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URBAN HOUSE PRICE GRADIENTS IN THE POST-COVID-19 ERA

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- the Centre for Entrepreneurship, SMEs, Regions and Cities (CFE),
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It contributes to the OECD Horizontal Project on Housing Policies for Sustainable and Inclusive Growth: Phase II.

Authorised for publication by Luiz de Mello, Director, Policy Studies Branch, Economics Department.

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ABSTRACT / RESUME

Urban house price gradients in the post-COVID-19 era

The COVID-19 pandemic has led to a significant shift in the way people work, with an increasing number of individuals opting to work from home. Fewer commutes allow people to live further away from the city centre, where jobs typically concentrate. Against this background, this paper tests the hypothesis of a shift in housing demand away from the city centre towards the suburbs using a novel granular house price data set covering 16 OECD countries. The results indicate a flattening of the house price gradients in most large urban areas with profound consequences for housing policies and the city of the future.

Keywords: housing, COVID-19, working from home, teleworking, digitisation, geospatial economics

JEL classification codes: R31, O18

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Gradients de prix des logements urbains dans l'ère post-COVID-19

La pandémie de COVID-19 a profondément modifié la manière de travailler, dans la mesure où elle a conduit un nombre croissant de personnes à choisir de travailler depuis leur domicile. La plus faible fréquence des trajets domicile-travail permet de vivre plus loin du centre-ville, dans lequel se concentrent généralement de nombreux emplois. Dans ce contexte, cet article teste l'hypothèse d'un remodelage de la demande de logements depuis les centres-villes vers les zones périphériques en utilisant un nouvel ensemble de données géographiques sur les prix des logements au niveau métropolitain dans 16 pays de l'OCDE. Les résultats indiquent un aplatissement des gradients de prix des logements dans la plupart des grandes zones urbaines, avec des conséquences profondes pour les politiques de logement et la ville du futur.

Mots clés : logement, COVID-19, télétravail, travail à distance, numérisation, transformation numérique, économie spatiale

Classification JEL: R31, O18

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Urban House Price Gradients in the post-COVID-19 era

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Introduction

1. Housing demand varies considerably within metropolitan areas. Following the seminal work by Alonso (1964[1]), Mills (1967[2]) and Muth (1969[3]), a large body of the economic literature has studied the relationship between distance to labour markets and residential real estate prices. Jobs and urban amenities are concentrated in the central business district, where space for residential structures is scarce. As citizens strive to reduce commuting time and costs, demand declines with the distance to the centre. As a result, house prices and rents generally fall with distance from central business districts in a pattern that is usually called a negative "house price gradient" consistent with the modelling assumption for "monocentric cities".

2. Digitalisation is reshaping housing location choices with increased adoption of remote work enabled by the spread of high-speed internet and advances in remote conferencing (OECD, 2021[4]). The adoption of working-from-home (henceforth WFH) has reduced commuting costs, which influences the intra-city allocation of jobs. Indeed, less frequent commuting makes far from the urban core residential areas more attractive, broadening the range of location choices. For instance, a worker who used to commute five times a week for thirty minutes might accept commuting three times a week for fifty minutes (Figure 1).

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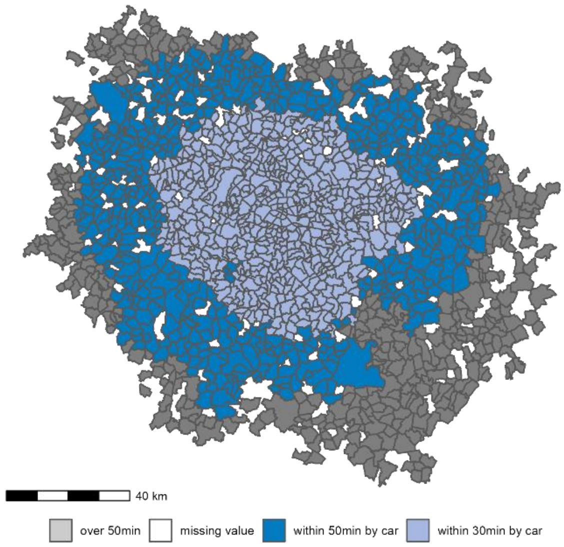
[1] Volker Ziemann, Manuel Bétin, Maria Paula Caldas, Boris Cournède and Pierre-Alain Pionnier are members of the OECD Economics Department; Rüdiger Ahrend, Alexandre Banquet and Marcos Díaz Ramírez of the OECD Centre for Entrepreneurship, SMEs, Regions and Cities, Daniel Sanchez Serra of the OECD Statistics and Data Directorate and Paolo Veneri of the Gran Sasso Science Institute. This work was conducted as part of the OECD Project on Housing Policies for Sustainable and Inclusive Growth. An earlier version of this paper was dicussed by the Working Party No. 1 on Macroeconomic and Structural Policy Analysis of the Economy Policy Committee on 17 March 2023. Preliminary results were discussed by the Regional Development Policy Committee at its 13 May 2022 meeting. The authors are grateful to the Delegates of Working Party No. 1 of the Economic Policy Committee and the Regional Development Policy Committee for their comments The authors would also like to thank Christophe André (OECD Economics Department) for his review. They are also indebted to Luiz de Mello and Alain de Serres (OECD Economics Department) for their comments on earlier drafts and guidance and insights throughout the project, Nathalie Bienvenu (OECD Economics Department) for editorial support as well as Claire Hoffmann (OECD Centre for Entrepreneurship, SMEs, Regions and Cities) and Francesco Palermo (OECD Statistics and Data Directorate) for substantial statistical support. Correspondence: volker.ziemann@oecd.org.

Figure 1. 5x30=3x50 minutes: working-from-home widens the potential residential area

Access to economic and social activity, Metropolitan area of Paris

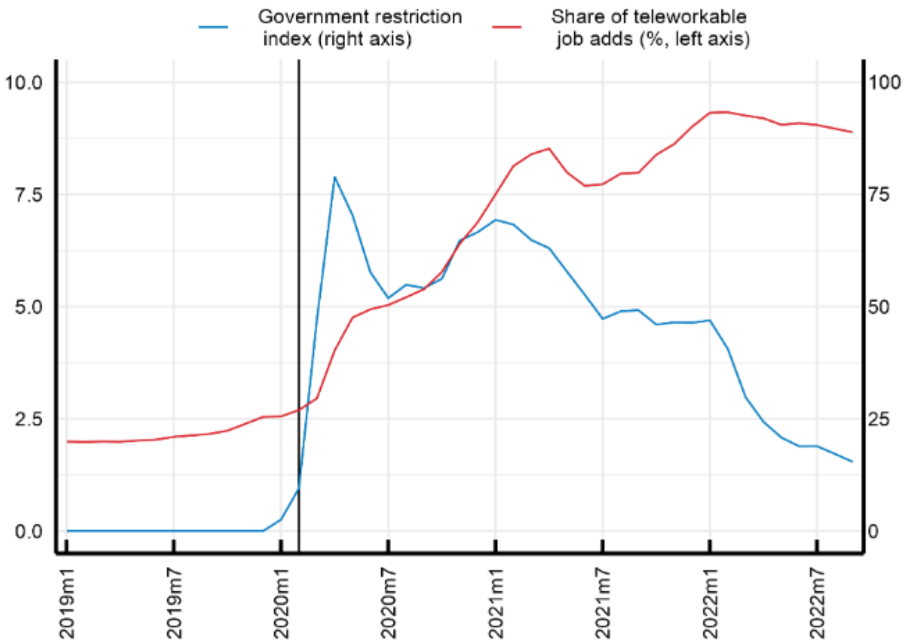


Note: Access to economic and social activity proxied by accessibility of 500 restaurants within 30 (50) minutes by car.
Source: OECD Urban Access Framework (OECD/ITF, 2019[5]).

3. The ramifications for housing markets can occur between and within cities (Brueckner, Kahn and Lin, 2021[6]). When full WFH is possible, or workers change jobs, inter-city movements can occur with a rebalancing of residential house prices from highly productive cities with low amenity endowments to less productive cities with high amenity endowments. Within cities, changes in residential preferences and more widespread adoption of at least partial WFH suggest that highly productive centres continue to attract highly productive jobs but allow workers to disconnect their places of work and residence (Aksoy et al., 2022[7]; Van Nieuwerburgh, 2022[8]; Dingel and Neiman, 2020[9]). In addition to WFH, the increasing development of e-commerce services for retail shopping may contribute to reassessing the need for proximity to local amenities and commercial real estate (Rosenthal, Strange and Urrego, 2022[10]; Hoesli and Malle, 2022[11]; Lashgari and Shahab, 2022[12]).

4. Before the pandemic, remote work was slowly gaining ground. The pandemic has sharply accelerated this trend, as containment and mitigation measures forced many companies to implement full WFH almost overnight. There are increasing signs that partial remote work is becoming the norm in many sectors. Surveys and job postings confirm that remote work is set to remain much more prevalent after the COVID-19 pandemic than before (Figure 2).

Figure 2. Remote work is here to stay



Note: The stringency of restrictions is measured with the Oxford COVID-19 Government Response Tracker (Hale et al., 2021[13]). Based on job data using proprietary information contained on the online job site "Indeed" for 20 countries, see the source for methodological detail.
Source: "Will it stay or will it go? Analysing developments in telework during COVID-19 using online job postings data" (Adrjan et al., 2021[14]).

5. With more than three years since the pandemic started, there is a growing body of evidence that seems to confirm initial anecdotes of flattening intra-city house price gradients in large metropolitan areas. Gupta et al. (2022[15]) show that house prices and rents have declined in most US metropolitan city centres while prices and rents have increased away from the centre, translating into a flattening of the urban house price gradient. The extent to which gradients decline depends on the intensity of working from home and the supply responsiveness to changing housing preferences in cities. Huang, Pang and Yang (2022[16]) show that the onset of COVID has reduced both the gradient in Chinese cities as preferences have shifted towards low-density areas associated with lower infection risks. Gokan et al. (2022[17]) found a significant reduction in the house price gradient in the London area.

6. Several authors have underscored the importance of remote work for the spatial redistribution of work and living places. Gokan et al. (2022[17]) illustrate how the rise of WFH among skilled workers triggers not only a flattening of the land-price gradient but also fundamentally restructures the distribution of local service provision and job opportunities for unskilled workers. Above a certain threshold, WFH turns gentrified cities into doughnut cities where the city centre not only loses attraction as a residential area for skilled workers but WFH also disrupts the business model for office spaces and local service providers. Kim and Long (2022[18]) demonstrate that lower congestion levels on the back of more WFH reduce commuting costs even for (often lower-skilled) workers who cannot work remotely, further reinforcing the gradient-flattening effect of WFH.

