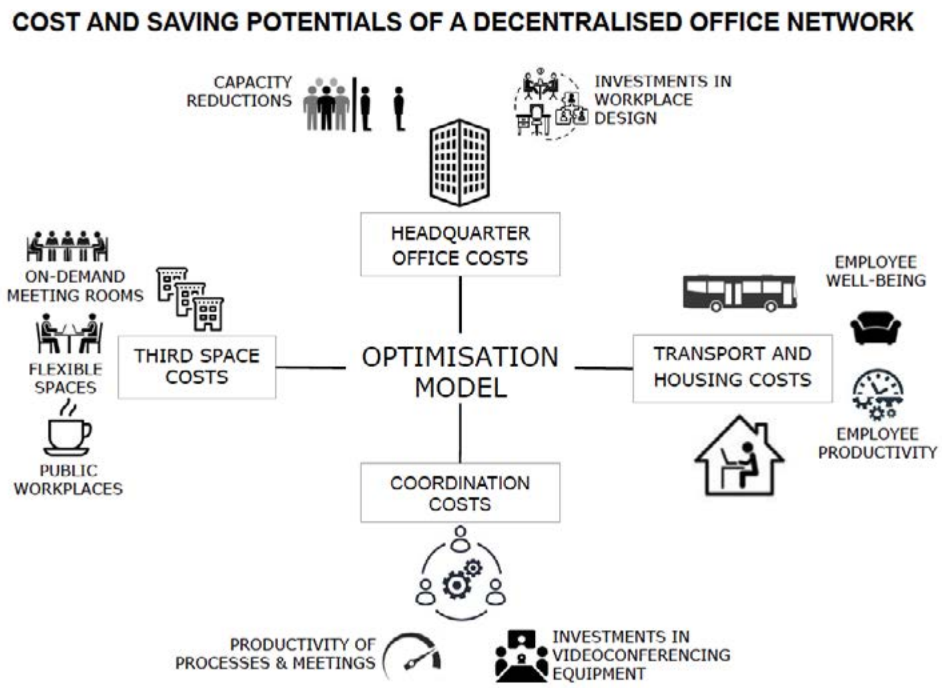

Figure 2 Cost factors associated with a decentralised office network: savings in the headquarter office are to be balanced with costs for coordination, housring, and third spaces.

In this context, workplace productivity and employee engagement are becoming more important. As described by Garton and Mankins (2015) employee engagement consists of three main components that build on top of each other [17]: *satisfaction*, *engagement*, and *inspiration*. Employee satisfaction – the basic layer regarding employee productivity – requires (a) having a safe work environment, (b) tools, training and resources to do the job that is requested, (c) no excess bureaucracy, (d) valuation and fair rewards. To engage employees, on top of the requirements to satisfy them, employers need to create a work environment that fosters (a) team-spirit, (b) autonomy, (c) learning and growth, (d) impact. The most productive employees, according to Garton and Mankins, are inspired employees. This requires (a) meaning and inspiration from the organisation's mission, and (b) leadership within the organisation. These components are influenced by an organisation's leadership and HR, but they can also be affected by the workplace design. Given the importance of talent retention and limiting the staff turnover (and associated costs) for companies, workplaces that are designed to increase employment engagement and satisfaction can be more attractive, particularly in the post-pandemic world of work. To make the office a destination with purpose that satisfies increased employee needs, workplace providers must deliver added value that is bigger than the cost savings that are achievable through a fully remote work setting. That requires amenities that enhance employee satisfaction and ultimately lead to increased productivity.

Some of the trends towards collaboration and workplace productivity have been playing out throughout the COVID-19 pandemic already, and sensor and utilisation data can be used to measure the shifting demands in the usage of office space by employees. In the Figures 3 and 4, we present data from the *Office App*, a tenant engagement platform that has shared some of their anonymised data on activity in offices that use the company's devices with the Oxford Future of Real Estate Initiative.

Figure 3 shows the total number of meeting room bookings in several offices in France, the Netherlands, Norway, and Poland throughout 2020 (left panel). Additionally, the right panel of the figure shows the total number of people accessing two office buildings throughout 2020. Red vertical lines in the left panel indicate the time when work-from-home policies or lockdowns were announced in the different countries. In all countries, the overall usage patterns coincide: the policies to fight the COVID-19 pandemic let to a major reduction of people coming to the office.

While the overall reduction in space utilisation throughout the pandemic is no surprise and might be a short-term consequence only, Figure 4 indicates how the pandemic might change the usage of 10 office space in a long-lasting way. The left panel shows the number of parking space bookings per person entering the office in 2020, and the right panel shows the number of meeting room bookings per person in the office in the same period in a number of office buildings.

Despite some large seasonality around public holidays and the summer, the data clearly shows a trend towards non-public modes of transportation (i.e. more parking space bookings) and, in particular, towards more meeting room bookings per person. In other words, even though the total number of employees coming to the office was substantially reduced during the pandemic, those who came to the office, did so for a different purpose: instead of being in the office to work at the desk or workstation, people came to interact and collaborate with their colleagues. This provides first empirical evidence for the hypothesis that the office is indeed becoming a 'destination with purpose' and a place for collaboration, while the home office becomes the place for desk-based types of work.

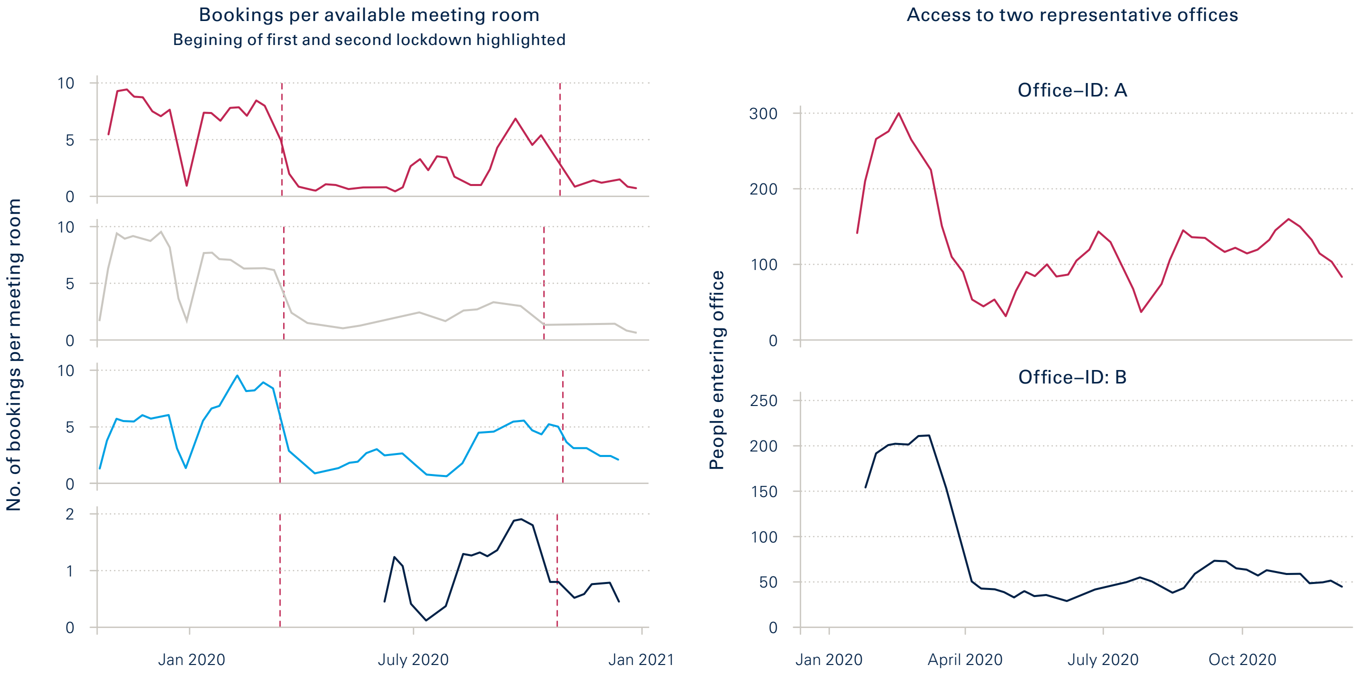

Figure 3 Activity in offices before and during the COVID-19 pandemic (left: meeting room bookings, right: access to two offices).

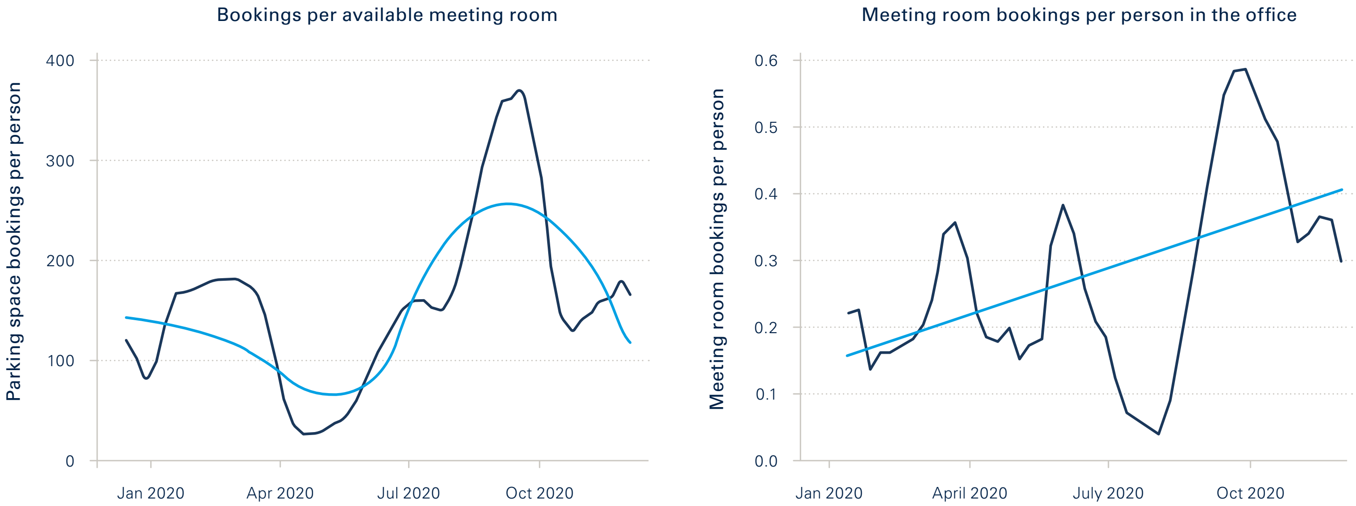

Figure 4 Changed behaviour of employees in office buildings during the pandemic (left: parking space bookings, right: meeting room bookings per person in the office).

Health impact of the workplace

Related to workplace productivity, The health impact of office buildings is gaining increasing traction in commercial real estate. In this context, the focus has been on so-called *Green buildings*. Office buildings are considered as green buildings when they have obtained a sustainability certificate from a third-party provider, such as BREEAM (Building Research Establishment Environmental Assessment Method) or LEED (Leadership in Energy and Environmental Design). Such buildings include health and well-being features such as operable shading, natural light and views, plants, outdoor space, ventilation and filtration, air quality etc. and they often have comparably low emission rates and energy consumption. The impact of green features on the value of office buildings or the rent level, however, is not well understood yet. For example, Sadikin et al.(2020) explore the financial impact of healthy buildings using a hedonic pricing framework [18]. They identify a 4-7% rent premium.

The topic is likely to become more relevant in the future due to the renewed focus on improving the office experience and employee well-being now that the work-from-home policies have offered an alternative to the headquarter office in the central business district.

2.2 Dynamic pricing and the platformisation of commercial real estate

Induced by the need to invest massively in virtual communication and capacity management tools during the lockdown, digital technologies were rapidly adopted in the built environment. These trends are likely to spark significant changes in the demand for office space and the way offices will be used [8, 9]. For example, sensor technologies make it possible to calculate utilisation-11 and workplace efficiency indicators [8], and to introduce dynamic pricing models for individual workstations to maximise per-desk revenue [2] and to reduce the under-utilisation of office space [19].

Technology adoption

The focus on workplace productivity, the changing spatial demand patterns for office space, and the drive towards healthy and green buildings will catalyse the adoption of digital technologies in commercial real estate. Sensors and digital devices enable the efficient design and management of productive workplaces: temperature control, capacity management, and workplace apps are associated with higher employee well-being and productivity [20], and flexible offices and coworking spaces equally require capacity control, booking systems, and smartphone apps to allocate workplaces on-demand.

These technologies increasingly introduce space-as-a-service business models in the office sector. They will most likely pave the way to more developments familiar from other sharing economy markets. In particular, the availability of usage data from buildings and associated apps, together with the increased focus on customer orientation, makes it possible to calculate utilisation- and workplace efficiency indicators [8]. These indicators allow property managers to assess the demand for individual rooms and desks in real-time, which gives them an incentive to introduce dynamic pricing models to maximise the per-desk revenue [2]. This, in turn, makes it possible to assess a building's value based on it's expected cash flow as a flexible office space, leading to additional business potentials for coworking providers [21].

To market the vast amount of under-utilised office space (almost 40% of all office desks are not utilised [19]) to employees and organisations looking for more flexible office space, large sharing platforms might evolve to connect the heterogeneous and distributed demand and supply [2], potentially disrupting established value chains in commercial real estate.

Platformisation of remote work[3]

The adoption of digital technologies sparked major organisational adjustments that allow business processes to operate productively at a distance [4, 9]. This could allow for the development of a fully remote labour market, organised via digital platforms.

Organisations can realise substantial cost savings and tap into global talent pools if they adopt remote working practices and start to outsource business processes to the remote workforce [23]. So-called online labour platforms are a prototype of a fully remote labour market. These online platforms have been established over the past 10 to 15 years, and they allow even small companies or individual employers

[3]This subsection is based on our recent working paper 'The polarisation of remote work' [22], and some text elements and results shown here are excerpts from the article.

to outsource knowledge work to a large crowd of individual freelancers [24]. Having started as niche marketplaces for IT freelancers, online labour platforms now cover the whole spectrum of knowledge work, from data entry to management consulting, with millions of platform workers involved globally [25–27], and rising adoption during the COVID-19 pandemic.

Remote work organised via online platforms could bring jobs to workers from all over the globe [28–30]. In doing so, remote work could help to mitigate the global imbalance between the excess supply of highly educated graduates in Global South countries [31] and the high demand for talent in the Global North. In bringing jobs and income to people in Global South countries and rural areas, remote work could help to foster more resilient, sustainable local communities [32, 33] and offer alternatives to the physical migration to places with more jobs and higher wage levels [34].

At the same time, several studies have reported that remote platform work is shaped by geographical frictions and biases that restrict participation [35–38]. Similar to other complex economic activities [39] remote work could cluster in large cities. In our recent study "The polarisation of remote work" [22], we find that remote platform work actually tends to gather in large cities. The data from a globally leading online labour market shows that remote work is polarised along three dimensions. First, countries are globally divided: North American, European, and South Asian remote workers attract most jobs, while many Global South countries participate only marginally. Secondly, remote jobs are pulled to urban regions; rural areas fall behind. Thirdly, remote work is polarised along the skill axis: workers with in-demand skills attract profitable jobs, while others face intense competition and obtain low wages.

Flows in the global online market between cities with majority buyers (blue) and sellers (red) in 2020 (5% sample)

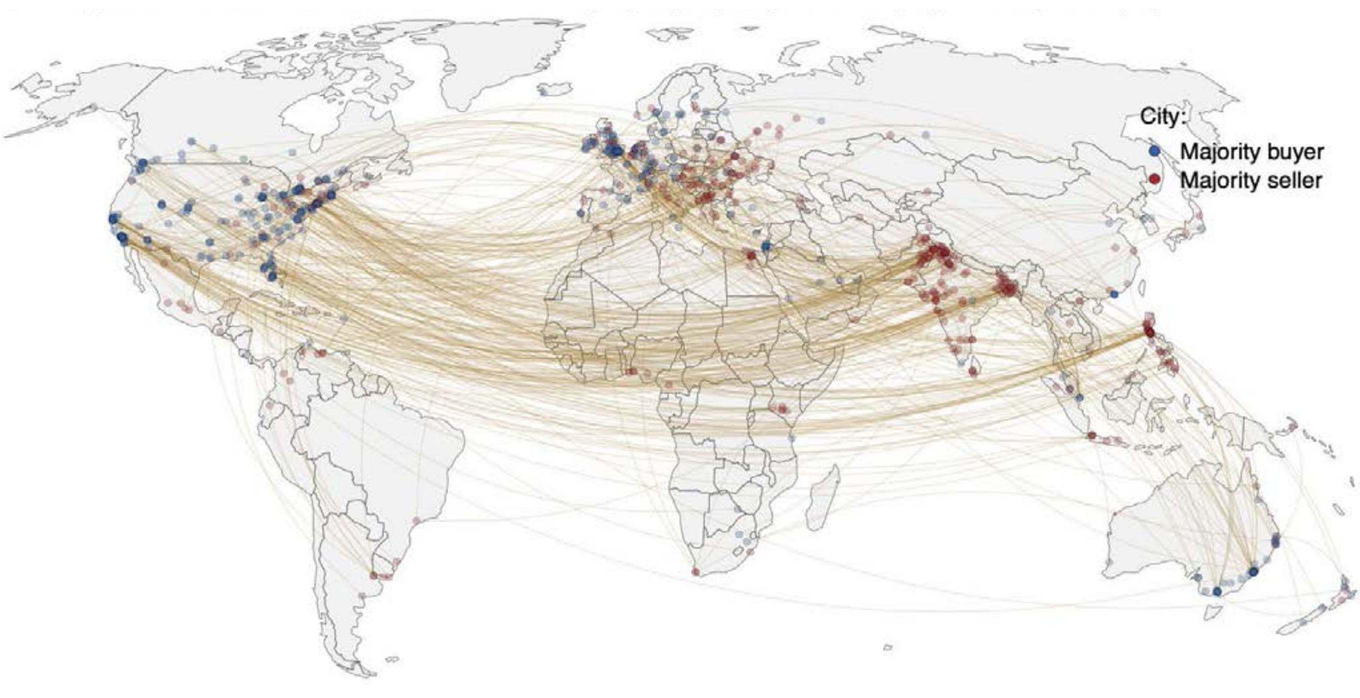

Figure 5 The global geography of platform work, based on data from a leading online labour market (Fig. from [22]).

Figure 5 from [22] displays the global geography of the online labour market as it shows the 13 connections (yellow) between buyers (blue) and sellers (red) of remote work. The vast majority of demand for remote platform work comes from metropolitan centres in North America, West Europe, and Australia. Most remote platform workers are located in urban areas in East Europe, South Asia and the Philippines.

The findings suggest that remote work is shaped by agglomerative forces, deepening the gap between urban and rural areas. Digital technologies that allow for a remote organisation of knowledge work are more likely not to distribute work more evenly across geographies, but instead to drive further geographical concentration and specialisation of the workforce in metropolitan areas. Remote work allows to connect spatially detached labour markets, but this is most likely limited to connecting large cities and urban talent pools from different parts of the globe. The reason for the unequal geographical participation in the remote platform labour market are the skill requirements in the different types of remote jobs. Many of the in-demand occupations require specialised digital skills and know-how, which are linked to place-bound institutions of the local economy. These institutions concentrate in urban centres. Overall, remote work is likely to reinforce urbanisation patterns, which might have important consequences for the spatial organisation of urban economies and the commercial real estate market.

As indicated in the previous sections, digital technologies and more flexibility allow for a network of different organisational spaces to be used by the workforce. Still, in the light of the results presented here, this is most likely limited to urban and suburban areas. The headquarter office in the central business district might be challenged by smaller satellite offices in other parts of the town or even in other countries, but the endeavour of co-locating closer to related industries and talent pools will imply that these satellite offices will, again, be located in urban areas. Education, vocational training, and business opportunities pull talent towards large cities and digital technologies are only amplifying this process. As the commercial real estate industry is reacting to this trend, offices might be more evenly spread within urban centres, but they will most likely not extend into the countryside.

2.3 The impact of the sharing economy on the workplace

The increased focus on collaboration drives the introduction of elements from the sharing economy in the built environment. Within real estate, coworking has become the dominant manifestation of the sharing economy. In general, sharing solutions are becoming an attractive market organisation principle if the following criteria are fulfilled [2]:

1. both demand for and supply of a scarce resource are distributed among many heterogenous market participants,
2. there is currently no efficient mechanism to match demand and supply,
3. doing so would come with financial incentives for all participants, i.e. customers, sellers, and intermediary platforms
4. the solutions needs to be scalable (i.e. fixed costs can be divided by large user base)

The sustainability of the sharing economy concept depends on transaction costs (search- and information costs, bargaining costs, enforcement costs). Within the office sector, digital technologies (sensors to measure office capacities etc.) reduce the transaction costs of space as-a-service solutions and enable the efficient provision of coworking spaces. In the increasingly modularised and flexible work environment, users search for knowledge exchange and a sense of community at their workplace [16]. This demand is met by coworking providers. They manage the user experience through the introduction of new job roles such as 'head of workplace' or 'community officer'.

Monetising the under-utilisation of space

The current under-utilisation of office space in major business centres makes it likely that *Airbnb*-like platforms will aim to connect the demand for flexible office space with the under-utilised space. Studies estimate that up to 30% of all office space in the US might be operated by a flexible lease model by 2030 [40]. Some startups are already working on such business models, but there is still not a market-dominating platform in the space-as-a-service sector [2].

The trend towards coworking and flexible offices might bring long-lasting consequences, which could be similar to changes witnessed in the hospitality market: (a) real estate owners could re-think their business model in terms of customer orientation and platform solutions, (b) thanks to novel utilisation-based KPIs, dynamic pricing for flexible space could be introduced at large-scale, (c) property values could, as a consequence, be calculated based on revenue per desk instead of long-term leases.

One of the most well-known co-coworking providers is *WeWork*. The company is transforming its business model from a pure space-as-a-service operator to a property owner [2]. The company targets buildings with low returns in the long-lease system and turns these low-return assets into coworking spaces to increase their revenue, which is harnessed by WeWork as the tenant. The more productive operation of the building as a coworking space in turn, increase the building's value, which is harnessed by WeWork as the landlord. In doing so, the company generates a novel income stream and further develops the vertical integration of the real estate value chain.

Key elements of the co-working model

At the core of coworking is the idea to foster coincidental knowledge exchange and network by designing the workplace with an interior that is driving collaboration. This is why coworking spaces generally have many cafeterias, lounges or community areas. However, it is not yet clear whether amenities such as breakout rooms or community spaces also translate into higher real estate returns. We investigate this relationship in more detail in chapter 4.

Independent of the question on the empirical evidence for increased returns of collaborationenhancing amenities in the commercial real estate sector, coworking spaces saw a massive growth in recent years. From 2013 to 2018, the number of coworking spaces has increased by ten-fold to hundreds of coworking providers operating around 19,000 coworking offices globally in 2018. In total, there has been a total investment of more than 10bn USD [21].

According to Bouncken et al. [16], the key elements of coworking spaces that have fuelled the success of the coworking model over the past years are:

Sense of community The sense of community is seen as the key driver of work satisfaction compared to remote work as it reduces the stress of working from home. The coworking space can create it due to the (a) interior, (b) location in a certain neighbourhood,(c) rules and values of the provider, and (d) the user base.

Linkage multiplicity For users, it is important that they can be integrated into or interact with multiple teams. This fluid setup increases the chances of knowledge flow and idea generation.

Openness and autonomy Coworking spaces are particularly attractive for people who value job autonomy. The focus on autonomy is very different from traditional office environments that impose a more rigid hierarchy on employees.

Participation The ease with which users can participate in coworking spaces is much higher than in closed-door office settings, which seems to be an important driver of work satisfaction.

Mutual knowledge creation The community areas in coworking spaces drive casual interaction and knowledge exchange. Despite these positive elements, coworking spaces might also negatively affect employee well-being and productivity. For example, some people might find coworking spaces uncomfortable due to various factors such as opportunistic behaviour or the noise in a coworking space. It could, thus, also decrease work satisfaction and individual productivity.

While coworking providers are theoretically considered as tenants, they enter a strategic interaction with the landlord [2] and are often able to obtain more tenant concessions than other tenants. An empirical analysis by Chegut & Langen (2019) of 200 coworking leases and 4,000 other lease contracts in 188 buildings in six US cities shows evidence that coworking providers are able to gain rent discounts and other tenant benefits [21]. This is particularly pronounced as coworking becomes more established in the cities under investigation.

Here, we complement the theoretical considerations and results from the literature with empirical insights into the coworking market in London. As described previously, coworking providers might more flexibly react to current trends in the office sector, in particular concerning to the location of office spaces, challenging the dominant paradigm of the central business district headquarter office, which is particularly pronounced in London.

To investigate whether coworking providers follow a different pathway or resemble the geography of the office market, we examined the location of 700 coworking spaces in London wards in relation to statistics about the local demography and economy in these wards.[4]

Figure 6A visualises the density of coworking spaces in London. As all the economic activity in London is pulled towards the city centre, it is little surprise that coworking spaces also tend to gather in the centre. To control for this overlapping effect, we divide the number of coworking spaces per ward by the number of office jobs in each borough. The number of office jobs is approximated by the number of jobs in the industry-codes J to O (professional services, finance, etc.). These are jobs that usually take place in offices and they provide the baseline to compare the number of coworking spaces in a given area of town with the 'office-ness' of the area (measuring in how far a certain area is specialised in office-based work).

The figure reveals that coworking spaces tend to cluster in the inner city, despite controlling for the office density in the London wards. However, there is also a considerable share of coworking providers in the peripheral districts outside the city centre, scattered across the different boroughs.

[4] We are grateful to Danny Rigby for his effort in assembling the list of coworking spaces in London.

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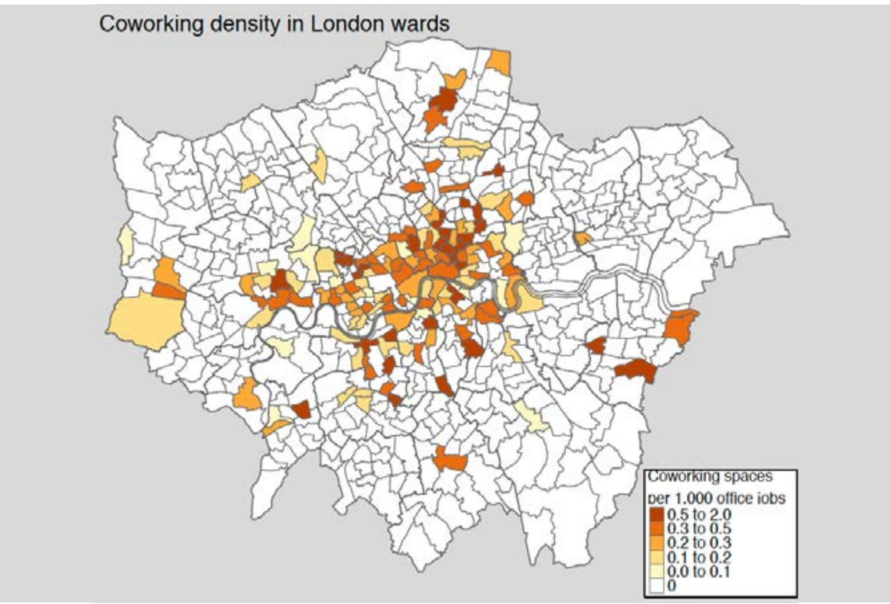

A. Coworking spaces per 1,000 office jobs (jobs in industry codes J-0) in London wards

Figure 6 Location of coworking spaces in London.

(A) Coworking density (no. of coworking spaces per 1,000 office jobs) in London: Coworking spaces are clustered in central boroughs, but they are also present in other areas.

Dependent variable:	No. of coworking spaces	Coworking spaces per 1,000 office jobs
Scale:	Logarithmic	Logarithmic
Geography	All wards with >1 coworking space	Wards in 'outer' boroughs[a]

Model:	(1)	(2)	(3)
No. of household spaces (logarithmic scale)	−0.6 (0.4)	-1.1^{***} (0.4)	-1.3^{***} (0.4)
Share of office jobs (% of all jobs in borough)	−2.1 (1.6)	-3.5^{**} (1.5)	-6.0^{***} (1.9)
Distance from city of London (km)	-0.03^{*} (0.02)	-0.03^{*} (0.02)	-0.02^{*} (0.02)
Public transport accessibility score	−0.01 (0.07)	-0.1^{**} (0.05)	-0.2^{***} (0.06)
Population density (logarithmic scale)	−0.08 (0.17)	0.2 (0.14)	0.5^{***} (0.2)
Share of people cycling to work	-0.04^{*} (0.02)	-0.06^{***} (0.02)	-0.05^{*} (0.03)
Median age	-0.05^{**} (0.02)	-0.07^{***} (0.02)	-0.08^{***} (0.02)
No. of office jobs (logarithmic scale)	-0.08^{***} (0.01)		
Constant	0.32 (4.24)	7.74^{*} (4.33)	9.21^{**} (4.55)
Observations	149	149	110
R^2	0.61	0.23	0.31
Adjusted R^2	0.59	0.19	0.26

Note: *p<0.1; **p<0.05; ***p<0.01

[a]*Excluded boroughs: Camden, City of London, Hackney, Islington, Westminster*

B. Regression models relating no. of coworking spaces to ward-level demographic and economic statistics

(B) Regression models relating the no. of coworking spaces to local demographic and economic statistics: while the total number of coworking spaces per ward (model 1) correlates mostly with the number of office jobs (row 8), the coworking density (models 2 and 3) is higher in areas that are less focused on office jobs (row 2) and less accessible by public transport (row 4).

To understand how far this geography is related to local demographic and economic factors, we have performed three regression models relating the number of coworking spaces (model 1) and the coworking density (models 2 and 3) to local factors, displayed in Figure 6.

The first model shows that coworking spaces per ward correlate mainly with office jobs (row 8) and the population's median age. In contrast, the coworking density (model 2) is higher in areas that are less focused on office jobs (see the negative and statistically significant coefficient in row 2), less accessible by public transport (row 4) and with a population that prefers to cycle to work (row 6). These correlations are even more pronounced when focusing on wards in the outer boroughs only (model 3). In addition, coworking providers being active in this part of town are also closer towards densely populated residential areas (see the positive coefficient of population density in row 5).

In other words, the data indicates that coworking providers have indeed already started to fulfil different market needs. Some coworking spaces operate in more residential areas instead of the city centre. In these areas, more people tend to cycle to work or use other alternative modes of transportation as these areas are not well integrated into the dense network of London's public transport. These areas are less focused on office-based work and, thus, the coworking providers offer a market niche for sub-urban dwellers that are looking for alternatives to the extensive commute to the headquarter office in the central business district.

3. ESG and commercial real estate

In 2004, financial institutions were invited by UN Secretary-General Kofi Annan to develop guidelines on how to better integrate environmental, social, and governance issues in asset management, securities brokerage services, and associated research functions.[5] ESG, as it came to be known, joined the growing list of frameworks and initiatives offering an alternative to Milton Friedman's 'self-interest' doctrine. Others include socially responsible investment (SRI), corporate social responsibility (CSR), triple bottom line, and quadruple bottom line.