7. This paper builds on earlier OECD Housing Horizontal Project work (Ahrend et al., 2022[19]), to shed fresh light on the new geography of housing demand in urban areas across 16 OECD countries. This report extends the dataset of small area unit house prices to 16 countries, uses new estimates of construction from machine-learning analysis of satellite imagery and presents novel econometric analyses investigating the existence and evolution of urban house price gradients. It draws policy conclusions on how housing policies can be tailored to the new geography of housing demand in the post-COVID-19 era.

Going granular: new data sources to track local housing markets

The OECD Geography of Housing Demand Database

8. The heterogeneous effects of the COVID-19 pandemic on labour markets and household preferences have underscored the need for disaggregated information to assess changes in residential mobility within the commuting area of the same metropolitan area. To this end, the OECD, supported by a network of public and private data providers, has assembled the Geography of Housing Demand (GHD) database of housing transaction prices for 16 countries at the smallest administrative unit available (Table 1). In most cases, the data are made available by national statistical agencies that collect them to compile house price indices (HPIs). France and the United Kingdom publish open-source data for every single transaction. Finally, private data operators from Germany ("vdpResearch"), Portugal ("Confidencial Imobiliário") and Sweden ("Svensk Mäklarstatistik") agreed to provide confidential granular house price data.

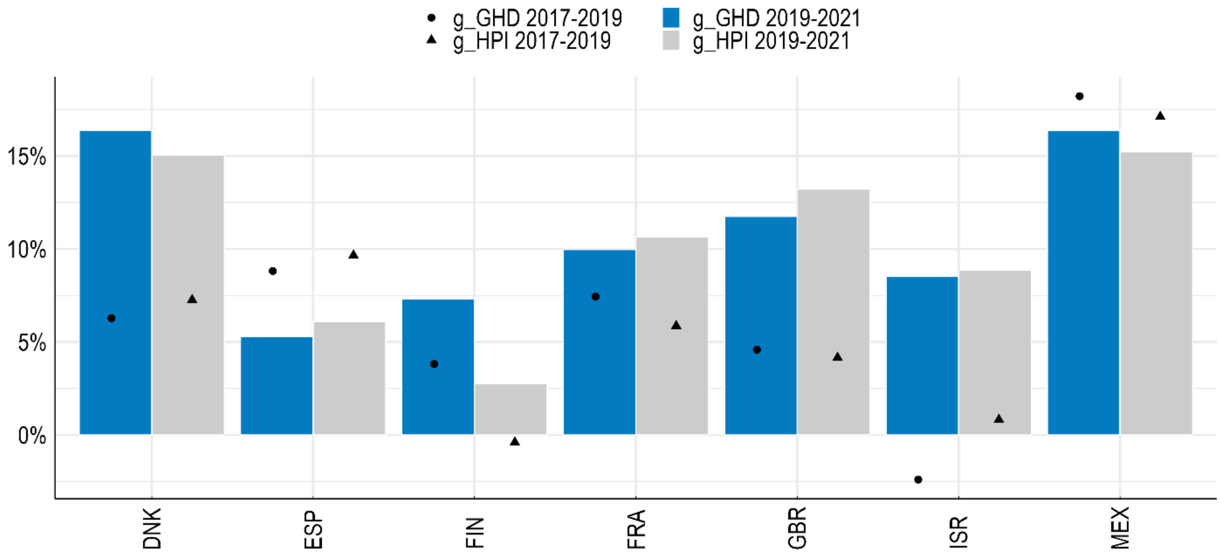
Table 1. Data sources and coverage by country

	Coverage			Local house price variable	Geographical units	Source
	Period	Population (%)	Area (%)			
AUT	2015Q1 - 2022Q1	62	24	Median price per m²	955 municipalities	Statistik Austria
BEL	2010Q1 - 2021Q4	94	77	Average price per m²	532 municipalities	STATBEL
DEU	2018Q1 - 2021Q4	74	60	Average price per m²	4,413 postal codes + 121 districts	vdpResearch
DNK	1992Q1 - 2022Q1	46	25	Average price per m²	582 postal codes	Statistics Denmark
ESP	2007Q1 - 2021Q3	92	51	Average price per m²	5400 municipalities +31 districts	INE
FIN	2010Q1 - 2021Q4	81	37	Average price per m²	225 municipalities	Statistics Finland
FRA	2014Q1 - 2021Q4	86	66	Median price per m²	1571 communes + 273 districts	Demande de valeurs foncieres
GBR	1995Q1 - 2022Q3	86	62	Average prices per type of	8,382 postcode sectors	UK Price Paid data
HUN	2008Q1 - 2022Q1	92	74	Average price per m²	2889 Settlements + 23 Districts	Hungarian Central Statistics
ISR	2006Q1 - 2021Q4	65	12	Average price per m²	798 cities	Central Bureau of Statistics
KOR	2018Q1 - 2021Q4	81	26	Average price per m²	250 municipalities	MOLIT
MEX	2016Q1 - 2021Q4	54	2	Average price per m²	10705 zip codes	Sociedad Hipotecária Federal
NOR	2006Q1 - 2022Q1	65	12	Average price per m²	56 large municipalities + 11	Statistics Norway
PRT	2009Q1 - 2021Q4	44	8	Average price per m²	1,222 parishes	Confidencial Imobiliário
SWE	2015Q1 - 2021Q4	90	98	Average price per m²	275 municipalities	Svensk Mäklarstatistik
USA	1996Q1 - 2022Q3	96	56	Zillow Home Value Index	29,827 zip codes	Zillow Research Institute

9. While official HPIs are adjusted for quality differences between dwellings sold in different periods, house prices in the GHD database are only scaled by the surface of the corresponding dwellings. The various data sources do not include detailed dwelling characteristics, preventing further quality adjustment. Nevertheless, a strong correlation between the evolutions of house prices in the GHD database and quality-adjusted HPIs is necessary to ensure that local residential market developments tracked by the GHD database are meaningful (Pionnier and Schuffels, 2021[20]). Figure 3 compares the growth rates of quality-adjusted HPIs and GHD prices during the pre-COVID period (2017-2019) and the period since the COVID outbreak (2019-2021) for 86 regions in seven countries.[2] The results suggest that discrepancies are minor, with substantial differences arising only in Mexico and Israel.

[2] From the 16 countries in the GHD sample, the United States is excluded from the consistency analysis because the number of transactions is not available and the Zillow house prices are model-based and already incorporate quality and representativity adjustments. Austria, Belgium, Germany, Estonia, Hungary, Portugal, Korea and Sweden are

Figure 3. GHD data broadly consistent with quality-adjusted HPIs



Note: The figures compare growth rates of prices per square meter weighted by the number of transactions in the GHD database with growth rates of quality-adjusted House price indices (HPI) published by national statistical agencies.
Source: GHD database, OECD database on national and regional HPIs, OECD calculations.

10. The average numbers might hide cross-regional heterogeneity within countries. Figure 4 (Panel A) suggests that GHD prices and quality-adjusted HPIs are broadly consistent at the regional level, except for Spain and Mexico. In France, the United Kingdom and Denmark, discrepancies[3] are broadly similar in all regions and lower than three per cent. In contrast, in Spain and Mexico, discrepancies are large for some regions. Still, they tend to decrease with population size, which is consistent with the view that differences in the quality of dwellings transacted in different periods are averaged out when there are enough transactions. Accordingly, the following econometric analysis will weigh observations by the number of transactions to reduce potential measurement errors.

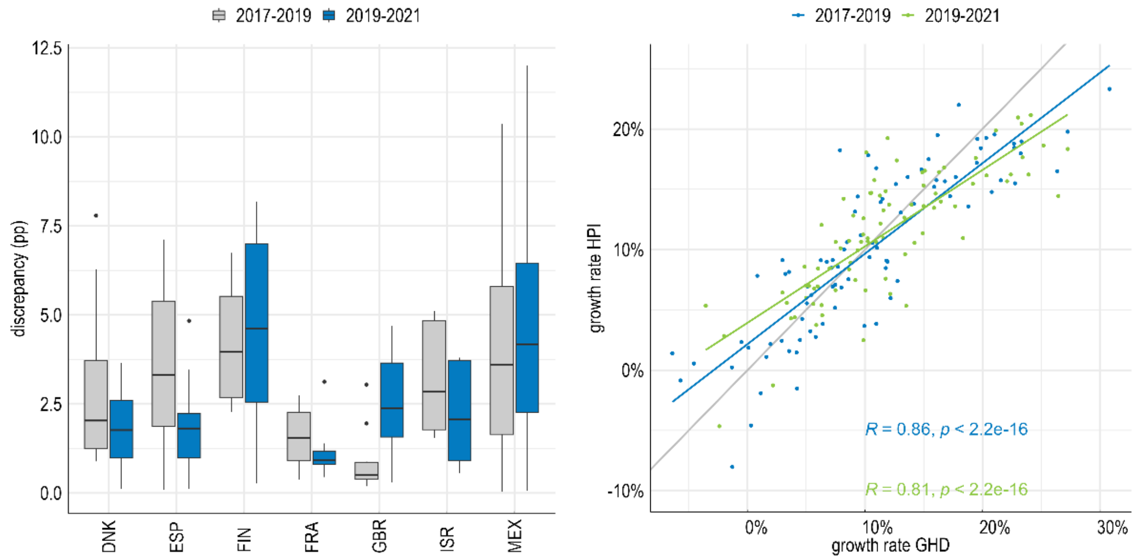
excluded because quality-adjusted HPIs do not exist at the sub-national level or cannot be mapped with the information in the GHD database. The obtained sample includes 86 regions from seven countries.

[3] Discrepancies are computed as the absolute value of the differences between the growth rate of HPI and the growth of GHD.

Figure 4. Strong correlation between quality-adjusted HPIs and GHD at the regional level

A. Distribution of GHD-HPI growth discrepancies

B. Correlation between GHD and HPI growth rates



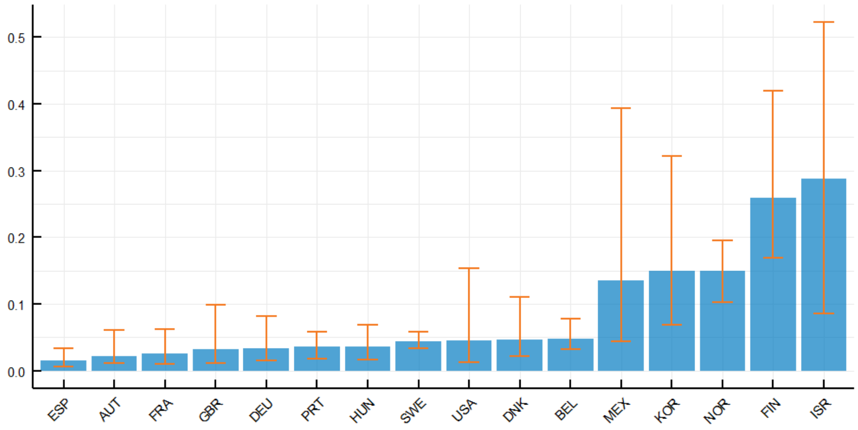
Note: The figures compare growth rates of prices per square meter weighted by the number of transactions in the GHD database with growth rates of quality-adjusted House price indices (HPI) published by national statistical agencies. Panel A shows the distribution of the discrepancy between HPI and GHD, computed as the absolute difference between the 2-year regional house price growth rates. The top (Bottom) of the rectangles denotes the 75th (25th) percentile. Each dot in Panel B represents a region (HPI) matched to an FUA (GHD).
Source: GHD database, OECD database on national and regional HPIs, OECD calculations.