As the world's largest asset class, real estate's approach to ESG has wide-ranging consequences. In 2019, the residential sector was responsible for over 15 percent of the UK's total greenhouse gas emissions. Business (industrial and commercial activity) was responsible for an additional 17 percent and agriculture 10 percent according to the 2021 Greenouse Gas emissions report by the UK Department for Business, Energy & Industrial Strategy.[6] When it comes to employment, 6.6 percent of the UK workforce are employed in construction (86.0 percent of whom are male), and 1.3 percent of the UK workforce are employed in real estate activities (50.7 percent of whom are male), according to the Employment by Industry Labour Force Survey (2021).

Those not directly employed in the construction or real estate sectors are still likely impacted by the asset class' approach to ESG. For instance, good air quality and green areas have been linked to the mental and subjective wellbeing of individuals [41]. Air quality and green areas are within the locus of control of the real estate sector, given the proliferation of air monitoring and conditioning technologies, as well as the role urban planners, architects, and property developers play in the provision of viable green space on public and private land.

Socially responsible investment

The literature concerning socially responsible investment (SRI) is heterogeneous but generally centres around the act of taking factors other than financial return into account when making investments. 'Ethical investment' and 'value-based investing' are also used in this context. SRI and its allied forms can be traced back at least as far as the establishment of Abrahamic religions–with Judaism, Christianity and Islam all offering guidelines on ethical investment. More recently, investor boycotts have been inspired by events such as Apartheid in South Africa, the Vietnam War, as well as climate change [42].

Triple and quadruple bottom line

The triple bottom line serves as a framework to operationalise stakeholder theory. Its proponents argue sustainability serves as the common ground shared by an organisation's business interests and the interests of the public (i.e. non-financial stakeholders). This common ground is referred to as the 'sustainability sweet spot'. As opposed to a conventional 'bottom line' approach to economic performance of an organisation, the triple bottom line also takes into account environmental and social performance [43]. The triple bottom line is popularised as consisting of *three P's: people*, *planet* and *profit*. A fourth bottom line of *purpose* is also used, resulting in a quadruple bottom line.

3.1 ESG and capital works

During the design, construction and retrofit of real estate assets, decision-makers have the opportunity to influence the asset's enduring ESG characteristics. However, there is still considerable progress to be made. In the second quarter of 2021, to bring an example from the residential sector, only 2 percent of new homes constructed in

[5]The Global Compact (2004): https://www.unglobalcompact.org/library/255

[6]https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/957887/2019_Final_greenhouse_gas_emissions_statistical_release.pdf

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the UK had an 'Energy Performance Certificate' (EPC) rating of A, which was less than half of the new homes constructed with the lower ratings of D and E.

Sustainable building practises

Construction waste has come to the forefront of industry awareness because of environmental sustainability and financial cost. According to the UK Department for Environment, Food & Rural Affairs[7], the UK generated 67.8 million tonnes of non-hazardous construction and demolition waste in 2018, which is 30.5 percent of the nation's total waste. Various solutions to this issue have been proposed and some implemented. Examples include:

- Reusing building materials (such as bricks) in new builds,
- Off-site construction (prefabrication),
- Selection of sustainable materials during the design process, and
- Methods of monitoring the construction site.

Property technology and construction technology start-ups have also received venture capital funding aimed at scaling solutions to construction site issues.

Building certifications

Starting with a phased approach from 6 April 2008, non-dwellings in the UK must have an Energy Performance Certificate (EPC) on construction, sale or rent. EPCs are issued on a scale from 'A' to 'G', with A being the most energy-efficient rating and 'G' being the worst. Buildings are rated on two dimensions: their current rating and potential rating.[8]

To establish sustainability standards for buildings, the UK-based Building Research Establishment (BRE) launched the Building Research Establishment Environmental Assessment Method (BREEAM) in 1990. The output from a BREEAM assessment is a six-star rating, with each star representing a graduating rating scale from acceptable to outstanding. Categories assessed include energy, health and wellbeing, innovation, land use, materials, management, pollution, transport, waste and water. It claims to have issued 594,011 certificates across 89 countries.[9]

Internationally, the 'Leadership in Energy and Environmental Design' (LEED) was developed by the US Green Building Council (USGBC). It claims status as a world-leading green building rating system with 79,000 participating projects across 160 countries and territories. There are four certification levels: certified, silver, gold and platinum.[10]

Another certification scheme is *Energy Star*. It is a US government-backed energy efficiency certification system for products, homes and non-residential buildings. Founded in 1992, Energy Star claims to have certified more than 7 billion products since 1992, deployed in more than 270,000 commercial properties in 2020, as well as 190,000 newly built and retrofitted US homes in 2020.[11]

3.2 ESG and real estate occupancy

Aside from capital works, the ongoing maintenance and occupancy of real estate assets serve as an additional focus area for ESG. Although construction is generally the most intensive period of greenhouse gas emissions for a building, its useful life of decades can determine whether its total carbon footprint worsens or improves over time. This incorporates not only decisions made during design and construction, but also decisions made during the useful life of the building.

Smart buildings

An essential component for a more considerate use of energy in office buildings is the usage of so-called *smart building* technologies. Baum, Saull and Braesemann (2020) identify the property technology (PropTech) revolution 3.0 as being driven by the global pressures of climate change and rapid urbanisation [2]. Within this family of real estate focused innovations, '*smart real estate describes technology-based platforms which facilitate the operation of real estate assets. . . The platforms may simply provide information about building or urban centre performance, or they may directly facilitate or control building*

[7]https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1002246/UK_stats_on_waste_statistical_notice_July2021_accessible_FINAL.pdf

[8]https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/666186/A_guide_to_energy_performance_certificates_for_the_construction_sale_and_let_of_non-dwellings.pdf

[9]https://www.bregroup.com/about-us/our-history/timeline/)(https://www.breeam.com/discover/how-breeamcertification-works/

[10]http://leed.usgbc.org/leed.html

[11]https://www.energystar.gov/about

services'. Examples of smart building attributes include assigning workspaces on the basis of individual schedules, climate control linked to the movement of people through buildings and their preferences, as well as controlling light in proportion to the availability of natural light through windows.

Occupant behaviour and preferences

Although technology can contribute to sustainability in the built environment, it still relies on inputs from occupants. For instance, a smart building can only efficiently assign workspaces based on schedules if those schedules do not conflict. Smart climate control innovations may be compromised when overridden by manual inputs. Occupant behaviour is therefore as crucial for sustainable buildings as technology, but this is likely to lead to trade-offs.

In April 2020, for instance, the UK Office of National Statistics conducted a working-from-home survey. 46.6 percent of respondents did some work at home, of which 86.0 percent were doing so due to the coronavirus pandemic. Occupations requiring higher level qualifications and seniority were more likely to have access to homeworking.[12] There is an increasing body of evidence pointing to a paradigm shift in remote working, giving rise to the 'hybrid working model' of working some days in the workplace and some from home. This could, as indicated in chapter 2, lead to a productivity and sustainability paradox for employers. Face-to-face collaboration is seen as a boost to productivity [16], but requires teams to attend the office at the same time. This impacts the dynamics of hotdesking arrangements. In addition, there is evidence that hot-desking has a negative impact on productivity and wellbeing [15].

Building maintenance and depreciation

Buildings designed and built to meet sustainability objectives rely on maintenance schedules that maintain or improve sustainability. Therefore, relaxed maintenance schedules and non-compliant replacement parts pose a risk to a building's sustainability. This risk exists across maintenance tiers, from activities as straightforward as replacing air filters and light fixtures to more mechanical tasks such as electrical motor maintenance, lubrication, and tuning. Since the feedback loop on inefficiency can be delayed and marginal, inefficiencies can develop over time without being noticed, or attributed to another factor such as age, occupant behaviour or even the inflation of energy prices. As Shen has already outlined in 1997 with respect to the prioritisation of planned maintenance schedules in public buildings, in reality, maintenance tasks are often delayed or abandoned entirely [44].

[12] https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/employmentandemployeetypes/bulletins/coronavirusandhomeworkingintheuk/april2020

4. Value drivers in London office space

In this chapter, we present the results of the quantitative analysis from a dataset of 200 office buildings in London. The buildings in the sample are part of the CBRE London City Rent Survey. The survey measures rental movements for a large selection of properties deemed representative of the London office market in terms of grade, location and specification. At quarterly intervals, a hypothetical 10,000 sqft unit of space is assigned a rental value by CBRE agents.

In the following, we describe the data collection process and related methodology before presenting some preliminary results.

4.1 Data collection

The main focus of the data collection is on amenities, environmental certificates, workplace productivity and employee wellbeing-oriented characteristics of the office buildings sample.

We consulted more than 20 different real estate websites containing some of the features and amenities associated with workplace productivity that could also be reflected in rent levels. The number of amenities reported on each website varies. In addition, basic building features such as the number of stories or the total size of the building in sqft or sqm often differ from one source to another if available at all.

In other words, collecting a comprehensive and comparable set of building features is a critical step in empirically investigating the premium for amenities in the landlord's (or property manager's) control. In the figures 7 to 11, we illustrate the information that is available on different websites about the sample buildings. For example, from *Realla* (Fig. 7) we gathered most of the quantitative data regarding basic physical features and the proximity to public transport (Fig. 8). If possible, these data were validated by consulting other websites, such as *Knight Frank* or *Rightmove*. The most crucial information for our study – the amenities – could be collected by consulting a variety of different web sources, building brochures and documents, and *Google Street View*.

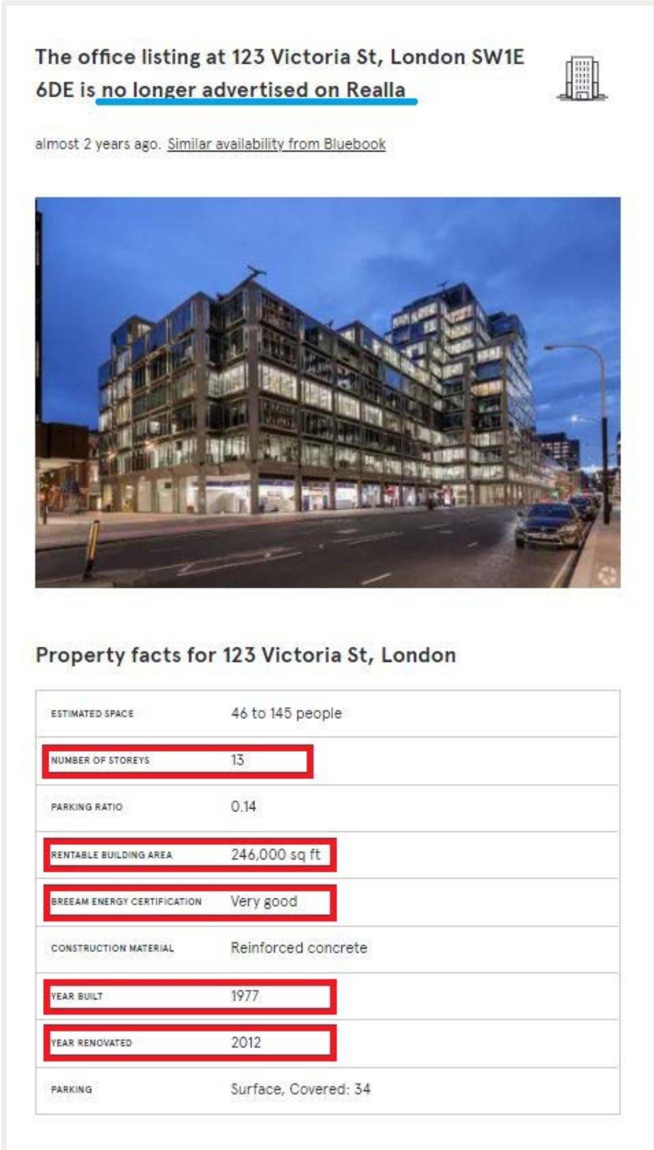


Figure 7 Screenshot of 123 Victoria Street from Realla.

As an example, Figure 9 shows the information that is available in a brochure about the building located at 123 Victoria Street. The booklet contains 59 pages, allowing us to gather comprehensive information about relevant amenities. Even though leaflets have the most accurate information, they are not always available. The varying levels of detail between different web sources are illustrated in the figures 11 and 10. Only few features (green) overlap between both sources; of other amenities (red) are only available in one of these sources. In total, we consulted up to 20 different web sources per building to build the final dataset.[13]

4.2 First observations from the data

During the data collection, we made several observations about patterns in the data, which partly corroborated, partly contrasted with results from the literature, and informed the further data analysis. For example, many studies have investigated the correlation between rent levels and sustainability (i.e. performance in green certificate programmes). However, we found that several landmark buildings, which are only a few years old and have been built to the highest standard, do not advertise any green certificates and little information on their amenities is available online. This might be due to their high visibility and recognisability, which allows these buildings to be in high demand even without extensive marketing of their extensive features.

In addition, contrary to the consensus in the literature, large buildings do not seem to command higher rent levels than smaller office buildings. Prominent skyscrapers with vast amounts of rentable building areas are primarily present in the medium to low medium rent category of our dataset. The highest rent levels seem to be achieved by medium-sized constructed office buildings with high quality amenities and outdoor spaces, which are centrally located and often command prominent positions in expensive or recognisable areas.

Many buildings in our dataset provide some form of outdoor space. The more expensive buildings offer high-quality roof terraces, often in combination with green roofs, rainwater collection, in addition to photovoltaic panels.

Buildings that command higher rents also differentiate themselves with sophisticated bike storage, and some offer parking spaces and charging options for electric vehicles. Moreover, better-equipped showers, changing areas and locker facilities also differentiate buildings.

Among the offices in our dataset, some features are prevalent: 150mm raised floors, LED lighting, suspended ceilings, 24-hour access and a manned reception with controlled access and some form of security systems such as CCTV, alarm system or onsite security. Most buildings have some form of air conditioning: the most common system is the four-pipe fan cooling air conditioning. However, especially in lower-rent buildings, two-pipe fan cooling air conditioning and other systems are also present.

These observations stood out during data collection and the first exploratory analysis. However, as we will show in the following, only some of these relationships were statistically significant. Instead, the most robust result from the statistical analysis seems to be that the market pays a premium for flexibility and amenities related to the freedom of occupiers to fit out the office space as they wish.

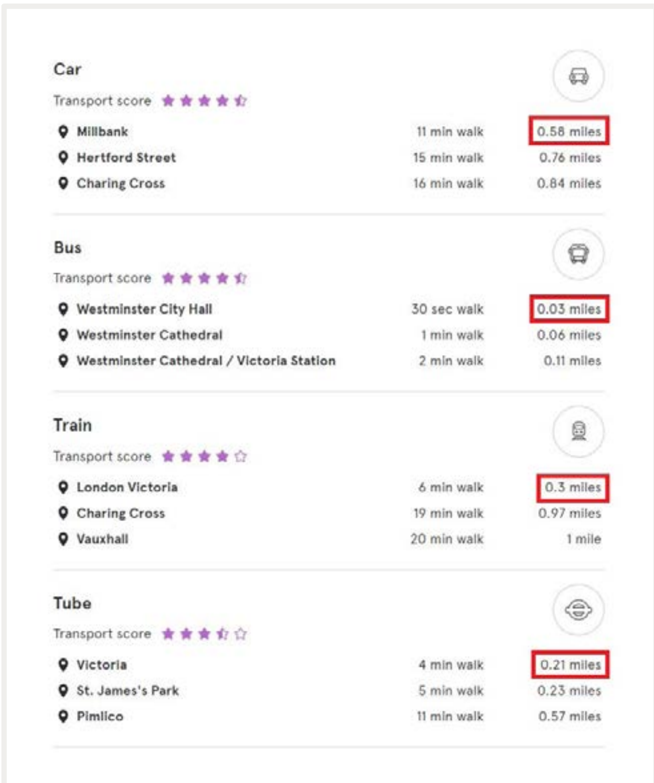


Figure 8 Screenshot of the connectivity of 123 Victoria Street to public transport.

[13]The most relevant websites used for the search are the websites of *Realla, Loopnet, Knight Frank, Savills, Rightmove, Primelocation, Zoopla, Openoffice, Matthews Goodman, Monmouth Dean, CBRE, JLL, and Cushman Wakefield.*

Figure 9 Screenshot of the PDF brochure of 123 Victoria Street.

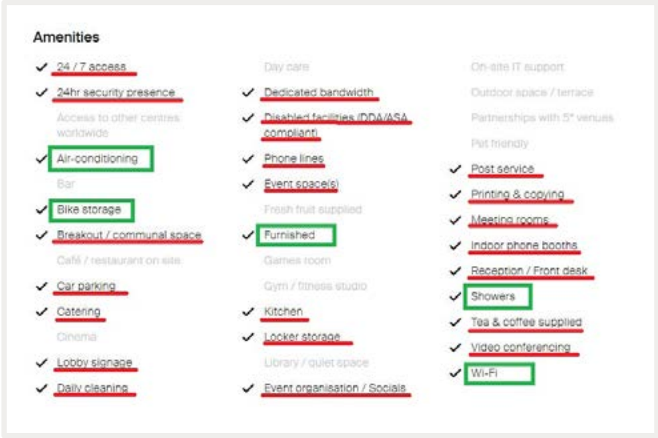


Figure 10 Screenshot of the amenities listed on the Knight Frank website available in 123 Victoria Street.

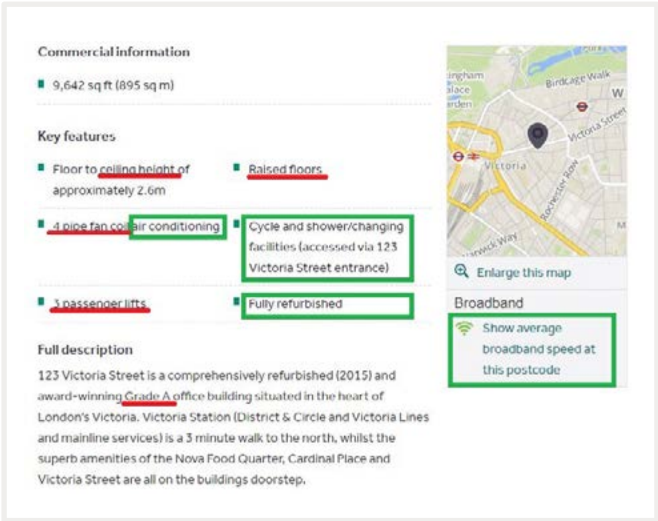


Figure 11 Screenshot of other building features in 123 Victoria Street listed on the Rightmove website.

4.3 Descriptive statistics

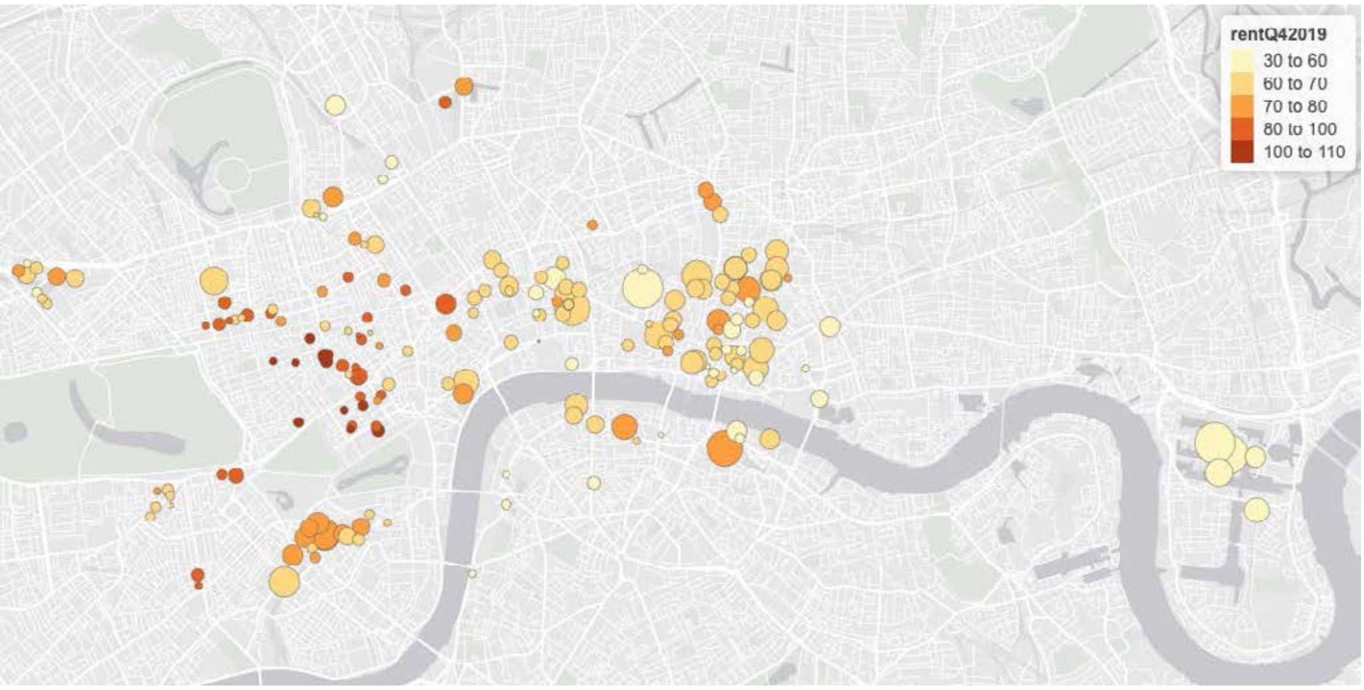


Figure 12 Location of the sample office buildings in London: most of the buildings are in the City of London, Covent Garden, Soho, and Westminster. The rent levels tend to be highest in Soho. Large buildings (dot size corresponds to estimated building size in sqft) tend to be located in Westminster, the City of London, and Canary Wharf.

The location of the office buildings is an important determinant of the achievable rent level, as can be seen in Figure 12, which displays the location of the office buildings in our dataset in central London. While the majority of the sample buildings is located in the City of London, the buildings with the highest rent levels (as measured by the rent level in Q4 2019, i.e. the last quarter before the COVID-19 pandemic) in the dataset are in Soho and Westminster (colour of the dots). Larger buildings tend to be located in the City of London and in Canary Wharf (size of the dots).

Despite the apparent relationship between location and rent levels, hedonic building features also tend to play a role in determining the achievable rent level. In this study, we extend the analysis of hedonic building features from considering solely basic high-level building features such as the size, number of stories, and the building age to a broader set of features. We investigate the rent effect of various specific amenities oriented towards employee-engagement, collaboration, communication and more; in other words, we consider all kinds of building features that could potentially drive workplace productivity, employee engagement and, hence, rent levels.

Figures 13 to 16 provide first insights into the relationship between these amenities and rent levels. Figures 13 and 14 display the distribution of 68 different types of amenities (grouped into ten different categories) in buildings in three different locations in London. For simplicity, we have grouped the different sub-markets into three categories: those in which the average rent level is below £60 per sqft (the postal districts Eastern, North Western, and South Eastern; red), those with an average rent between £60 and £70 per sqft (postal districts Eastern Central and Western Central; white), and those with an average rent above £70 per sqft (postal districts South Western, Northern, Western and Paddington; blue). Both figures reveal differences in the distribution of amenities in the buildings of the different location categories.

For example, while many amenities related to employee collaboration seem to be distributed evenly, conferencing facilities and board rooms are underrepresented in buildings in low-rent rent locations but cluster in higher rent locations. Similarly, sophisticated well-being features such as Wellness or Cinema are only present in higher rent locations. In contrast, communication-oriented amenities seem to be uniformly distributed among buildings in different locations, while there is a clustering of sustainability features in buildings in high-rent locations. Figure

14 furthermore shows the uneven distribution of certificates among the buildings and a some other uneven distributions. For example, there are no buildings in the highest rent locations with very simple Fit-Out (i.e. 'Fit-Out Cat 6 Cabling').

The rent premiums associated with the different types of amenities also differ by location, as shown in Figure 15 and 16. The figure compares the average rent level in buildings with a particular feature with those buildings that do not have this feature in the three location groups. For example, notable features that are correlated with rent differences are Conferencing Facilities and Board Rooms in the low-rent group. Buildings with these amenities in the low-rent locations tend to show a rent level that is more than 20% higher than in buildings without these amenities. In higher-rent locations, there is no such effect. A potential reason for this might be that conferencing facilities and board rooms are a more standard feature in these locations, while it is perceived as a more special feature in lower rent locations.

In general, the rent effect of specific amenities seems to be more pronounced in the low-rent (red) and the high-rent (blue) locations than in the areas with intermediate average rents. In some cases, the rent effects of amenities in magnitude and direction between the different location types. For instance, offices that offer a Category A Fit-Out have a strong negative association to rent levels in locations with an avg. rent of less than £60 per sqft, but a positive association in the high-rent locations.

Amenities related to 'Sustainability' seem to be associated with higher rent levels, particularly in the buildings in high-rent locations. This is most likely because advanced sustainability features such as rainwater harvesting or photovoltaic panels are cost-intensive amenities that can only be installed in expensive developments, which also tend to charge relatively high rent levels. This points to a general difficulty in isolating the relationship between rent levels and individual amenities. In the observational data investigated here, we can not disentangle whether particular amenities drive rent levels or whether it is the high rent levels (and hence expected revenue per sqft) that allow landlords to install particular types of amenities into their buildings.

Figure 16 provides a more detailed picture regarding amenities with potentially relevant rent effects in the categories 'Building Specification', 'Certificates', and 'Food and Service'. Outdoor space seems to be positively correlated with rent levels in all types of

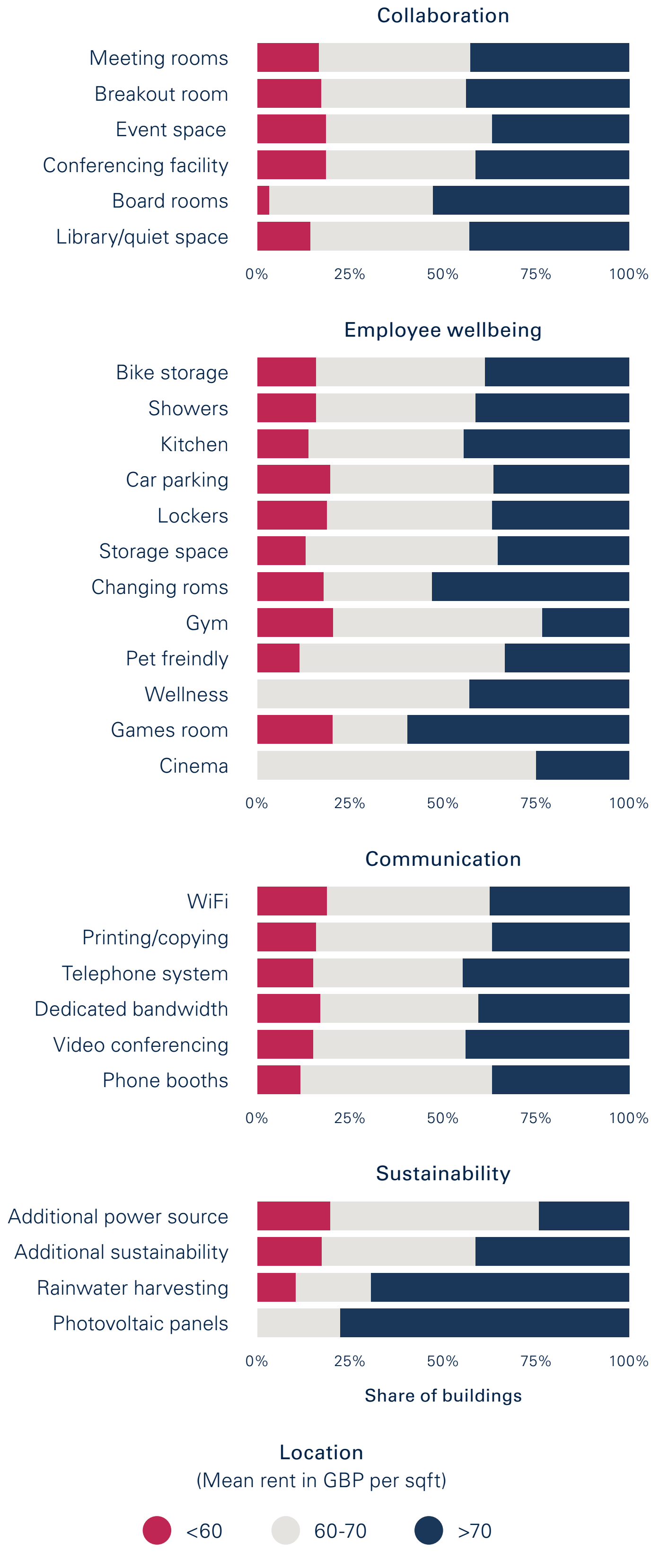


Figure 13 Share of buildings with certain amenities in four groups – Collaboration (top left panel), Communication (top right panel), Employee Well-being (bottom left), and Sustainability (bottom right) – and three location categories: Locations with an average rent (a) lower than £60 per sqft: red, (b) between £60 and £70 per sqft: white, and (c) higher than £70 per sqft: blue.

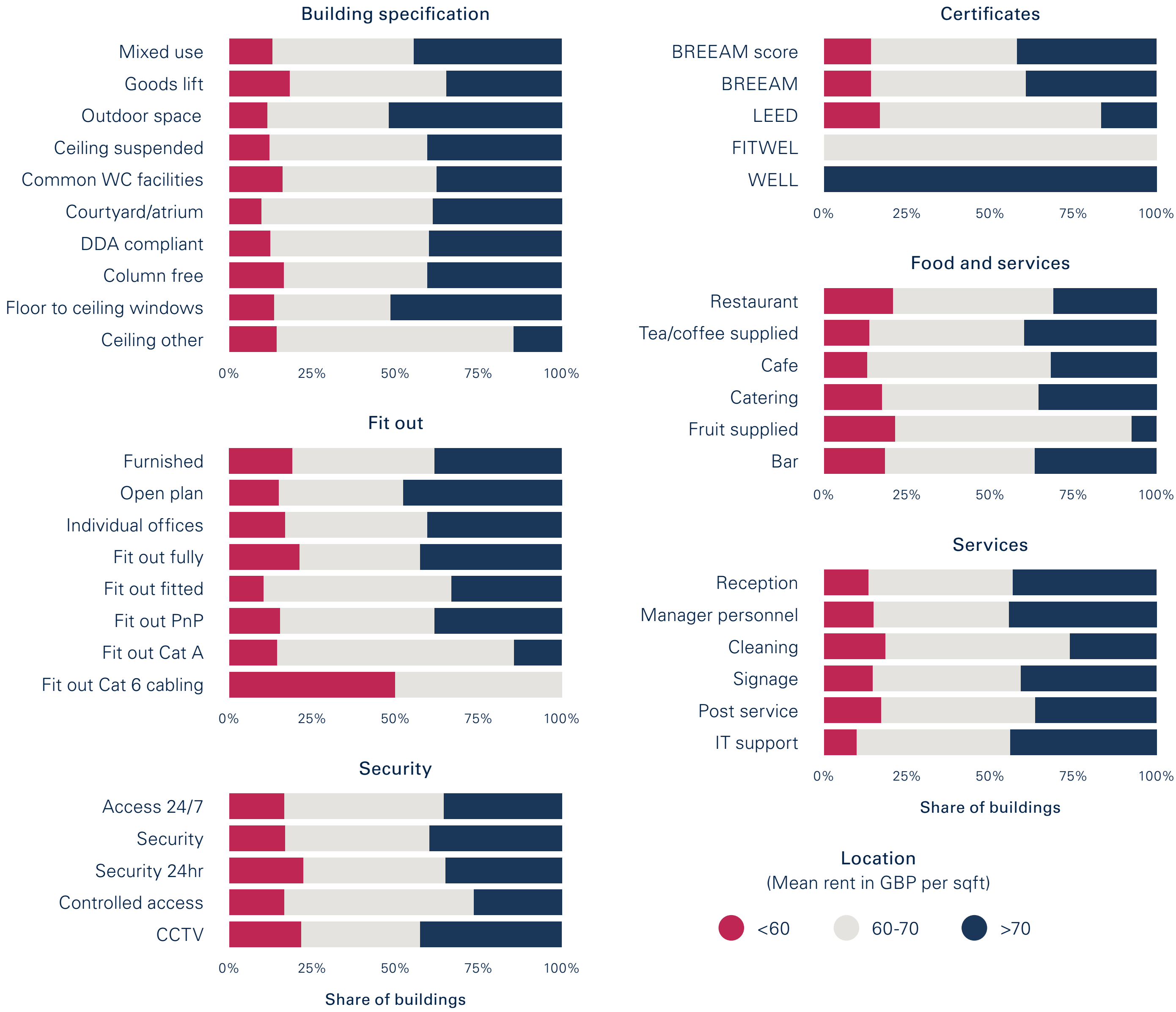


Figure 14 Share of buildings with certain amenities in six groups – Building Specification (top left panel), Certificiates (top right panel), Fit-Out (middle left), Food and Service (middle right), Security (bottom left), and Services (bottom right) – and three location categories: Locations with an average rent (a) lower than £60 per sqft: red, (b) between £60 and £70 per sqft: white, and (c) higher than £70 per sqft: blue.

locations, while mixed-use buildings (office space in combination with retail or other non-office usage) are positively associated only in low-rent locations, and Column Free buildings show a strong positive association only in the group of high-rent locations. In almost all cases, buildings with Certificates, such as WELL, FITWEL, BREEAM, or LEED seem to achieve higher rent levels than their counterparts without certificates. This finding highlights the signalling power that certificates have in providing a quality signal to potential tenants.