A granular measure for new residential construction

11. As with all market prices, house price changes reflect demand and supply forces. Accordingly, interpreting price shifts as pure demand shifts might be inaccurate. While supply can be assumed fixed over short time horizons, supply adjustments cannot be ignored over the medium to long term, even after considering long construction delays and general scarcity of constructible land in dense urban areas. New geospatial data sources analysed with machine-learning algorithms open the door to tracking construction activity in quasi-real-time. Recent OECD work has built an image segmentation model on Sentinel satellite imagery using the Copernicus Urban Atlas as a training set to identify and track different forms of land use, notably including "residential", "commercial and industrial", "transport infrastructure", "open space" and "water and wetlands" (Banquet et al., 2022[21]). The change in built-up residential areas from 2019 to 2021 provides a proxy for the new construction of residential buildings (Figure 5).

Figure 5. The dynamism of residential supply differs across countries

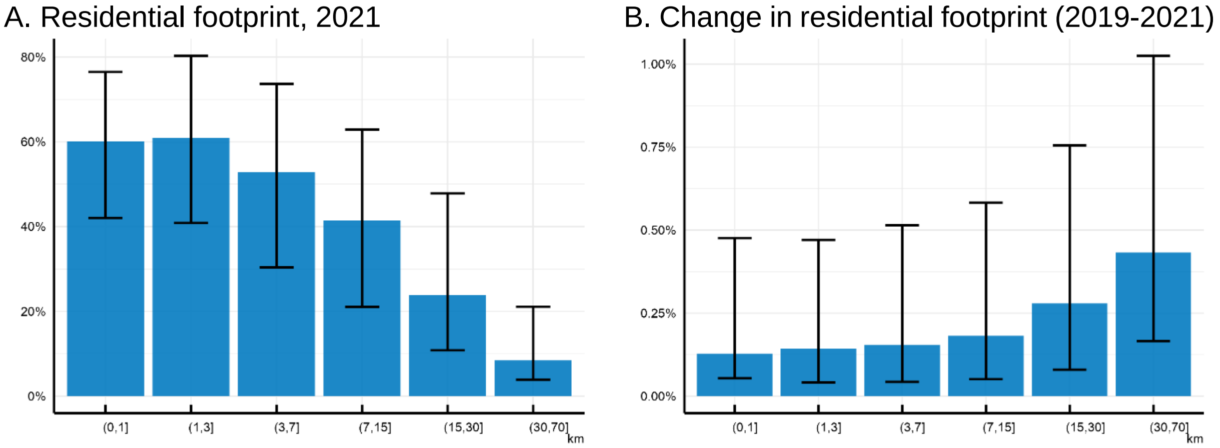
Percentage point increase in the share of residential land use by local unit, 2019-21



Note: Blue bars denote the median expansion of the residential footprint across each country's local units. Error bars indicate respectively the 25th and the 75th percentile of the increase in residential land use across units.
Source: "Monitoring land use in cities using satellite imagery and deep learning", (Banquet et al., 2022[21]).

12. The distribution of land use within Functional urban areas (FUAs) corroborates stylised facts for population densities as the share of residential land declines with distance to the FUA centre (Figure 6, Panel A). Interestingly, over the period from 2019 to 2021, satellite images suggest that residential construction activity was more buoyant in peripheral districts (Figure 6, Panel B). In areas experiencing strong demand for housing, additional supply is expected to attenuate the pressure on house prices. Accounting for local residential construction activity thus allows for delineating housing demand dynamics better. Indeed, rising house prices could reflect scarce supply, buoyant demand, or both. Disentangling these dynamics is essential to assess the new geography of housing demand.

Figure 6. Residential construction activity increases with distance to the FUA centre



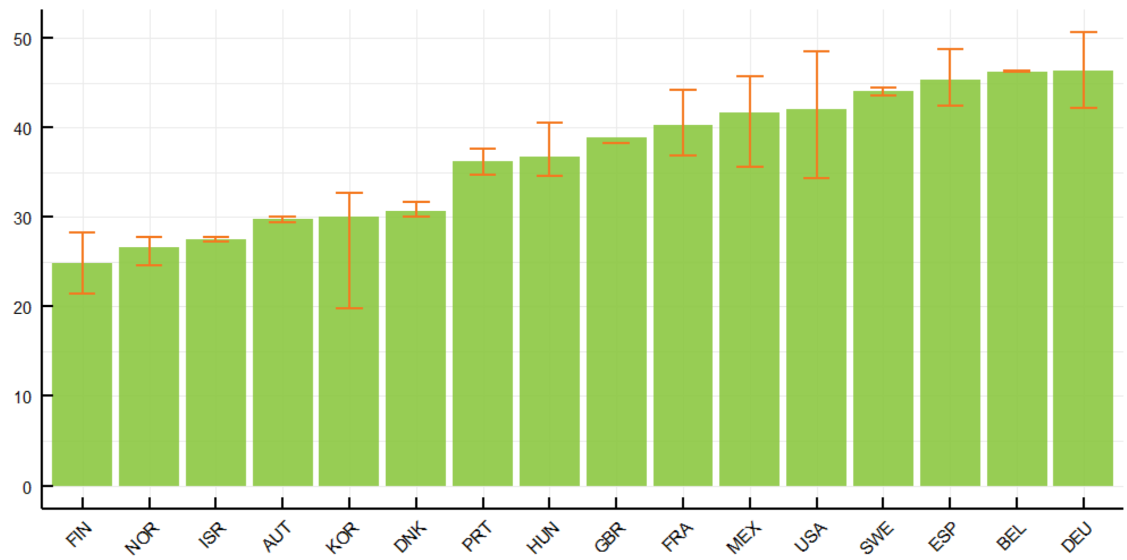
Note: The figures illustrate the share (Panel A) and its change (Panel B) of residential land use by distance bracket (distance being the distance to the FUA centre). Blue bars show the medians within a distance bracket, while the error bars illustrate the 25th and the 75th percentiles.
Source: "Monitoring land use in cities using satellite imagery and deep learning" (Banquet et al., 2022[21]) and OECD calculations.

Measuring the adoption of WFH practices at the regional level

13. The pandemic and the ensuing containment measures have boosted the share of employees working from home (Figure 7). Worker surveys measuring the uptake of WFH are difficult to compare across countries, especially outside Europe. To overcome this difficulty, web search data have been used to compare the adoption of working from home across regions. Web search queries typical for WFH have been used, as they show a tight statistical link with survey results where both sources are available (Figure 8).

Figure 7. Adoption of WFH varied across and within countries

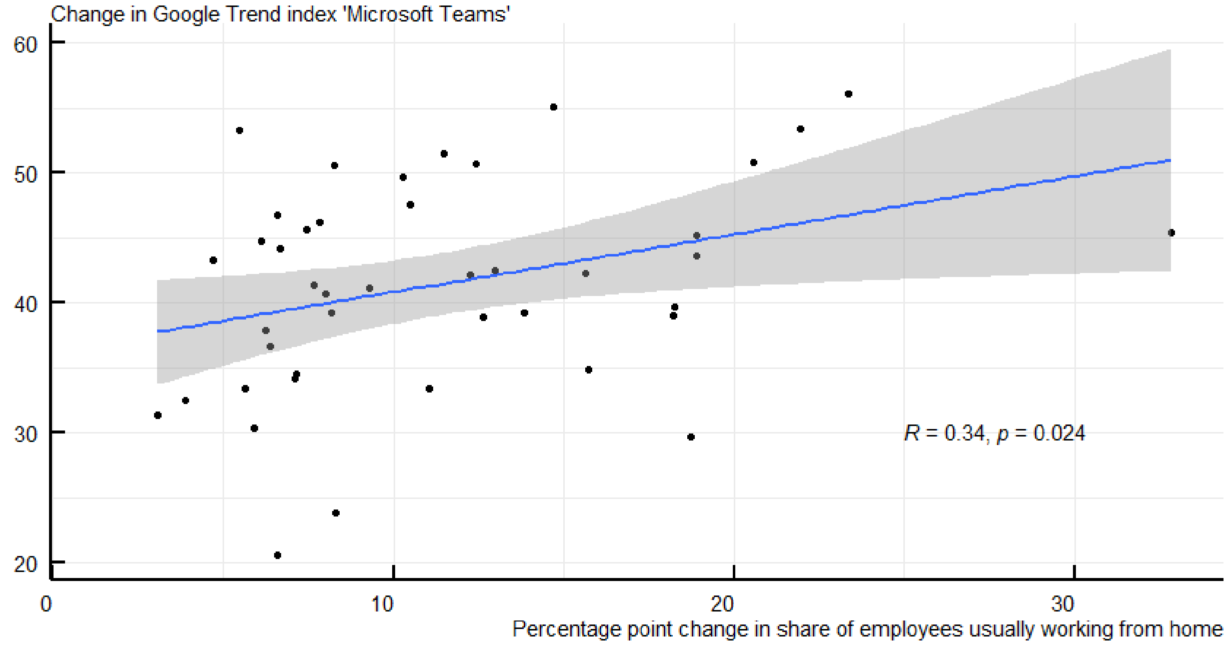
Percentage point change in the Google Trend index "Microsoft Teams" between early 2020 and early 2022



Note: Working from home proxied by Google Trend subject "Microsoft Teams". Percentage point changes between early 2020 and early 2022 by region are shown. Green bars denote the median change in working from home across a country's FUAs. Error bars indicate respectively the 25th and the 75th percentile of that change across regions. This Google Trend variable is correlated with 99% statistical significance with the share of the total workforce that reports having usual telework arrangements in the regional module of the 2021 Eurostat Labour Force Survey.
Source: Google Trends and OECD calculations.

Figure 8. The WFH proxy is strongly correlated with the uptake of remote work across EU countries

Changes from 2019 to 2021



Note: Each point represents a European TL2 region from a GHD country with data 2019 and 2021 in the Eurostat labour survey, namely 43 regions from Germany, Finland, France, Portugal and Sweden.
Source: Google Trends and Eurostat (Labour Force Survey).

Assessing the impact of remote work on urban house price gradients

"Monocentric" cities

14. To start with, the extended database is used to test for the "monocentric" hypothesis postulating that cities exhibit a negative house price gradient, that is, declining house prices as the distance to the city centre increases. The following specification is the formal test of this hypothesis:

$$\ln P_{i,j} = \alpha_j + \beta_j \ln D_i^j + \varepsilon_{i,j} \quad (1)$$

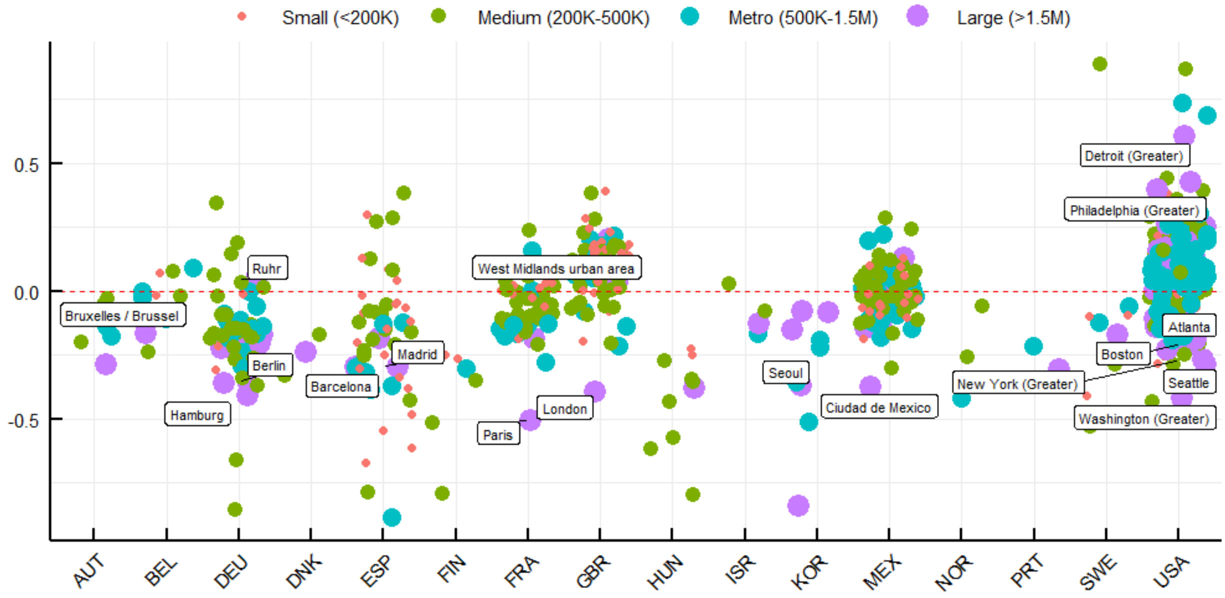
where $P_{i,j}$ denotes the house price in local unit *i* of FUA *j* in 2018 and D_i^j the distance in metres from local area *i* to the centroid of the largest high-density cluster of the corresponding FUA *j*. The estimated coefficient β_j is referred to as *house price gradient,* denoting the estimated percentage change in prices for a 1% increase in distance from the centre.

15. The results support the hypothesis of negative house price gradients for many large OECD cities, including London, New York, Washington, Mexico City, Paris, Berlin, Hamburg, Brussels, Barcelona and Madrid (Figure 9). However, a few large cities have no significant negative gradient. Most of these cases are sprawled metropolitan areas in the United States or polycentric FUAs such as Germany's Ruhr area and England's West Midlands, for which it is not surprising not to find a negative house prices gradient predicted by the monocentric model.[4] Overall, more than half of large FUAs exhibited negative house price gradients (38 out of 71 FUAs), while this share drops with the size of the FUA: 59 out of 153 metro-sized FUAs, 82 out of 244 medium-sized FUAs and only 28 out of 124 small FUAs.

[4] "West Midlands" includes cities like Birmingham and Wolverhampton.

Figure 9. House prices decline with distance from the centre in large metropolitan areas

Estimated percentage change in prices for a 1% increase in distance from the centre, 2018



Note: The figure displays gradient estimates β_j for each FUA based on the specification $\ln P_{i,j} = \alpha_j + \beta_j \ln D_i^j + \varepsilon_{i,j}$ (equation (1) above). Detailed results are displayed to Annex B.
Source: OECD calculation based on the Geography of Housing Demand database.

16. Urban areas with a significantly negative house price gradient will henceforth be called "monocentric", referring to the seminal work initiated by Alonso (1964[1]), Mills (1967[2]) and Muth (1969[3]) who postulated a negative house price gradient in monocentric cities where social and economic activity concentrates in the central business district and workers face the trade-off between commuting costs (higher in the periphery) and housing prices (lower in the periphery). This terminology is a shortcut, as the cities labelled "monocentric" may exhibit several high-density areas presenting the usual properties of centres.

Testing the hypothesis of flattening gradients

17. The core hypothesis is whether intra-FUA house price gradients have flattened in the wake of the COVID-19 pandemic as WFH has become more widespread. To test this hypothesis, the change in local house prices between the second half of 2019 (pre-COVID-19) and the second half of 2021 (the latest uniformly available data since the COVID-19 outbreak) is regressed on the distance to the corresponding FUA centroid.

$$\Delta \ln P_{i,j} = \alpha + \delta \ln D_i^j + \mu_j + \varepsilon_{i,j} \quad (2)$$

with Δ a difference operator (measuring the change from 2019H2 to 2021H2 in per cent) and μ_j FUA fixed effects. A positive slope coefficient δ in the difference equation (2) implies that the intra-FUA house price gradient β_j from the level equation (1) has flattened.

18. The results suggest that, on average, house prices have increased with distance to the city centre since the onset of the pandemic (Table 2). The relevant coefficient δ is positive and statistically significant for the full set of observations (1st column). For FUAs exhibiting a negative house price gradient going into the pandemic (labelled as "monocentric"), the coefficient is significantly larger (2nd column), corroborating the idea of a flattening of the house price gradient. However, results by FUA size indicate that only large metropolitan areas show statistically significant flattening (last two columns).

Table 2. Baseline results by FUA size

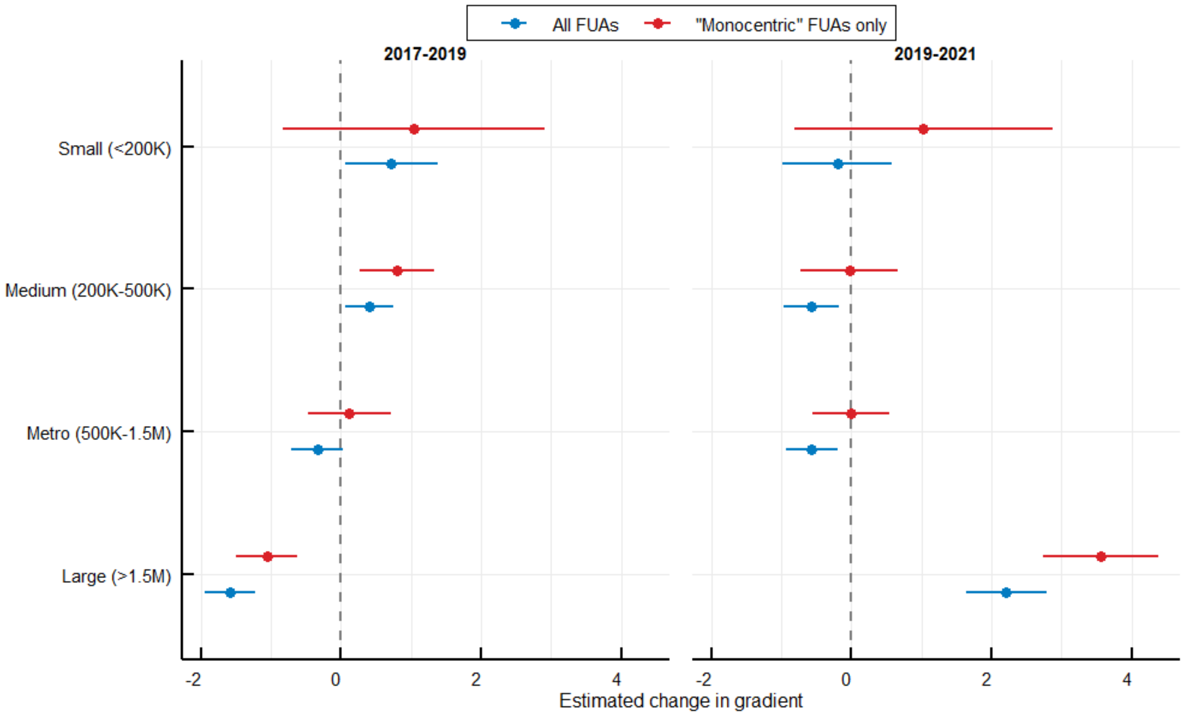
Dependent variable: log change of local area house prices between 2019H2 and 2021H2.

	All FUAs		Small (<200K)		Medium (200K-500K)		Metro (500K-1.5M)		Large (>1.5M)	
	All	"mono-centric"	All	"mono-centric"	All	"mono-centric"	All	"mono-centric"	All	"mono-centric"
Log-distance	0.957***	2.352***	-0.201	1.028	-0.571***	-0.032	-0.572***	-0.001	2.215***	3.556***
	(0.173)	(0.278)	(0.390)	(0.922)	(0.196)	(0.345)	(0.184)	(0.275)	(0.291)	(0.413)
R2	0.413	0.326	0.4	0.445	0.389	0.268	0.449	0.268	0.402	0.348
# Obs.	30366	15752	1557	360	6734	3016	8550	3531	13525	8845
# FUAs	595	207	124	28	247	82	153	59	71	38
# Countries	16	16	11	8	14	12	14	14	14	14
FUA fixed effects	X	X	X	X	X	X	X	X	X	X

Note: « Monocentric » FUAs are characterised by a significant negative house price gradient in 2018. * p < 0.1, ** p < 0.05, *** p < 0.01

19. One reason the flattening mainly occurred in large cities might be that commuting costs are higher in these areas. If commuting costs are negligible or low, the possibility offered by remote work to reduce the number of commutes should have little impact on location choices. Indeed, conceptually, the reason behind a flattening gradient is that commuting is a binding constraint, which is more likely to be the case in large metropolitan areas with steep house price gradients and long commuting distances (cf. Figure 1). Comparing the 2019-21 period to the preceding 2017-19 period further underscores that flattening typically occurs in large FUAs but not in smaller ones (Figure 10). Only in large FUAs did the estimated coefficient turn from significantly negative to significantly positive (Annex A).