Counter-intuitively, buildings in which catering facilities are provided seem to achieve lower rent levels. There is also a negative premium for features from the categories 'Security' and 'Services' in high-rent locations.

Many of the negative correlations are surprising, as some of these amenities are supposed to drive employee engagement and productivity, potentially positively affecting corporate outcomes and, hence, rent levels. Several reasons might explain the lack of positive (or negative) relation to rent levels. First, as it is well-known, rent levels are sticky, and they might not (yet) reflect the positive impact of productivity-enhancing amenities on a building's productivity and rent levels. Secondly, some of the amenities recorded

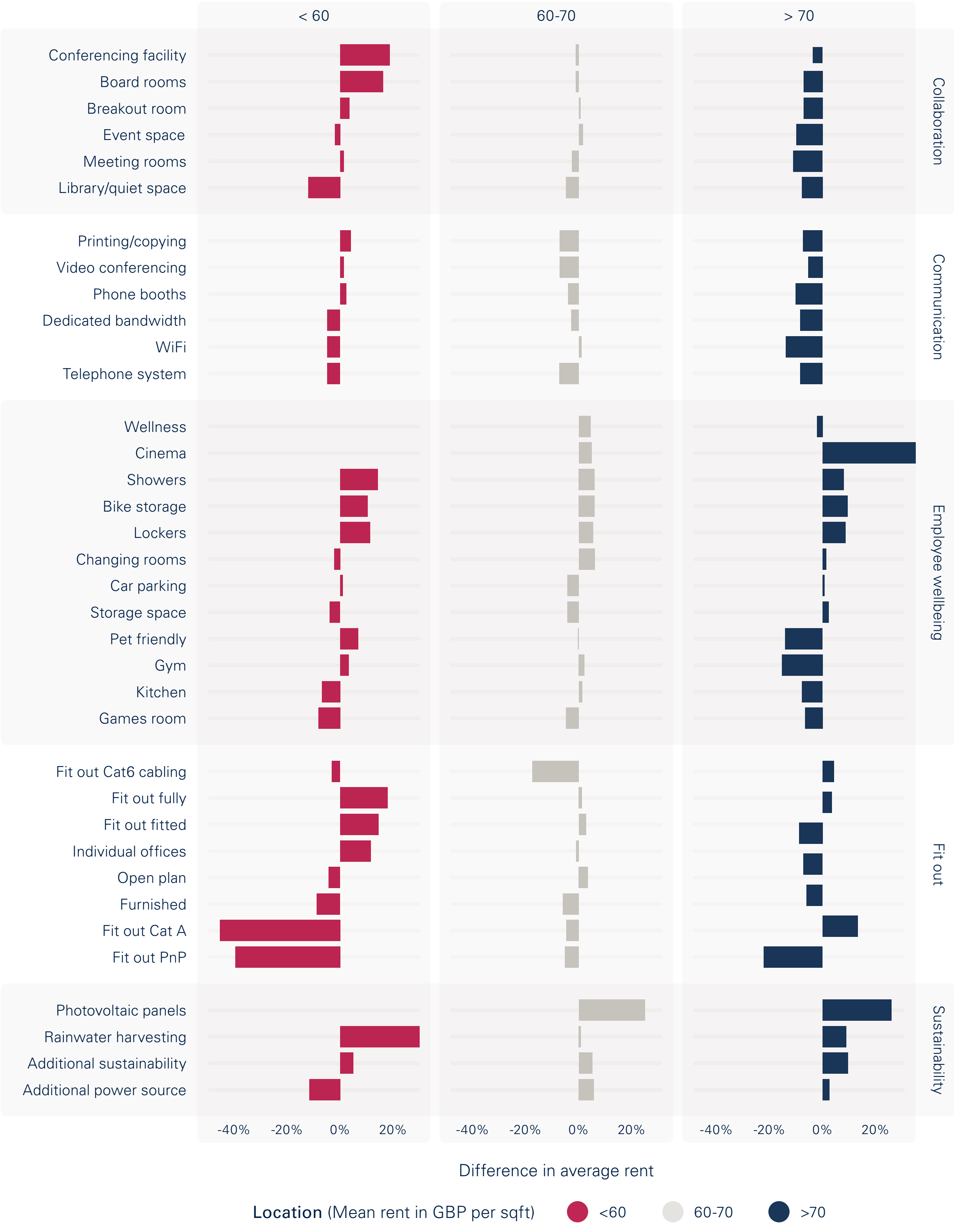


Figure 15 Comparison of average rent levels of buildings with certain types of amenities and those without these amenities in five groups – Collaboration, Communication, Employee Well-Being, Fit-Out, and Sustainability – and three location categories: Locations with an average rent (a) lower than £60 per sqft: red, (b) between £60 and £70 per sqft: white, and (c) higher than £70 per sqft: blue

in the dataset are correlated with certain types of usage, in particular, the presence of coworking spaces. In this case, it might be that productivity-enhancing features drive the rate of hot desks in the coworking space, but these features are not taken into consideration when calculating the rent per sqft.

Thirdly – and this is an interpretation that brings the different positive and negative correlations together – there seems to be a premium for flexibility in the usage of space. Column-free offices tend to achieve higher rent levels. This is because occupiers can fit-out the office as they wish. In contrast, furnished offices and those with all kinds of existing features (gyms, catering, etc.) obtain lower rent levels. This might be because all these features limit the options for occupiers to use the space as they like. In other words, the descriptive results indicate that the current rent levels in London offices do not embrace employee well-being, communication or collaboration. In contrast, they focus on space usage flexibility, leaving the concrete fit out to occupiers.

4.4 Unsupervised statistical learning

The descriptive results provide first insights into the different correlations between amenities and the rent level in office buildings in London. However, the simple descriptive statistics do not allow to control for several confounding factors or to understand the extent to which amenities tend to cluster together. To reveal the more subtle patterns in the data, we have applied two unsupervised statistical learning techniques: *Principal Component Analysis* and *Cluster Analysis*.

The purpose of Principal Component Analysis is to cut down the multi-dimensionality of large datasets with many variables (such as in our case) to a smaller set of linear combinations of these variables – so-called principal components. The principal components are constructed to represent a large share of the overall variation in the data. In other words, the principal components show the main dimensions of variation in the data as they group together variables that often appear together.

Figure 17 visualises the results of a Principal Component Analysis applied to the London office dataset. It shows the first four principal components (i.e. the first four main dimensions of variation in the data). Each cell represents the loading (i.e. the importance) of a variable in each component. Red values represent variables with a positive loading; blue values represent variables with a negative loading. To better highlight groups of similar variables in the plot, an hierarchical clustering algorithm has been applied to identify related groups of variables (see the tree-like dendrogram at the top of the plot).

In summary, the plot shows the loading of 67 binary variables. Abstracting from the loading of individual variables, the figure reveals groups of amenities that are often installed together. For example, Principal Component 1 loads heavily on extras such as CCTV, Security, Dedicated Bandwith, Telephone System, WiFi, IT Support, and other variables from the category 'Communication and Security'. In contrast, Principal Component 2 loads most strongly on variables around Sustainability and particular building features (Outdoor space, Courtyard, Showers, Bike Storage, Open Plan office space, Board Rooms). The third Principal Components is also focused on Sustainability features and well-being (Cinema, Bar, Pet Friendly, Wellness), while the fourth Principal Component does load negatively on well-being features and not very highly most of the other features.

From the Principal Component Analysis, we can conclude that the highly multi-dimensional feature space of more than 60 amenities can be broken down into a smaller set of feature combinations that often appear together in the data.

To shed further light on the patterns in the distribution of amenities and other features in the dataset of London office buildings, we have also conducted a Cluster Analysis (k-means clustering) of the data; a technique that aims to reveal groups of observations that tend to be similar to each other. Table 1 shows summary statistics (median values) of a number of variables in four clusters in each of the three location categories: (a) lower than £60 per sqft: left, (b) between £60 and £70 per sqft: middle, and (c) higher than £70 per sqft: right. In each location group, the cluster with the highest average rent level is highlighted in bold font.

While the clustering algorithm has only considered the 67 binary variables used in the Principal Component Analysis and not the rent level, it reveals clusters of similar buildings that show higher rent levels in the low- and high-rent locations. Only in the areas with intermediate rent levels, the algorithm is not able to identify groups of buildings that differ substantially in terms of rent levels.

In the group of buildings in low-rent locations, the 13 buildings in cluster 2 have an average rent level of £62 per sqft, compared to an average of £54 per sqft for the other buildings in the same type of location. Compared to the other buildings, those in Cluster 2 also

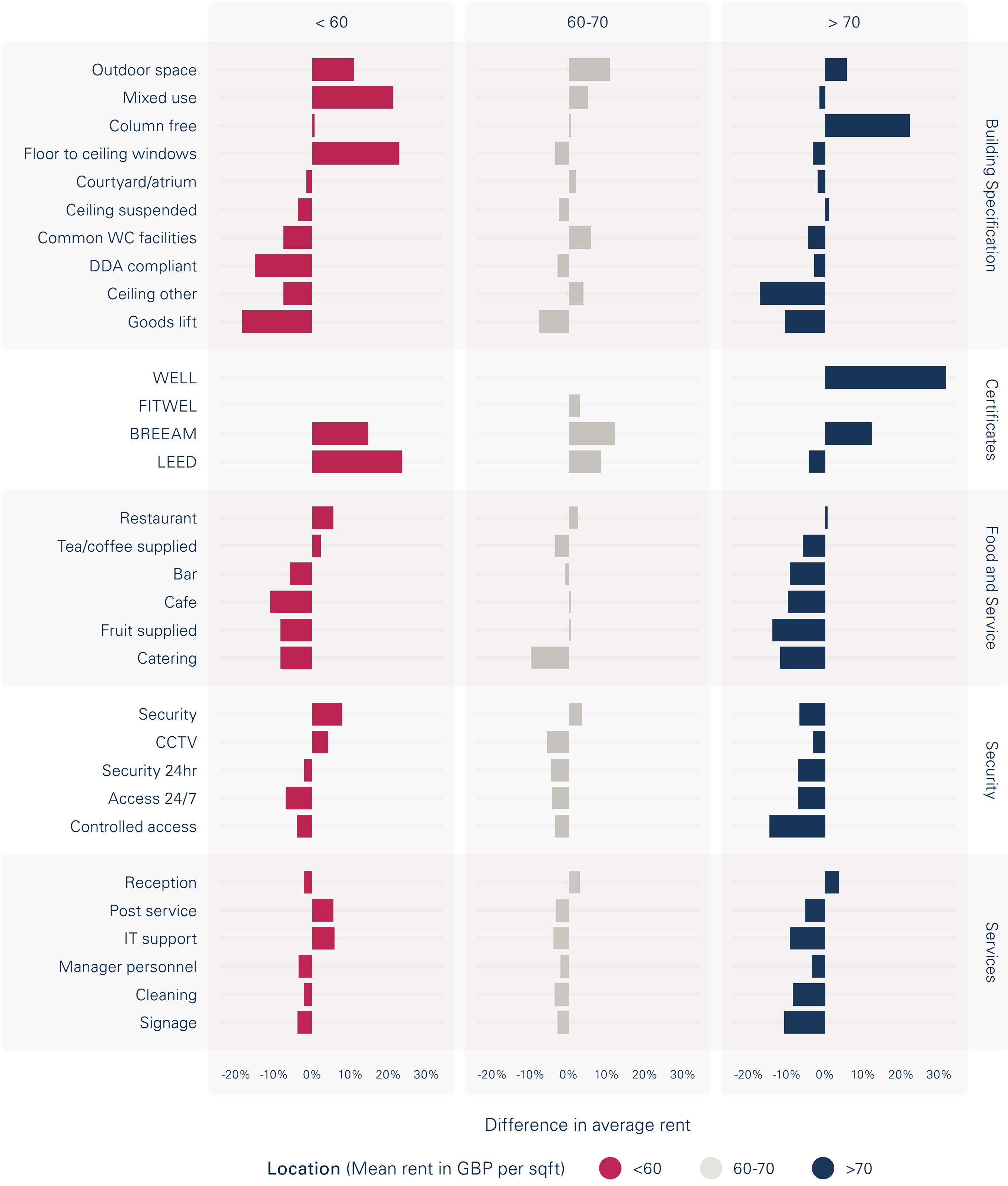


Figure 16 Comparison of average rent levels of buildings with certain types of amenities and those without these amenities groups – Building Specification, Certificates, Food and Service, Security, and Services – and three location categories: Locations with an average rent (a) lower than £60 per sqft: red, (b) between GB 60 and £70 per sqft: white, and (c) higher than £70 per sqft: blue.

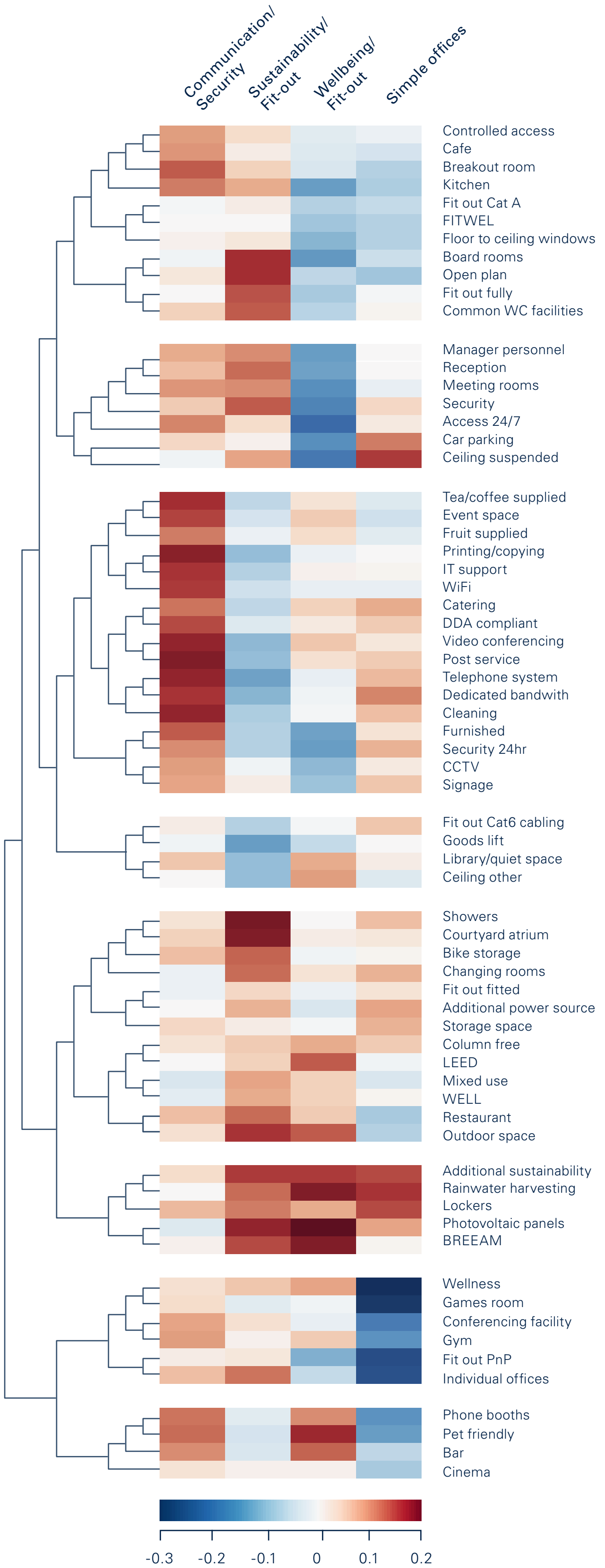


Figure 17 Heatmap of principal component loadings of the four main principal components based on dimensionality reduction of the 67 binary variables in the dataset. The algorithm identifies four main dimensions of data points that show similar characteristics: Communication and Security (PC1), Sustainability and Fit-Out (PC2), Well-Being and Fit-Out (PC3), and Simple offices (PC4).

seem to be smaller (10 stories on average) on larger parcels (1.3 acres on average) and with an intermediate share of amenities. In the high-rent locations, the 38 buildings in cluster 3 show a considerably higher rent level of £82 per sqft compared to other buildings. These buildings, however, seem to have a low share of amenities, in contrast to other buildings with lower rent levels in the top-location group.

This finding corroborates the observation made earlier in the descriptive results section that many amenities are not necessarily related to higher rent levels. Instead, particularly in expensive areas of London, it might be that specific amenities rather have a negative effect on rents as they limit the flexibility of the occupier to design the fit-out as they wish. Furthermore, the unsupervised learning techniques explored in this section show that there are patterns in the data that can be used to train supervised statistical learning models to identify robust associations between rent levels and amenities.

4.5 Machine learning models used for feature selection

The preliminary descriptive results in the Figures 13 to 16 give some insights into the relation between rent levels and amenities. However, the visualisations focusing on comparing average values disregard the correlation between amenities and the relationship to other relevant factors such as basic hedonic building features.

A regression model needs to be implemented to disentangle the individual components that influence rent levels and to provide a statistically accurate representation. However, the number of variables (78 in total) is too large to include them all in a simple regression model. Instead, we need to employ other statistical learning techniques to conduct feature selection to find an effective statistical model.

As a first step, we want to reduce the number of features to a smaller set of amenities that are most likely associated with higher or lower rent levels. To do so, we use a regression analysis method, called LASSO (Least Absolute Shrinkage and Selection Operator), which performs both variable selection and regularisation to provide an accurate and interpretable predictive model. In simple terms, the LASSO regression adds a penalty term to regression coefficients, so that some coefficients can become zero and eliminated from the model, leading to a smaller set of variables and a simpler model.

Table 1 Summary statistics (median values) of office buildings grouped into four clusters according to a statistical clustering algorithm in three location categories: Locations with an average rent (a) lower than £60 per sqft: left, (b) between £60 and £70 per sqft: middle, and (c) higher than £70 per sqft: right. The clustering algorithm is able to identify buildings with higher than average rent levels in the low- and high-rent locations (cluster 2 and cluster 3, respectively), which also show differences with respect to amenities in these buildings compared to other buildings in the same location category.

Location (£ per sqft)	<60				60 - 70				>70			
Cluster (similar buildings)	1	2	3	4	1	2	3	4	1	2	3	4
No. of buildings	5	**13**	12	2	13	**26**	38	**11**	12	27	**38**	6
Avg. rent (£)	50	**62**	55	54	62	**65**	64	**65**	74	70	**82**	68
Building age (years)	17	**18**	16	18	17	**22**	16	**36**	33	23	**12**	10
No. of stories	33	**10**	12	34	18	**9**	10	**10**	8	10	**8**	10
Lot size (acres)	0.9	**1.3**	0.5	1.2	1.2	**0.9**	0.7	**1.3**	0.4	1.1	**0.4**	1.5
Distance to tube (miles)	0.06	**0.18**	0.17	0.07	0.16	**0.13**	0.16	**0.08**	0.14	0.14	**0.16**	0.18
Distance to train (miles)	0.3	**0.4**	0.2	0.7	0.3	**0.2**	0.2	**0.1**	0.4	0.5	**0.7**	0.2
Share of amenities by group												
Building specifications (%)	50	40	20	35	50	**40**	30	**60**	50	40	**30**	55
Certificates (%)	0	25	12	25	25	**25**	25	**25**	25	0	**25**	25
Collaboration (%)	50	33	0	58	50	**33**	0	**67**	50	33	**0**	58
Communication (%)	83	17	0	100	67	**17**	0	**100**	83	17	**0**	100
Employee well-Being (%)	50	42	17	46	42	**38**	25	**58**	46	33	**25**	54
Food (%)	33	17	0	67	33	**0**	0	**67**	25	0	**0**	50
Security (%)	100	60	0	70	80	**40**	20	**80**	70	40	**20**	60
Services (%)	83	33	0	67	83	**33**	17	**83**	67	33	**17**	83

Figure 18 shows the coefficients of variables with a magnitude of more than 0.03 resulting from a Logistic LASSO regression classifying the buildings in the dataset as being higher or lower than the average value of £68 per sqft. The variables are grouped by location/amenity type and sorted by the magnitude and direction of the coefficient. The most critical group of variables, is, little surprisingly, location, which is to be controlled for in the final regression model. From the large set of amenities, the LASSO regression identifies sustainability indicators (BREEAM certificate, the total number of certificates, Photovoltaic Panels, and Additional Sustainability features), Outdoor Space, Showers, and Reception as the most relevant variables that are positively correlated with rent levels. Other variables (Floor to Ceiling Windows, a Plug & Play Fit-Out, Signage, Catering, WiFi, and Controlled Access) are associated negatively with rent levels. Interestingly, the model does not pick up any of the standard hedonic features (number of stories, building age, building size) as relevant variables.

In contrast to simple descriptive statistics, the LASSO regression model considers correlations among a large set of variables simultaneously, reducing the set of variables to a small group of relevant predictors. It is, thus, a suitable method for identifying a reduced set of variables for the application in the final regression model. However, the LASSO regression method does not account for non-linearities or interactions among the predictors, which might drive the rent level.

We have applied tree-based models to identify interactions between amenities and the potential effects these interactions might have in predicting rent levels. Figure 19 visualises a *Decision tree* applied on all 78 continuous and binary variables in the dataset. Starting at the top, the tree aims to split the dataset at each branch in a way that the final leave nodes of the tree at the bottom contain subsets of observations that are as close as possible to each other (in terms of rent levels) and as distinct as possible from other observations in the dataset. In other words, the decision tree aims to identify certain areas of the variable space that predict high vs. low rent levels.

Each node in the decision tree is coloured according to the average rent level of the buildings in the node. For example, in the top node 1 (i. e. before the first splitting of the data), the average rent level is £69 per sqft (first number), and the node contains 100% of the data (second number). The final leave nodes at the bottom vary from a low-rent group of observations (£53 per sqft; 8% of the data) on the left to a top-rent group of observations (£94 per sqft; 6% of the data) on the right.

The tree shows that a small number of splits is sufficient to obtain a relatively clear-cut distinction of observations into high- and low-rent buildings. The decision tree only considers a small subset of all variables in the dataset. Consistent with the previous observations, locations form the most important splitting variables at the top of the tree. For example, buildings that are in the Western postal district tend to have higher rent levels than other buildings - after the first split on node 1: £79 per sqft on average for buildings in this district (node 3) vs. £66 per sqft on average for buildings in other districts (node 2). The next most important group of splitting variables are amenities (Column Free, Certificates, Mixed Use, Furnished, WiFi), further splitting the dataset into subsets of observations with higher or lower rent levels.

In contrast to the LASSO regression, the decision tree, however, also considers basic hedonic features such

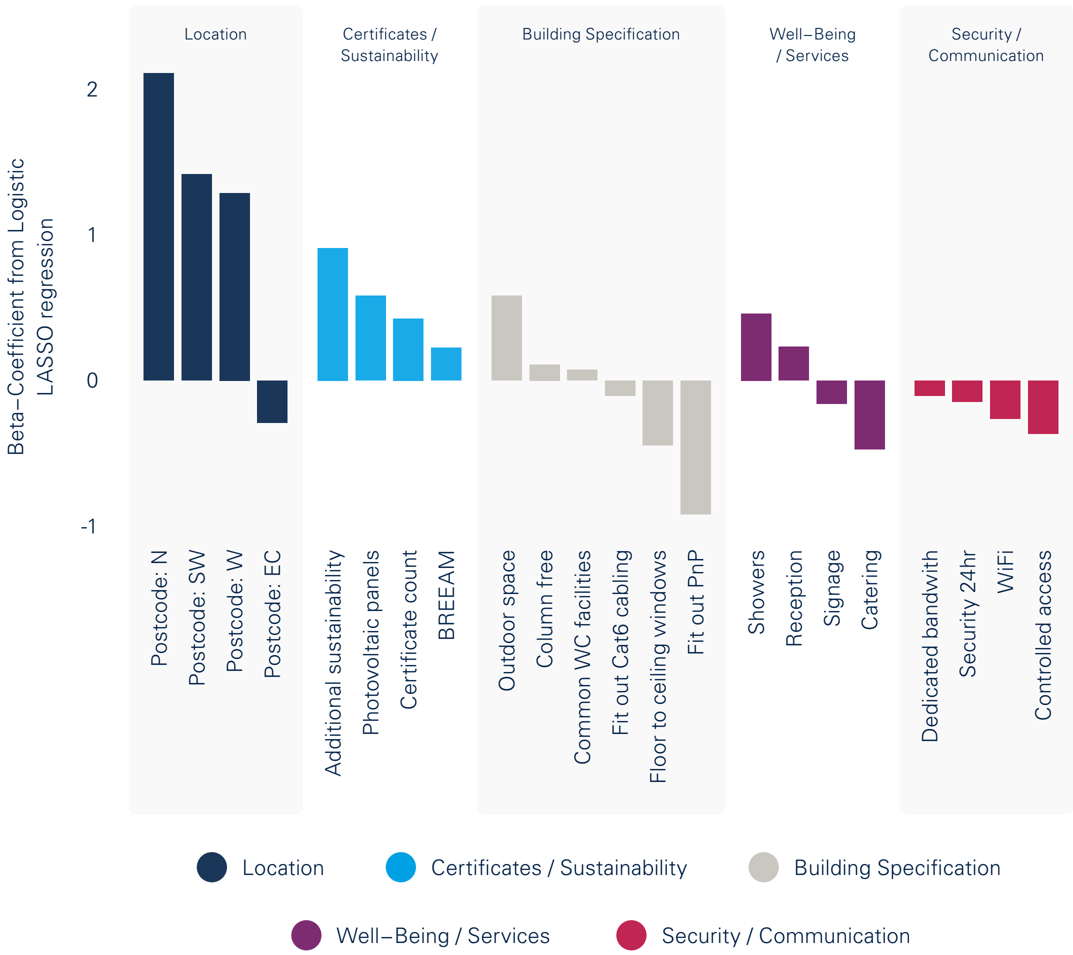


Figure 18 Feature importance scores (β-coefficients from a Logistic LASSO regression with λCV −min = 0.027, i.e. a choice of the λ tuning parameter that minimises the cross-validated error according to the Area Under the ROC Curve measure; for details on the computational implementation in R, see [45]) of variables with coefficients larger than 0.03. In contrast to location variables, other features play a smaller role.

as age and the number of stories as essential splitting variables (eight out of 13 nodes). However, these variables are only considered after amenities and location variables have been used to split the data. In other words, basic hedonic features play a role in predicting rent levels, but they do so only in interaction with other variables and further down in the splitting process.

The interactions revealed in the decision tree visualisation in Figure 19 point towards more intricate, non-linear relationships between the data points. However, the simple decision tree models are path-dependent, i.e. splits at the top of the tree determine the observations that remain in leave nodes, influencing the subsequent splitting of the data. To obtain more robust results from the tree-based model, we have applied a *Random Forest*, an ensemble model that runs 500 trees and provides average importance scores. These scores are displayed in Figure 20. In the figure, three groups of variables are highlighted by different colours: amenities in grey, basic features in red, and postal districts (locations) in blue.

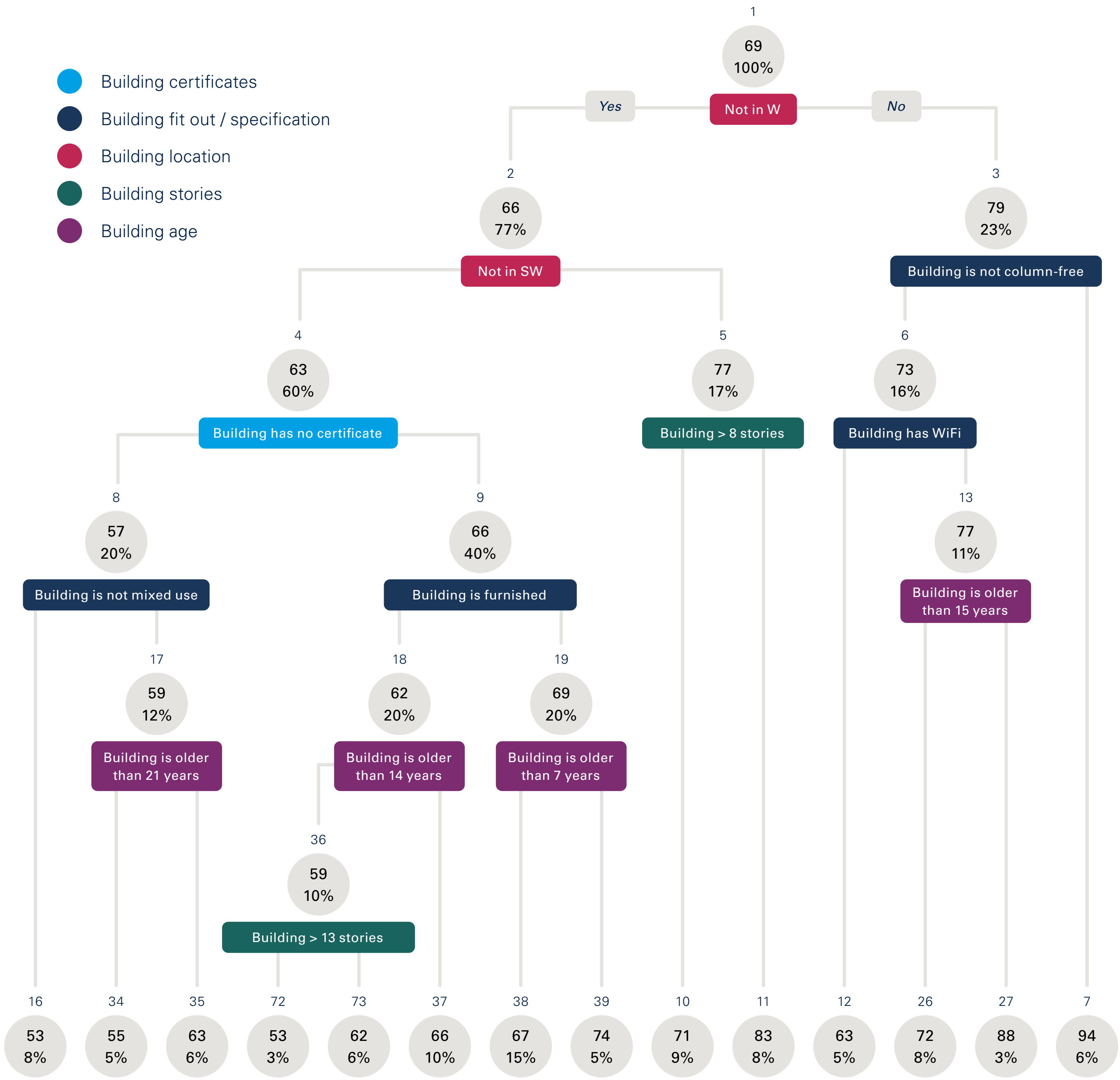


Figure 19 Illustration of a decision tree using all available 78 binary and continuous variables to predict the rent level in Q4 2019, using a complexity parameter of 0.1 (for details on the computational implementation in R, see [46]). The splitting of the variables at different points in the tree underlines relevant interactions in the data.