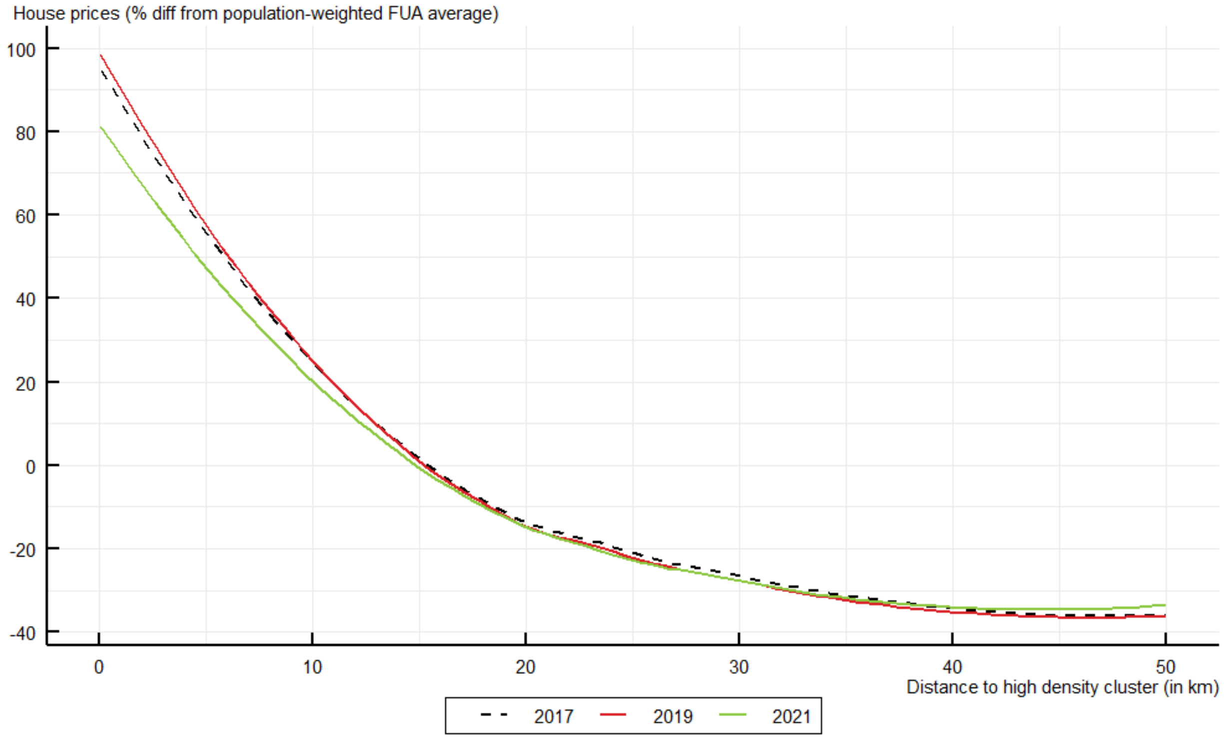
Figure 10. Visualisation of estimated change to FUA-specific house price gradients



Note: Error bars reflect two standard deviations around the estimated coefficient. "Monocentric" functional urban areas (FUA) exhibit a negative price-distance gradient in 2018. See Annex A for detailed regression results.
Source: OECD Geography of Housing Database and OECD calculations.

20. A visual inspection of the evolution of within-FUA house price gradients from 2017 to 2019 and 2021 suggests that the flattening operatedmostly through a reduction of the inner-city premium (Figure 11). The relative increase in house prices beyond a distance of 40km is also visible, albeit smaller in size. Finally, the graphs also illustrate the continued steepening of house price gradients from 2017 to 2019 (cf. Figure 10), corroborating the view that currently observed trends of a shift in housing demand towards the peripheral areas of large FUAs indeed started with COVID-19 and not before.

Figure 11. Evolution of house price gradients in large monocentric FUAs



Note: The graph plots gradients measured by applying local projection techniques (loess filter) to all local-unit-level observations of price and distance to the centre.
Source: OECD Geography of Housing Database and OECD calculations.

21. To better gauge demand shocks in price movements, the reduced-form baseline estimation (equation 2) is augmented by a proxy for new residential construction[5] (S_i):

$$\Delta P_{i,j} = \alpha + \delta_0 \ln D_i^j + \boldsymbol{\delta_S}(\mathbf{ln}\, \boldsymbol{D_i^j} \times \boldsymbol{S_i}) + \boldsymbol{\gamma}\, \boldsymbol{S_i} + \mu_j + \varepsilon_{i,j} \quad (3)$$

22. Finally, using the evidence of heterogeneous strength in the adoption of WFH across countries and FUAs sheds light on the drivers of flattening, allowing for gauging causal links between the consequences of the pandemic and the spatial distribution of the demand for housing:

$$\Delta P_{i,j} = \alpha + \delta_0 \ln D_i^j + \boldsymbol{\delta_{WFH}}(\mathbf{ln}\, \boldsymbol{D_i^j} \times \boldsymbol{WFH_j}) + \delta_S(\ln D_i^j \times S_i) + \gamma\, S_i + \mu_j + \varepsilon_{i,j} \quad (4)$$

where WFH_j is the percentage point change in WFH between the first semester of 2020 and the second semester of 2022 for FUA j as mapped from the regional Google Trend indices for the search topic

[5] Percentage point increase in the share of residential land use by local unit” as defined in Figure 5.

"Microsoft Teams" (cf. Figure 7). Annex C provides robustness tests with alternative proxies for the prevalence of WFH practices, including the Google Trend index "Zoom" and a task-based measure of average teleworkability of a region's industry structure derived from OECD's Survey of Adult Skills (PIAAC).

23. The "flattening" coefficient δ from equation (2) can accordingly be rewritten as a function of the rise in WFH and additional supply (S) weighted by the respective elasticities:

$$\delta_{i,j} = \delta_0 + \delta_{WFH} WFH_j + \delta_s S_i$$

where the coefficient δ_{WFH} is expected to be positive in line with the proposition that adopting WFH practices shifts preferences for housing and modifies the *hedonic geographical equilibrium*, i.e. the relationship between where people live and work. The reallocation of demand for housing away from the jobs towards more affordable areas in the suburbs is expected to relax price pressures in the city centres and increase price pressures in the suburbs depending, among other things, on local supply responsiveness. The coefficient δ_s is expected to be negative since more supply relieves demand pressure on prices.

24. Table 3 presents the results for the augmented specifications described by equations (3) and (4). Estimations for two subsamples are given at each stage. The first wider subsample includes FUAs of more than 1.5 million inhabitants (Large FUAs) and adds FUAs with less than 1.5 million. The second subsample restricts observations to locations that are in FUAs that are both large and "monocentric".

Table 3. Results of the augmented specification with supply and WFH

Dependent variable: log change of local area house prices between 2019H2 and 2021H2.

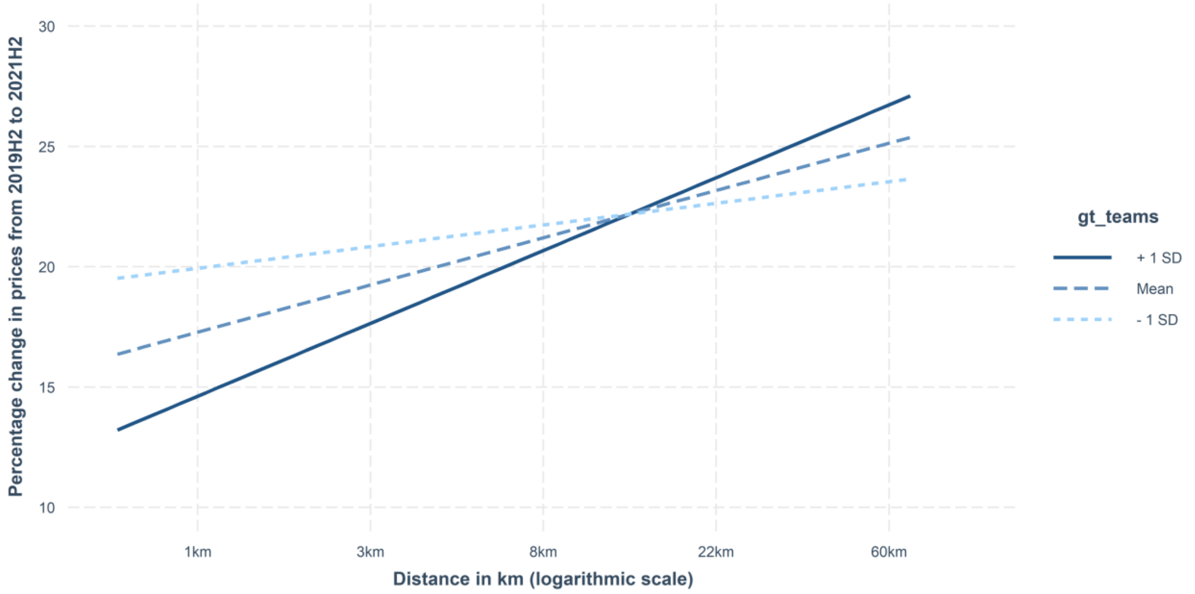
	Baseline		WFH		Supply		WFH & Supply	
	All	Large	All	Large	All	Large	All	Large
Log distance	2.352***	3.556***	2.182***	3.230***	3.197***	3.661***	2.964***	3.368***
	(0.278)	(0.413)	(0.248)	(0.378)	(0.523)	(0.610)	(0.456)	(0.544)
Log distance x WFH			0.152***	0.139***			0.152***	0.140**
			(0.034)	(0.044)			(0.050)	(0.057)
Supply					0.019	0.041	-0.029	-0.006
					(0.105)	(0.107)	(0.102)	(0.103)
Log distance x Supply					-0.356***	-0.386***	-0.282***	-0.314***
					(0.093)	(0.096)	(0.083)	(0.086)
# Obs.	15752	8845	15752	8845	6175	4958	6175	4958
# FUAs	207	38	207	38	59	38	59	38
# Countries	16	14	16	14	16	14	16	14
R2	0.326	0.348	0.331	0.352	0.383	0.385	0.389	0.390
FUA fixed effects	X	X	X	X	X	X	X	X

Note: The samples include only monocentric FUAs (see Table 2 and discussion above). * p < 0.1, ** p < 0.05, *** p < 0.01

25. Figure 12 illustrates the estimated non-linear relationship between house price growth and distance to the city centre depending on the adoption of WFH graphically. Areas that experienced a higher adoption of remote work (thick dark blue line) witnessed more extensive flattening of the house price gradient. Areas with below-average adoption of WFH (dotted light blue line) still experienced some flattening or at least a stabilisation of existing gradients, but the size of the estimated effect is much smaller.

Figure 12. More remote work amplifies shift of demand towards the suburbs

Estimated impact of remote work controlling for homebuilding area by area



Note: The plots illustrate how the relationship between distance and price changes depends on the level of remote work (Table 3) proxied by the variable gt_teams, which denotes the change in the Google Trend Index topic "Teams" from 2019 to 2021: this variable is tightly correlated with a direct measure of working from home while offering the benefit of much wider coverage. For illustrative purposes, three levels of the interacted variables are shown: "Mean" (the average value for remote work, equivalent to the price-distance slope without interaction), "+ 1 SD" (remote work one standard deviation above its average value) and "- 1 SD" (remote work one standard deviation below its average value).
Source: Geography of Housing Database, Google Trends and OECD calculations.

26. The estimation is robust to controlling for the type of urban expansion measured by changes in the built-up area from satellite imagery and classified by Banquet et al. (2022[21]). The empirical evidence further suggests a correlation between the type of urban expansion (denser and more concentrated) and a weaker flattening of the gradient. In other words, upward price pressures in suburban areas are lower when met by a responsive supply that allows already existing and highly demanded residential areas to densify. Another interpretation is that people were less interested in dense areas during the pandemic partly because amenities were closed. People may be less keen to move out of the city centre if the alternatives are also densely populated.

Addressing heterogeneities and determinants in the spatial shift of housing demand

27. The specifications outlined so far do not account for heterogeneities within urban areas other than distance-related ones. Accounting for local characteristics can help shed light on the potential drivers of observed shifts in the spatial distribution of housing demand and inform policymaking. The econometric specification (4) can be augmented by including area- or FUA specific characteristics (X_i):

$$\Delta P_{i,j} = \alpha + \delta_0 \ln D_i^j + \delta_{\mathrm{WFH}}(\ln D_i^j \times WFH_j) + \delta_S(\ln D_i^j \times S_i) + \boldsymbol{\delta_X}(\mathbf{ln}\, \boldsymbol{D_i^j} \times \boldsymbol{X_i}) + \gamma S_i + \mu_j + \varepsilon_{i,j} \qquad (5)$$

28. A synthetic measure for the non-distance-related value of local amenities is obtained by regressing the level of local house prices on their distance to the respective FUA centre, defined as the largest high-density cluster in the FUA (equation 1). The residuals of the estimation, which capture the portion of house prices unexplained by distance, can be interpreted as measuring the amenity value of the corresponding zip-code areas ("P_amenity"). Satellite imagery used to gauge local construction activity can also be

mobilised to compute geographically granular estimates for open space (Banquet et al., 2022[21]).[6] Open space, a key driver of housing demand already before the pandemic (Farrow et al., 2022[22]), may have become an even more powerful force of attraction after the pandemic.

Table 4. Other drivers and covariates

Dependent variable: log change of local area house prices between 2019H1 and 2021H2.

	Baseline		P_amenity		Open.space	
	All	Large	All	Large	All	Large
Log distance	2.182***	3.230***	2.460***	2.892***	2.686***	3.041***
	(0.248)	(0.378)	(0.506)	(0.585)	(0.524)	(0.604)
Log distance x WFH	0.152***	0.139***	0.127**	0.111*	0.144***	0.132**
	(0.034)	(0.044)	(0.051)	(0.058)	(0.050)	(0.056)
Supply			-0.067	-0.045	-0.02	0.002
			(0.095)	(0.096)	(0.102)	(0.103)
Log distance x Supply			-0.220***	-0.253***	-0.284***	-0.310***
			(0.081)	(0.084)	(0.086)	(0.090)
P_amenity			-2.964**	-2.876*		
			(1.501)	(1.608)		
Log distance x P_amenity			0.823	0.913		
			(1.009)	(1.102)		
Open.space					0.070**	0.072**
					(0.031)	(0.035)
Log distance x Open.space					-0.037	-0.031
					(0.024)	(0.028)
# Obs.	0.331	0.352	0.402	0.401	0.394	0.395
# FUAs	15752	8845	5752	4624	6175	4958
# Countries	207	38	59	38	59	38
R2	16	14	16	14	16	14
FUA fixed effects	X	X	X	X	X	X

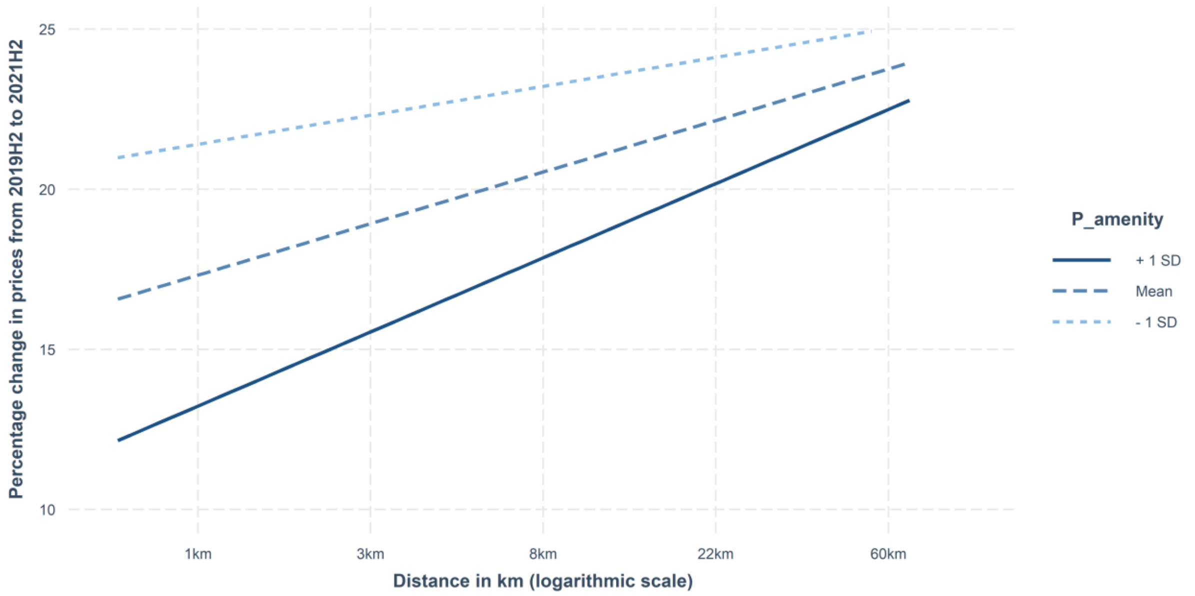
Note: The samples include only monocentric FUAs (see Table 2 and discussion above). * p < 0.1, ** p < 0.05, *** p < 0.01

29. Results suggest a general catch-up in-house prices. First, lower-valued districts experienced sharper increases in house prices from 2019H2 to 2021H2. Second, the extent of the flattening, i.e. the change in the slope of the gradient, is stronger in higher-valued areas (Figure 13). This finding suggests that the higher attractivity of the suburbs does not occur homogeneously. Local amenities seem to be valued more strongly in remote areas than near the city centre. Indeed, the loss of urban amenities (access to recreation and cultural facilities, schools, medical services, etc.) is typically seen as one of the opportunity costs of moving to the suburbs.

6 According to the refered land use categories, « open space » indludes forests, herbaceous areas, open space without vegetation (beaches, bare land), green urban areas, sports and leisure facilities.

Figure 13. Local amenities have a stronger price impact in peripheral areas

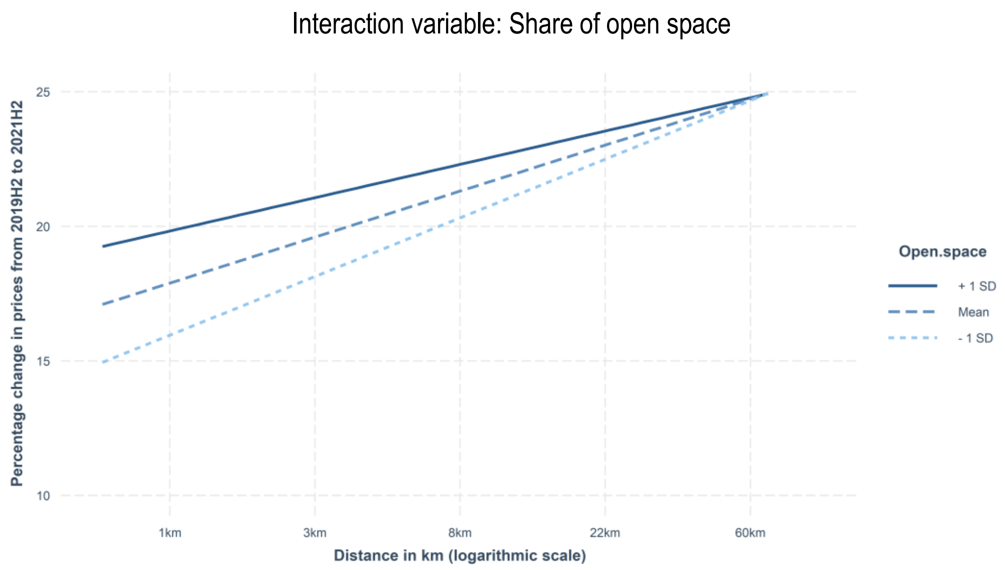
Interaction variable: valuation of local amenities



Note: The plot illustrates how the relationship between distance and price changes depends on the level of the interacted variable (here: "P_amenity"; see Table 4). For illustrative purposes, three levels of the interacted variables are shown: "Mean" (the average value for the respective interacted variable, equivalent to the price-distance slope without interaction), "+ 1 SD" (the value of the interacted variable one standard deviation above its average value) and "- 1 SD" (the value of the interacted variable one standard deviation below its average value). "P_amenity" is a proxy for the value of non-distance-related average characteristics obtained as the residuals from a regression of the logarithm of house price levels on the logarithm of the distance to the FUA centre.
Source: OECD calculations.

30. Much of the amenity value associated with locational choices comes from environmental quality. Open space and access to green spaces played a particular role in location choices during the pandemic. Such amenities provide health benefits due to reduced congestion and better air quality. They also promote social cohesion and improve the quality of life in urban areas, values increasingly demanded since the pandemic. Places with scarce open space experienced a sharper shift in demand from the city centre to the periphery (Figure 14).

Figure 14. Environmental quality is a major driver of price shifts away from city centres



Note: The plots illustrate how the relationship between distance and price changes depends on the access to open space as inferred from satellite imagery. For illustrative purposes, three levels of the interacted variables are shown: "Mean" (the average value for the respective interacted variable, equivalent to the price-distance slope without interaction), "+ 1 SD" (the value of the interacted variable one standard deviation above its average value) and "- 1 SD" (the value of the interacted variable one standard deviation below its average value).
Source: "Monitoring land use in cities using satellite imagery and deep learning" (Banquet et al., 2022[21]); Geography of Housing Demand database and OECD calculations.