The Figure corroborates some of the findings from the decision tree shown before. In contrast to the LASSO model, basic features are identified as important variables: all three are listed in the top four of the most relevant variables. Different locations are considered as important splitting variables in the random forest model. After the first 11 variables, the feature importance reduces sharply. Among these variables, only some of the previously identified relevant variables (Column Free, Photovoltaic Panels, Certificate Count) appear, others, such as Outdoor Space, are considered less relevant.

In summary, the LASSO regression and the tree-based models have highlighted a subset of relevant variables from the large set of potential predictors (and the potential role of interactions), which will be used in the final regression model presented in the next section.

4.6 Final regression model

Building on the insights from the previous section about the feature selection and potential interaction effects between the variables, we have run a large number of statistical regression models with different specifications. Table 2 shows the results of the final regression model with the best performance in predicting the rent level in 196 office buildings in London in Q4 2019 (model 6 in the table). The model contains of three main elements: (a) indicator variables for the different postal districts in London to control for location in estimating the rent level, (b) basic hedonic features as they are usually included in empirical studies on real estate markets, and (c) a number of amenities that have been suggested to be relevant by the exploratory machine learning models discussed in the previous section. Moreover, as we use the ordinary

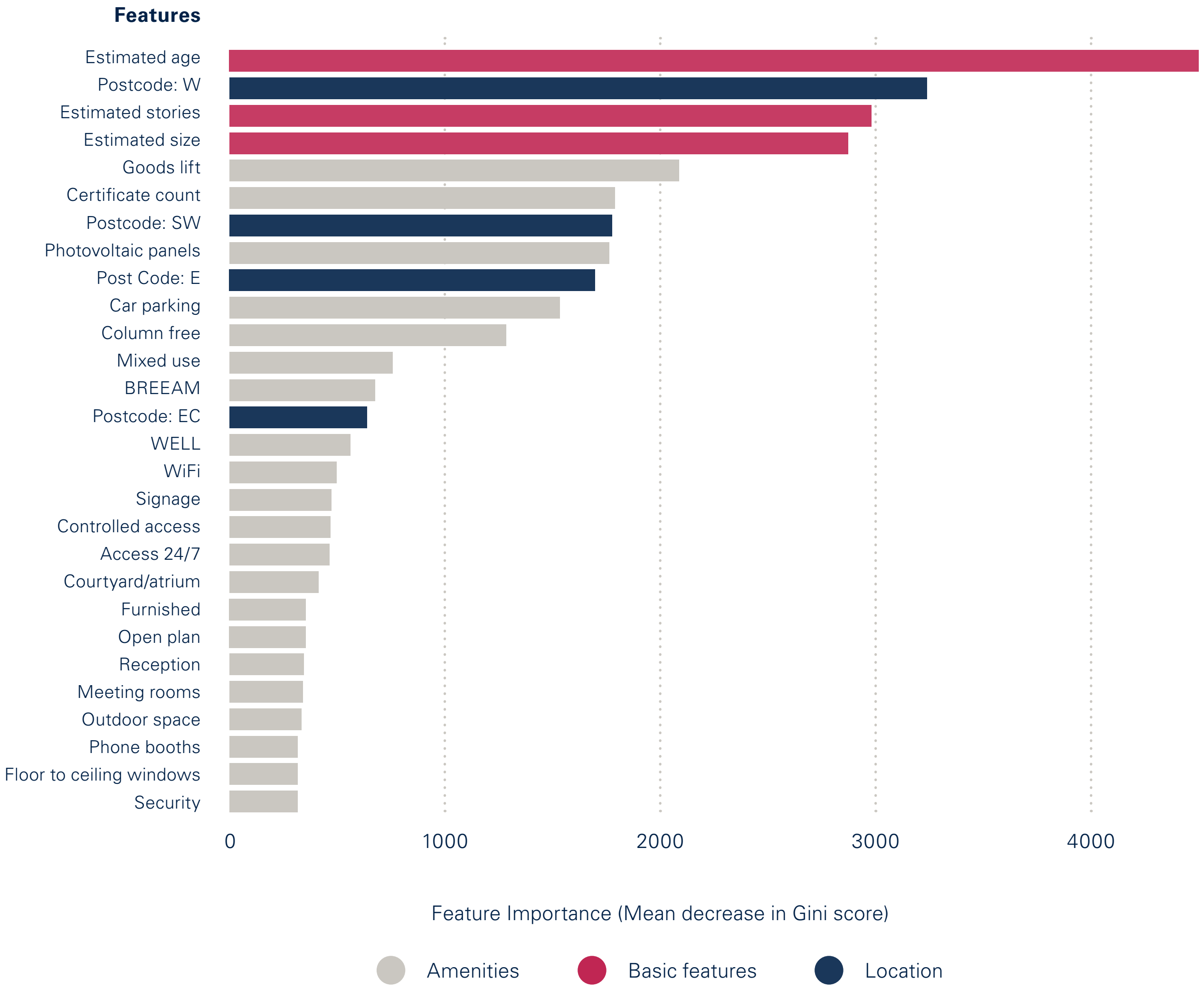


Figure 20 Feature importance scores of different variables from a 500-tree Random Forest regression model predicting the rent level in Q4 2019 with all available 78 binary and continuous variables (feature importance measured by the mean decrease in Gini from splitting on the variable, averaged over all trees; for details on the computational implementation in R, see [47]).

least squares regression approach, the model also contains an intercept. Overall, the model capture more than 60% of the variation in rent levels among the London office buildings (R^2 = 61%). To compare the predictive performance of the model and to infer the changing explanatory power of the different variables over time, Table 2 also includes regression models that aim to explain the rent levels in the 4th quarter of each year in 2014 to 2018, in Q4 2020, and Q2 2020, the last quarter in the dataset.

Confirming the previous observations and in line with real estate theory, location is a significant driver of rents. Compared to the baseline postcode district Western Central, office buildings in Eastern and North Western districts achieve significantly lower rent levels. Buildings in South Eastern, South Western and Western & Paddington achieve significantly higher rent levels. The other districts do not differ substantially from the baseline district. The district with the largest premium is Western & Paddington with £9.30 per sqft compared to Western Central.

Controlling for location effects and amenities, basic hedonic building features (building size, age, number of stories) do little in explaining rent level differences between the buildings. At least to some extent, this is because some features tend to be correlated with the location, i.e. higher or newer buildings might cluster together in certain parts of London. These findings, moreover, illustrate clearly that more detailed datasets help to more accurately identify drivers of rents in office buildings. In the absence of amenities data in the regression model, the coefficients of basic features would have been statistically significant. For example the coefficient of Building age would have been estimated as $b = -2.95$, implying that that every additional year in the age of an office building would reduce the expected rent by £2.95 per sqft on average. The model presented here, however, shows that it is actually amenities (or the lack of certain amenities) that influence rent levels. These amenities, on the other hand, are correlated with the building age, which would have caused the incorrect estimation of building age as a significant predictor in the absence of more detailed data.

Some of the amenities, but not all, show a statistically significant relationship with the rent level, corroborating the interpretation derived from the descriptive results in the previous section. The variables Column Free, Photovoltaic Panels, and No. of Certificates are positively correlated with rents: each certificate that a building has, tends to increase the rent level by £4.10 per sqft. The effect is even larger for the variable 'Column free': buildings without columns show rents that are £5.20 higher per sqft on average than buildings with columns. The largest positive effect comes with photovoltaic panels, which are estimated to increase the rent level by £10.70 per sqft on average. This finding, however, might be a case of reversed causality pointing towards a crucial limitation of the data investigated in this study. While we have time series data for rent levels, the amenities dataset is a cross section only, without time stamps. In other words, we can not know whether photovolatic panels actually increase rents (because they are perceived as highly valued amenity by occupants or because they serve as a sustainability or quality signal to the market), or whether such an expensive amenity is only installed in buildings that have high expected rent levels in any case (maybe because these buildings are in locations with high rents, or photovoltaic panels are only installed in high-rent landmark buildings that are supposed to include advanced technological gadgets).

Other amenities are identified to affect rent levels negatively. For example, offices with Plug & Play Fit-Out, i.e. fully fitted out office suites[14] tend to obtain lower rent levels: on average £9.90 less per sqft. Similarly, WiFi is also estimated to drive rents downwards, by £3.90 per sqft on average. Other variables that are supposed to increase employee satisfaction, engagement or security (Showers, Controlled Access, Outdoor Space) do not seem to have strong statistically significant relationships with rent levels. All the other amenities that are not included in the final regression model also do affect rent levels, if controlled for the variables included in the model.

The best performing model uses only a small set of all the available data to explain a large share of the overall variation in rent levels. The in-sample goodness-of-fit is 61% (R2 = 0.61). The regression model predicts more than half of the overall variation, as shown in Figure 21. The Figure displays the leave-one-out cross-validated prediction accuracy (i.e. all but one observations have been used to train the model to predict the rent level of the excluded observations; this has been conducted for all observations), which averages on 54% in the total sample. Of all observations, more than a third (36%) have a prediction error of less than 5%, and only 13% of the sample have a prediction error of more than 20%. In other words, overall, the parsimonious model displayed in Table 2, model (6) is able to predict the rent level in many office buildings in London with a high accuracy.

How can these results be interpreted? The findings confirm the interpretation developed from the descriptive statistics and the exploratory machine learning approaches. Besides location, which is still a substantial influential factor affecting rent levels,

Table 2 Regression models relating the rent level in £per sqft to (a) location, (b) basic hedonic features, and (c) amenities in a set of London office buildings from 2014 to 2021. Combining the three features explains 33%to 61% of the total variance. Besides location, the most relevant factor driving rent levels seems to be the occupant's possibility to design the office fit-out in a flexible way, as indicated by the positive coefficient for 'Column Free', and the negative coefficients for 'FitOut: Plug & Play' and 'WiFi' (i. e. variables implying a pre-specified fit-out). Additionally, sustainability features ('Photovoltaic Panels' and the 'No. of Certificates') are associated with higher rent levels. Basic features do not have much explanatory power.

Dependent variable: Rent level (£per sqft)								
(a) Location	Q4 2014	Q4 2015	Q4 2016	Q4 2017	Q4 2018	Q4 2019	Q4 2020	Q4 2010
Postcode: EC	−4.6 (3.0)	−3.8 (3.2)	−2.5 (2.8)	−2.7 (2.5)	−3.0 (2.5)	−3.9 (2.6)	0.04 (2.5)	−1.8 (3.0)
Postcode: N	−0.7 (8.1)	6.5 (8.6)	5.3 (7.6)	7.5 (6.7)	11.0 (6.7)	9.2 (7.0)	10.5 (6.9)	12.5 (8.2)
Postcode: SW	4.7 (3.1)	6.3* (3.3)	7.9*** (2.9)	7.0*** (2.6)	6.5** (2.6)	7.8*** (2.7)	7.0*** (2.7)	9.1*** (3.2)
Postcode: W	5.0 (3.0)	6.5** (3.2)	9.3*** (2.9)	7.7*** (2.5)	9.1*** (2.5)	9.3*** (2.7)	9.1*** (2.6)	10.7*** (3.1)
Postcode: E	-13.6*** (4.7)	-11.5** (5.0)	-10.4** (4.4)	-15.2*** (3.9)	-14.6*** (3.9)	-15.1*** (4.1)	-9.4** (4.0)	-11.1** (4.8)
Postcode: NW	-10.7** (5.1)	-12.5** (5.4)	-9.0* (4.8)	-9.7** (4.2)	-8.7** (4.2)	-9.4** (4.4)	-8.2* (4.4)	-8.3 (5.2)
Postcode: SE	0.8 (5.1)	-7.7* (4.0)	-7.6** (3.5)	-6.1* (3.1)	-6.1* (3.1)	-6.0* (3.3)	-3.7 (3.2)	-5.4 (3.8)
(B) Basic features								
Estimated Size (sqft)	−0.4 (1.2)	−0.6 (1.3)	−0.5 (1.1)	−1.1 (1.0)	−0.5 (1.0)	−0.5 (1.0)	−0.5 (1.0)	−0.8 (1.2)
Estimated Age (years)	−0.05 (0.7)	−0.001 (0.8)	−0.3 (0.7)	−0.4 (0.6)	−0.8 (0.6)	−0.8 (0.6)	−0.6 (0.6)	−0.7 (0.7)
Estimated Stories	−1.1 (2.5)	−1.1 (2.6)	−0.3 (2.3)	−0.6 (2.1)	−0.8 (2.1)	−0.7 (2.2)	−0.5 (2.1)	−1.0 (2.5)
(c) Amenities								
Outdoor Space	1.1 (1.8)	1.9 (1.9)	2.7 (1.7)	2.4* (1.5)	2.6* (2.5)	2.5 (1.5)	2.6* (1.5)	2.8 (1.8)
Column Free	4.3** (2.0)	4.9** (2.2)	5.2*** (1.9)	4.9*** (1.7)	4.3** (1.7)	5.2*** (1.8)	5.1*** (1.7)	6.9*** (2.1)
FitOut: Plug & Play	-6.6* (3.6)	-5.8 (3.8)	-7.3** (3.4)	-8.2*** (3.0)	-8.7*** (3.0)	-9.9*** (3.2)	-9.4*** (3.1)	-9.9*** (3.7)
Showers	-0.1 (2.0)	0.7 (2.1)	-0.1 (1.8)	1.3 (1.6)	2.0 (1.6)	2.9* (1.7)	2.9* (1.7)	3.8* (2.0)
Controlled Access	-3.4* (2.0)	-2.8 (2.1)	-3.4* (1.9)	-2.0 (1.7)	-2.7* (1.6)	-2.9* (1.7)	-2.6 (1.7)	-3.1 (2.0)
WiFi	-3.3* (1.7)	-3.4* (1.8)	-2.8* (1.6)	-3.4** (1.4)	-3.3** (1.4)	-3.9** (1.5)	-3.4** (1.5)	-4.2** (1.8)
Photovoltaic Panels	-0.7 (3.9)	-0.8 (4.1)	6.8* (3.6)	6.8** (3.2)	5.9* (3.2)	10.7*** (3.4)	10.2*** (3.3)	11.8*** (4.0)
No. of Certificates	0.9 (1.1)	1.2 (1.2)	1.1 (1.1)	2.0** (0.9)	2.6*** (0.9)	4.1*** (1.0)	3.7*** (1.0)	4.5*** (1.2)
Constant	71.9*** (12.7)	75.8*** (13.5)	73.6*** (12.0)	78.1*** (10.6)	71.4*** (10.5)	71.7*** (11.0)	63.0*** (10.9)	68.7*** (13.0)
Observations	114	146	163	178	188	196	197	197
R^2	0.33	0.35	0.47	0.54	0.56	0.61	0.54	0.56
Adjusted R^2	0.26	0.29	0.42	0.50	0.52	0.57	0.50	0.51
Res. Std. Error	10.7	11.3	10.0	8.9	8.8	9.3	9.1	10.9
F Statistic	4.8***	5.4***	8.8***	11.6***	12.7***	15.5***	11.7***	12.3***

Note: *p<0.1; **p<0.05; ***p<0.01

amenities that allow for a flexible fit-out are correlated with higher rent levels. The pricing of space in the London office sector does not seem to take employee well-being, satisfaction, or workplace productivity into account, as can be seen by the insignificant coefficient estimates of many amenities. Offices that limit the freedom of occupiers on how to use the space, for example, because they offer a Plug & Play Fit-Out, or they have invested in communication or security amenities tend to see a negative premium on the rent. In other words, the market seems to pay a premium for office space that gives occupiers maximum flexibility with respect to how they want to fit-out and use the space. Landlords, property managers, and agents seem not to have a financial incentive to invest in or to advertise productivity-enhancing amenities or technologies. These features come not only with additional costs, but they limit the freedom of occupiers on how to use the space, which result in lower rent levels achievable in the current market environment. Sustainability features and certificates seem to mark an exception. Buildings with these features are associated with higher estimated rent levels. This might be because such features constitute a quality signal to the market, which is picked up by potential tenants or occupiers.

In contrast, amenities that do not contribute to higher rents might not be perceived as relevant quality signals. It could also be – this is not unlikely, given how difficult it was for us to collect the amenities dataset – that potential tenants do not know about the amenities or that the market as a whole has not yet derived a price signal from these amenities, because there is currently no established methodology to list amenities and alternative forms of data in an accessible and comparable way or to evaluate their market potential (as shown in the chapter on common real estate valuation methods).

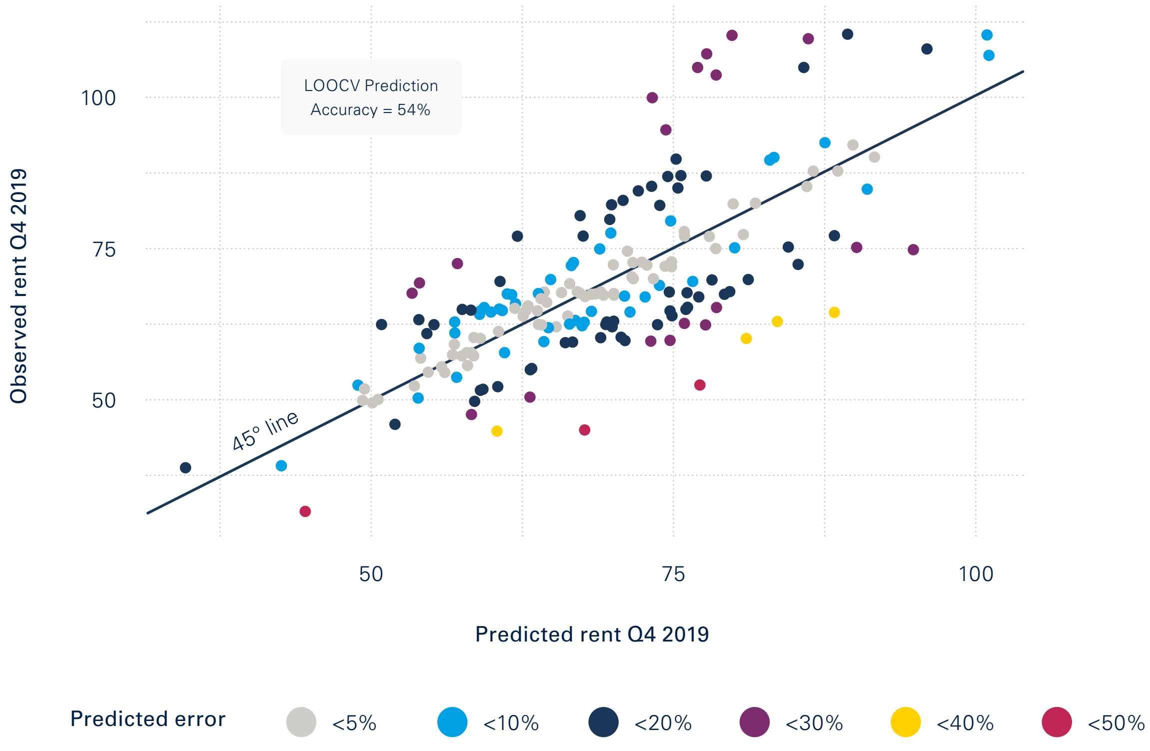
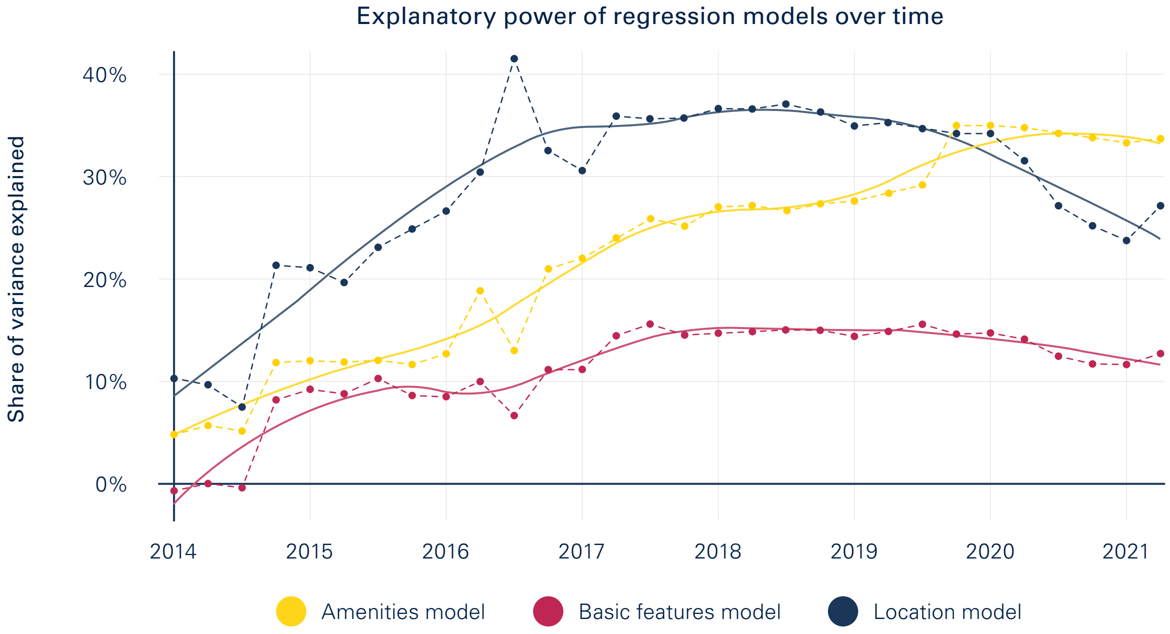


Figure 21 Leave-one-out cross-validated predictive accuracy of the final regression model. Using all but one observation as training data to predict the rent level of the excluded observation yields an overall average prediction accuracy of 54%, i. e. the final regression model can predict more than half of the overall variation in rent levels with a small set of variables capturing (a) location, (b) basic hedonic building features, and (c) amenities.

[14]More details on the trend towards different forms of office Fit-Out are described here: http://www.mixinteriors.com/property/plug-and-play-offices-the-new-normal/.

While the regression model identifies only a few amenities as statistically significant contributors to rent predictions, the importance of amenities in predicting rent levels has been growing over the past years, as shown in Figure 22. The figure displays the share of explained variance (R2) from 90 regression models over the past 30 quarters: in each quarter starting in Q1 2014, the rent level is regressed onto location variables (part (a) of the Table 2), basic hedonic building features (part (b) of the Table 2), and amenities (part (c) of the Table 2). In addition, in the lower panel, the figure shows the share of missing rent-level observations in the dataset over time.



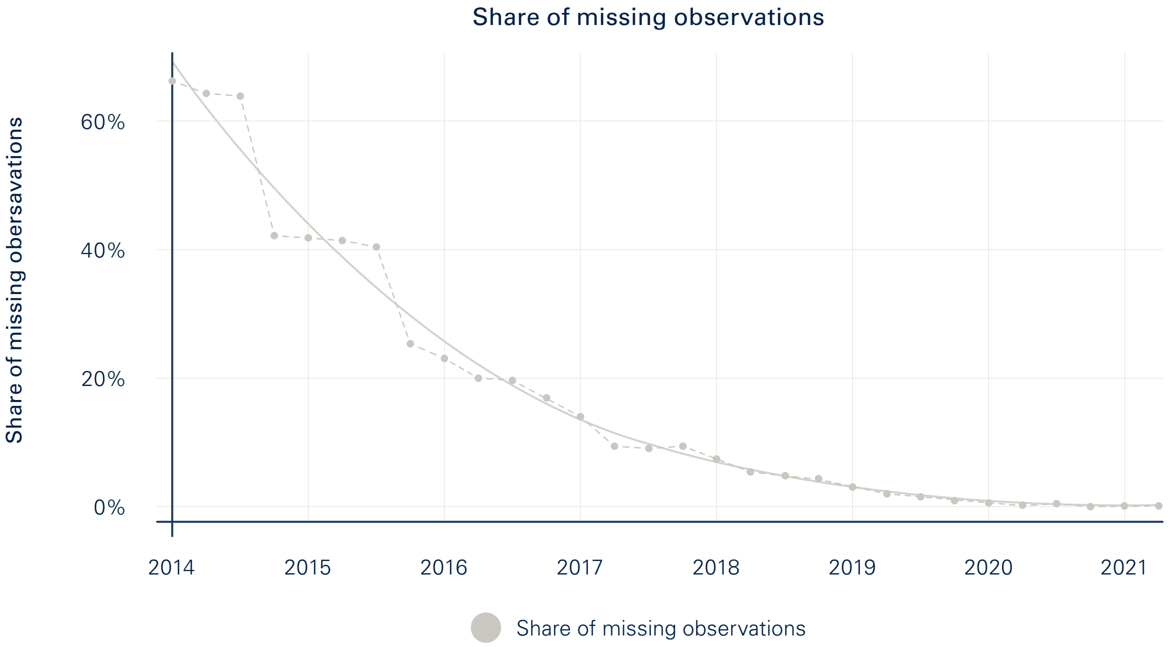


Figure 22 Regression models over time, relating the quarterly rent level in the set of London office buildings from 2014 to 2021 to location factors only (blue), to basic hedonic building features only (red), and to amenities only (orange). While the importance of location remained constant from 2017 to 2019, it became less important in the time of the COVID-19 pandemic, amenities became a more relevant factor in explaining rent levels throughout the complete observation period. The lower panel shows the share of missing observations in rent levels over time.

The figure suggests that, in general, the explanatory power of the variables included in the regression models increased over time. This is most pronounced in the case of location factors, a finding that is most likely driven by the reduction in missing values over time. In other words, a lower share of missing observations tends to be correlated with higher statistical accuracy of the models. This is because more data points tend to increase the power of statistical learning algorithms. That effect is more relevant for the early years of the time series data, where the share of missing observations is decreasing faster than in the later observations, for which we have almost a complete dataset.

Independently of this statistical effect, which is not affecting the differences in explanatory power between the three types of models at a given point in time, the figure shows how location, basic hedonic features and amenities change in their relative importance in explaining the rent levels in the set of London office buildings over time.

From 2017 to 2020, the overall relevance of location in explaining rent levels did not change. In other words, while having been the most crucial individual determinant of prices in the office sector, the location did not become more important in recent years. In contrast, the location became less relevant throughout the COVID-19 pandemic in 2020 and 2021. The most recent data point from Q2 2021, however, might already point towards a recovery of location as a key determinant of rents.

Similarly, basic hedonic features stayed essentially constant in their contribution to rent levels. They explain only a minor share of the variation in rent levels compared to location, but this share has remained stable since 2014.

On the other hand, amenities saw a constant and consistent rise in importance throughout the observation period. Their relevance increased from less than 5% in 2014 to almost 35% in 2021, overtaking location as the most crucial individual determinant of rent levels. In contrast to location, the relevance of amenities in explaining rent levels did not decrease during the pandemic, pointing towards a relative rise of importance in recent years.

The findings presented here provide empirical evidence towards a trade-off between location, occupiers' freedom of choice, employee well-being, amenities, and rent levels, which change over time. The application of unsupervised and supervised statistical learning tools has enabled us to identify a quantitative relationship between all these factors in the current market for office space in London with a unique dataset. The analysis reveals a number of features that correlate positively or negatively with rent levels, but it also poses a number of open questions with respect to the interpretation of the findings and the role of data management and the market's capability to process relevant information in valuating commercial real estate in the age of big data.

5. Conclusion

This report addresses social, environmental and technological trends shaping the future of office space. We develop a quantitative research methodology that provide new insights into these trends. The statistical model assesses the contribution of amenities and technologies in explaining the rent levels in a sample of office buildings in London.

First, we discuss recent trends in the office sector, such as the COVID-19 pandemic's impact on remote working, the platformisation of commercial real estate, and the sharing economy's role. Next, we provide a brief history of ESG and commercial real estate. This can be broken into factors surrounding capital works and real estate occupancy. The main contribution of the report is in section 4: we provide an in-depth quantitative analysis using state-of-the-art statistical and machine learning tools to derive a robust quantitative relationship between rent levels and workplace technologies in a sample of office buildings in London. In contrast to previous studies on the value drivers of commercial real estate, which often had to rely on datasets containing only basic hedonic features, our study could use a uniquely granular dataset, which we manually collected from various web sources.

Our results indicate that, in addition to location, specific amenities – particularly those related to environmental sustainability – matter in predicting rent levels. However, many features that are supposed to drive employee engagement or workplace productivity do not correlate with rent levels. Instead, features related to the occupiers' flexibility in fitting out office space to their preference seems to be associated with higher rent levels. From the empirical findings, we draw the conclusion that the current real estate market in London values flexibility, and to some extent, sustainability. Location is still a key driver of commercial rents, but building features are becoming a more relevant determinant. Standard building features (such as height or age), however, do not seem to play a major role in predicting rent levels. The findings point toward data gaps as an important bottleneck of more transparency in the real estate market. The market will only be able to correctly assign a premium to features that are supposed to drive the productivity of the workplace if standardised data in high volumes is made available regarding individual amenities, technologies, and building features.

Our findings have implications for real estate research and practice. The granular dataset used in this study revealsmore nuanced correlations between building features and rents than currently used, state-of-the-art datasets that only contain basic features. Deriving conclusions from such data might obscure the actual drivers of real estate value, which could lead to the misallocation of investments, if recommendations are derived from such research. Instead of yielding final conclusions with respect to rent drivers, the findings call for further research and for the development of an industry-wide data strategy. The lack of up-to-date, accurate, and detailed information on the building level is the most relevant bottleneck for evidence-based decision making and investments in technologies and amenities influencing workplace productivity and employee engagement. As long as there is not enough data in the market for occupiers and tenants to account for the presence of particular amenities in making their rental decisions, there will be no incentive for landlords and property managers to invest in these amenities.

The data collection methodology presented here could help overcome the data limitations. It could serve as a prototype for an automatised approach to collect relevant building information from public web sources alone. To do so, the data collection methodology would need to be rolled out to a larger sample of office buildings in London or other locations and tracked over a longer period of time using data mining and machine learning to automatically identify and collect relevant data points. Then, the methodology would yield a granular and comprehensive data set on rents, building features, and amenities that could be used to conduct longitudinal studies. This could lead to a quantitative understanding of the evolving market value of workplace productivity and employee engagement technologies in the built environment.

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