Tailoring housing policies to shifting demand

31. While the question remains about the extent to which the observed shifts are permanent, the changing patterns in housing demand arising from digitalisation reinforce the need for policy action to unlock supply and avoid the build-up of new inequalities. Policy environments that make it easy for households to relocate according to the new possibilities opened by working from home will have benefits in terms of not only satisfaction with housing but also city productivity. The shift to the peripheries of large cities offers a way of alleviating the housing bottlenecks that have thwarted the economic growth of the most productive cities (Glaeser and Gyourko, 2018[23]). Policymakers can consider several options depending on local conditions, social preferences and policy settings.

Urban planning

32. Land-use regulations are important policy tools to respond to the new geography of housing demand within urban strategies compatible with environmental, transport and public service provision objectives. Shifts in the geography of housing demand magnify the benefits of regularly revising geographic boundaries for urban development to accommodate city growth while ensuring forms of expansion compatible with environmental objectives. Where regulations allow it, flexibility to convert commercial property and office space for residential use would facilitate the reallocation of structures to evolving demand for different uses, potentially making housing more affordable. However, there is a risk that disaffection for city centres gives rise to housing segregation as the better-off move away. These trends pose challenges for urban planning, land-use design and zoning regulations.

33. The governance of urban planning is often fragmented across government levels and sometimes across ministries or government agencies (OECD, 2021[24]). This situation can complicate reforms if public bodies with responsibility over one area, for instance, land regulation, do not have authority in other areas,

such as taxation or social housing, that would allow them to design integrated reform packages. Responsibilities and decision-making should be delegated to the metropolitan rather than the local level to avoid not-in-my-backyard dynamics and foster inter-municipal cooperation, including in the provision of public services and transport. Meanwhile, there is merit in enhancing tax and spending autonomy at the local level to boost housing supply responsiveness (Dougherty, Cournède and van Hoenselaar, 2023[25]).

34. The new geography of housing demand entails increasing distances between workplaces and residences. Fewer but also longer commutes might require rethinking urban passenger transport systems, notably in light of continuing efforts to decarbonise transport. Compact and transit-oriented development, commonly defined as mixed-use urban development with mass-transit facilities within walking distance of residential buildings, can make public transport more convenient, encourage ridership and decrease car dependency (ITF, 2019[26]).

Amenity provision

35. Environmental policies can do much to support the provision of amenities. Despite their myriad benefits, environmental amenities remain undersupplied in many urban areas. Public investments with strong spatial dimensions, such as the provision of open space, can increase house prices and burden residents who do not benefit from the associated gains, leading to an unequal distribution of the net benefits of the provided goods. Such effects should be anticipated by environmental policies to support amenity provision, and particular attention should be paid to the distributional effects that occur between renters and owners in affected areas. Additional attention should be paid to displacement effects, whereby residents can face pressure over time to relocate out of the area due to amenity-induced increases in housing costs.

36. Amenity provision may need to be accompanied by complementary measures designed to mitigate economy-wide effects (OECD, 2018[27]) and negative distributional impacts that can occur via housing markets. Examples of policy measures that address both environmental issues and equity include subsidising the retrofitting of the existing housing stock and investments in green social housing, i.e., social housing that incorporates environmental amenities (OECD, 2021[24]). Enabling portable eligibility with respect to social housing could also be included in the toolkit of feasible interventions (OECD, 2021[28]). Relaxing building height restrictions can also improve access to environmental amenities.

37. Low-income areas tend to be overlooked in green renewal project planning (Haase et al., 2017[29]; Anguelovski et al., 2016[30]). There is scope to introduce greater equity into the urban planning process at the earliest stages of such projects. One means of doing so is to facilitate the inclusion of residents of all socio-economic statuses in participatory planning processes. Enhancing amenity provision in amenity-scarce areas would generate greater marginal benefits than their provision in areas with substantial existing supply. To be effective, this probably needs to be combined with mechanisms to make green construction and renovation more affordable.

38. Existing local fiscal and land-use policies, public finance mechanisms, as well as the spatial profile of amenities, tenure status and income, determine the potential for distributional impacts. As a result, these conditions should be taken into account when evaluating the appropriateness of potential compensation mechanisms. For example, successful implementation of land value capture mechanisms should take into account factors such as the maturity of land markets, land use regulations, investment policies, legal frameworks, fiscal and governance structures, as well as local circumstances and conventions regarding land rights (OECD, 2021[28]). The welfare impact of property taxes, for example, will depend not only on their magnitude but also on the relation between the tax rate on land and differences in rates across different land use categories (Brandt, 2014[31]).

Land value capture

39. Land value capture measures, including infrastructure levies or developer obligations, as well as smart ways to manage and re-adjust land use, can be used to encourage the expansion of housing supply and help densify existing residential areas (OECD/Lincoln Institute of Land Policy, PKU-Lincoln Institute Center, 2022[32]). Such measures can also contribute to financing the infrastructure and amenities needed to improve the accessibility of economic and social facilities in remote areas. Existing land value capture strategies include betterment contributions and special assessments, impact fees, land readjustment, and inclusionary zoning (OECD, 2021[28]; Farrow et al., 2022[22]).

40. Potential uses of these revenues vary according to the specific context and can include investment in social housing and the provision of housing subsidies for low-income households. Pricing mechanisms can also be used to recover the costs generated by environmental disamenities. The revenues generated by these pricing mechanisms can serve to compensate households that may disproportionately suffer from the impacts of disamenities.

41. Deploying land-value captures, however, involves difficulties, starting with resistance by property owners (OECD/Lincoln Institute of Land Policy, PKU-Lincoln Institute Center, 2022[32]). Proper calibration is also required to maintain adequate incentives for development. Administrative capacity, including a high-quality cadaster or land registry, and an adequate legal framework are additional requirements for successful land value capture.

Housing taxation

42. The design of housing taxes influences residential mobility. The use of taxes levied on housing transactions generates efficiency losses mainly through lock-in effects that hold back residential mobility (OECD, 2022[33]). In addition, reliance on transaction taxes may strengthen incentives to buy less expensive land, which generally lies far from city centres and transport infrastructure, while deterring transactions that might help put land to more efficient uses, including residential ones. They also encourage the purchase of undeveloped land for new development rather than upgrading developed areas (Blöchliger and Kim, 2016[34]). Substituting at least partly recurrent property taxes for transaction taxes would make tax systems and housing markets more efficient, with benefits for residential and labour mobility (OECD, 2022[33]).

43. There is significant scope for improving the design and functioning of recurrent taxes on immovable property (OECD, 2022[33]). While all OECD countries levy recurrent taxes on immovable property, they are, in many instances, based on outdated property values, significantly reducing the associated revenue potential while harming equity and economic efficiency. Opting for a split-rate design, whereby land is taxed at a higher rate than structures, would encourage the development of vacant or underused land in suburban areas, thereby fostering compact development and attenuating urban sprawl.

44. Property taxes provide local governments with stable revenue to finance the provision of local public goods and services, which in turn is a key determinant of residential settlement decisions, particularly for residents planning to relocate from amenity- and service-rich urban centres. In areas where housing supply shortages coincide with an abundance of vacant homes, recurrent taxes on these vacant homes can help increase housing supply. Such taxes should be flanked by credible measures to monitor compliance and avoid loopholes for short-term rentals (OECD, 2022[33]) and might require compensatory measures to avoid hardship for “house-rich, income-poor households.

Rental market policies

45. Rental-market regulations can discourage supply when they involve overly tight rent controls (OECD, 2021[24]). Strict tenant-landlord regulation resulting in high tenure security and rent control can

lower the expected returns from the residential rental supply, thereby reducing residential investment, including renovation, or encouraging alternative uses of the existing stock by owners.

46. Tight rental contract restrictions also adversely affect vulnerable renters, posing obstacles to residential and labour mobility. Excessive protection of tenants implies that renters with uncertain labour market prospects find it difficult to sign a lease. Strict regulations in rental markets further reduce residential mobility, as tenants in rent-controlled dwellings will be reluctant to move if rents are below market levels. As there is also a case for providing tenants with reasonable security over tenure and rent levels, a balanced system can involve a degree of rent stabilisation, whereby rents can be adjusted for new contracts (and potentially renewals) but regulated in line with market developments during the duration of a contract.

Digital transformation

47. Digitalisation offers several options for technological change and innovation in the construction and "smart" management of buildings, not least through artificial intelligence and the internet of things. Innovations in urban planning and management are already taking place and can improve the management of traffic, urban amenities and infrastructure, as well as the energy efficiency of buildings and cities at large. Digital platforms can enhance competition and improve the matching of supply and demand for dwellings. Housing fintech can broaden access to finance and reduce borrowing costs to the extent that these activities are regulated appropriately to avoid new sources of financial risk.

48. Effective digital infrastructure is a prerequisite for digitisation and remote work. Tackling the digital divide between urban and rural areas is particularly important in the context of spatial shifts in the demand for housing. Governments would do well to ensure widespread access to high-speed internet, upgrade technical and managerial skills, and implement product and labour market reforms to facilitate the adoption of digital technologies by firms (Sorbe et al., 2019[35]). The development of digital government services can ensure a better and more inclusive response to citizens' needs and improve access to public services in disadvantaged communities. Closing the digital skills divide by providing all citizens with ICT, literacy and numeracy skills requires equal opportunities for training, education, re-skilling and upskilling for the jobs and societies of the future (OECD, 2020[36]).

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Annex A: Baseline regressions results by sample and period

Unbalanced panel (cf. Figure 10 and Table 2)

Dependent variable: log change of local area house prices between **2017H2 and 2019H2.**

	All FUAs		Small (<200K)		Medium (200K-500K)		Metro (500K-1.5M)		Large (>1.5M)	
	All	"mono-centric"	All	"mono-centric"	All	"mono-centric"	All	"mono-centric"	All	"mono-centric"
Log-distance	-0.748***	-0.435***	0.716**	1.044	0.403**	0.799***	-0.338*	0.118	-1.591***	-1.063***
	(0.107)	(0.154)	(0.329)	(0.934)	(0.169)	(0.265)	(0.184)	(0.296)	(0.180)	(0.221)
R2	0.369	0.418	0.364	0.543	0.401	0.451	0.323	0.301	0.374	0.429
Num.Obs.	28267	13931	1550	331	6764	3102	8006	2960	11947	7538
Num. FUAs	528	156	120	26	217	62	133	40	58	28
N° of countries	14	14	10	7	13	11	12	12	12	12
FUA-fixed effects	X	X	X	X	X	X	X	X	X	X

Dependent variable: log change of local area house prices between **2019H2 and 2021H2** (same as Table 2)

	All FUAs		Small (<200K)		Medium (200K-500K)		Metro (500K-1.5M)		Large (>1.5M)	
	All	"mono-centric"	All	"mono-centric"	All	"mono-centric"	All	"mono-centric"	All	"mono-centric"
Log-distance	0.957***	2.352***	-0.201	1.028	-0.571***	-0.032	-0.572***	-0.001	2.215***	3.556***
	(0.173)	(0.278)	(0.390)	(0.922)	(0.196)	(0.345)	(0.184)	(0.275)	(0.291)	(0.413)
R2	0.413	0.326	0.4	0.445	0.389	0.268	0.449	0.268	0.402	0.348
N° Observations	30366	15752	1557	360	6734	3016	8550	3531	13525	8845
N° FUAs	595	207	124	28	247	82	153	59	71	38
N° of countries	16	16	11	8	14	12	14	14	14	14
FUA-fixed effects	X	X	X	X	X	X	X	X	X	X

Balanced panel

Dependent variable: log change of local area house prices between **2017H2 and 2019H2.**

	All FUAs		Small (<200K)		Medium (200K-500K)		Metro (500K-1.5M)		Large (>1.5M)	
	All	"mono-centric"	All	"mono-centric"	All	"mono-centric"	All	"mono-centric"	All	"mono-centric"
Log-distance	-0.775***	-0.496***	0.649*	0.678	0.368**	0.665**	-0.319*	0.092	-1.595***	-1.073***
	(0.110)	(0.158)	(0.340)	(0.988)	(0.177)	(0.284)	(0.187)	(0.299)	(0.181)	(0.223)
R2	0.377	0.429	0.389	0.569	0.434	0.506	0.33	0.31	0.372	0.427
Num.Obs.	26249	12671	1371	286	5735	2387	7480	2699	11663	7299
Num. FUAs	523	156	117	26	215	62	133	40	58	28
N° of countries	14	14	9	7	13	11	12	12	12	12
FUA-fixed effects	X	X	X	X	X	X	X	X	X	X

Dependent variable: log change of local area house prices between **2019H2 and 2021H2.**

	All FUAs		Small (<200K)		Medium (200K-500K)		Metro (500K-1.5M)		Large (>1.5M)	
	All	"mono-centric"	All	"mono-centric"	All	"mono-centric"	All	"mono-centric"	All	"mono-centric"
Log-distance	0.648***	2.104***	-0.343	1.279	-0.736***	-0.314	-0.489***	0.386	1.781***	3.227***
	(0.138)	(0.225)	(0.399)	(1.096)	(0.202)	(0.357)	(0.179)	(0.285)	(0.225)	(0.312)
R2	0.471	0.366	0.415	0.449	0.419	0.3	0.48	0.235	0.479	0.404
Num.Obs.	26249	12671	1371	286	5735	2387	7480	2699	11663	7299
Num. FUAs	523	156	117	26	215	62	133	40	58	28
N° of countries	14	14	9	7	13	11	12	12	12	12
FUA-fixed effects	X	X	X	X	X	X	X	X	X	X

* p < 0.1, ** p < 0.05, *** p < 0.01

Annex B: Estimated gradients by FUA, large FUAs only, 2018

The table displays gradient estimates for large metropolitan urban areas obtained as the β_j from weighted least squares estimation of the specification $\ln P_{i,j} = \alpha_j + \beta_j \ln D_i^j + \varepsilon_{i,j}$ where $P_{i,j}$ is the average house price of small area unit *i* in FUA *j* in 2018, D_i^j the distance of small area unit *i* to the centroid of FUA *j.* The number of transactions in 2018 are used as weights. Gradient estimates for all FUAs are illustrated in Figure 9 and can be obtained upon request from the authors.

Country	FUA ID	FUA Name	FUA population	gradient estimate	p.value	Significance level
KOR	KOR05	Seo	1601278	-0.841	0.121	
FRA	FR001	Paris	12793694	-0.506	0.000	***
DEU	DE002	Hamburg	3173328	-0.410	0.000	***
GBR	UK001	London	11981795	-0.396	0.000	***
MEX	MEX01	Ciudad de Mexico	20534813	-0.375	0.000	***
HUN	HU001	Budapest	2968030	-0.375	0.000	***
USA	USA04	Washington (Greater)	8885634	-0.370	0.000	***
KOR	KOR01	Seoul	23833144	-0.368	0.000	***
DEU	DE005	Frankfurt am Main	2576940	-0.354	0.000	***
DEU	DE001	Berlin	4951693	-0.326	0.000	***
PRT	PT001	Lisbon	2924630	-0.305	0.000	***
ESP	ES002	Barcelona	4746186	-0.297	0.000	***
ESP	ES001	Madrid	6612371	-0.293	0.000	***
USA	USA14	Seattle	3599914	-0.282	0.000	***
AUT	AT001	Vienna	2828159	-0.278	0.000	***
USA	USA01	New York (Greater)	19609888	-0.270	0.000	***
DNK	DK001	Copenhagen	1806839	-0.237	0.000	***
USA	USA28	Charlotte	1979242	-0.228	0.000	***
DEU	DE003	Munich	2823485	-0.223	0.000	***
USA	USA10	Atlanta	5520553	-0.223	0.000	***
USA	USA11	Boston	4129660	-0.203	0.000	***
DEU	DE011	Dusseldorf	1518704	-0.202	0.000	***
DEU	DE007	Stuttgart	2658826	-0.199	0.000	***
USA	USA30	Austin	2015332	-0.196	0.000	***
FRA	FR003	Lyon	2016253	-0.187	0.000	***
ESP	ES003	Valencia	1628912	-0.185	0.026	**
DEU	DE004	Cologne	1950980	-0.172	0.000	***
SWE	SE001	Stockholm	2163128	-0.166	0.000	***
BEL	BE001	Bruxelles / Brussel	3217155	-0.164	0.000	***
MEX	MEX04	Puebla	2709953	-0.156	0.000	***
USA	USA20	Portland	2265230	-0.152	0.000	***
KOR	KOR04	Gwangsan	1651346	-0.151	0.295	
MEX	MEX02	Guadalajara	5262893	-0.147	0.000	***
MEX	MEX03	Monterrey	5355795	-0.142	0.000	***
USA	USA05	San Francisco (Greater)	6245572	-0.128	0.076	*
ISR	ISR10	Tel Aviv	2805937	-0.125	0.001	***
USA	USA08	Houston	6701372	-0.107	0.039	**

USA	USA03	Chicago	9572054	-0.098	0.030	**
KOR	KOR03	Dalseong	2442697	-0.082	0.623	
KOR	KOR02	Gimhae	4286600	-0.076	0.052	*
USA	USA07	Dallas	7297622	-0.067	0.216	
MEX	MEX05	Toluca	2385433	-0.045	0.241	
MEX	MEX06	Tijuana	1755376	-0.019	0.746	
USA	USA18	Denver	2733110	0.006	0.837	
MEX	MEX08	Queretaro	1591067	0.019	0.671	
GBR	UK008	Manchester	3292808	0.034	0.172	
USA	USA34	Salt Lake	1584660	0.043	0.289	
USA	USA23	Orange	2416126	0.046	0.299	
DEU	DE038	Ruhr	5020226	0.050	0.052	*
USA	USA12	Phoenix	4750749	0.062	0.216	
USA	USA15	Minneapolis	3445672	0.062	0.015	**
USA	USA31	Columbus	1978236	0.071	0.230	
MEX	MEX07	Leon	1656728	0.129	0.001	***
USA	USA02	Los Angeles (Greater)	17696127	0.134	0.000	***
USA	USA16	San Diego	3207010	0.145	0.001	***
USA	USA24	Jackson (MO)	2020821	0.158	0.022	**
USA	USA09	Miami (Greater)	5919726	0.164	0.000	***
GBR	UK002	West Midlands urban area	3020175	0.166	0.000	***
USA	USA17	St. Louis	2620934	0.172	0.013	**
USA	USA21	Cincinnati	2112147	0.174	0.000	***
USA	USA29	Sacramento	2331021	0.179	0.000	***
USA	USA19	San Antonio	2392908	0.200	0.000	***
GBR	UK003	Leeds	2576558	0.205	0.000	***
USA	USA25	Indianapolis	1993782	0.221	0.001	***
USA	USA06	Philadelphia (Greater)	6418873	0.239	0.000	***
USA	USA27	New Haven	1781746	0.260	0.008	***
USA	USA22	Las Vegas	2358256	0.295	0.000	***
USA	USA33	Jacksonville	1553725	0.338	0.000	***
USA	USA32	Milwaukee	1560447	0.399	0.000	***
USA	USA26	Cuyahoga	2005283	0.425	0.000	***
USA	USA13	Detroit (Greater)	4242255	0.646	0.000	***

Annex C: Alternative measures for working from home intensity by FUA

The main text uses the Google Trend search category "Microsoft Teams" to build a representative proxy for the takeup of remote work in the aftermath of the coronavirus pandemic (change from 2019 to 2021). Other measures exist. This annex tests two of them as a means to infer the robustness of the empirical results. The first is an alternative search category from Google Trend indices, namely "Zoom". The second one ("Teleworkability") is derived from (Espinoza and Reznikova, 2020[37]), who compute teleworkability scores for each industry based on representative tasks sourced from OECD's Survey of Adult Skills (PIAAC). Industry scores for teleworkability are aggregated for each FUA depending on the area's industry mix according to OECD's Regional Demography dataset to build the "Teleworkability" indicator.

For both alternative measures, the results suggest that the estimated covariates are similar to the ones obtained with the baseline proxy (Google Trend "Microsoft Teams"), albeit somewhat smaller in magnitude and less significant. A likely explanation of the weaker identification power of the "Google Trends Zoom" measure compared with "Google Microsoft Teams" is that the search term "Zoom" is likely to capture more queries unrelated to remote work (including those related to photography) than "Microsoft Teams". As for teleworkability, it is an indicator of the sector-structure-based potential rather than the takeup of WFH. The effective takeup of WFH depends not only on the potential offered by the sectors that make up the local economy but also on framework conditions such as digital connectivity, labour-market policies and practices around remote work, etc. This wedge between potential and actual is likely to vary across functional urban areas, explaining the weaker identification power of teleworkability compared to more direct measures of working from home.

	Google Trend Microsoft Teams				Google Trend Zoom				Teleworkability			
	All	Large	All	Large	All	Large	All	Large	All	Large	All	Large
Log-distance	2.182***	3.230***	2.964***	3.368***	2.215***	3.411***	2.800***	3.200***	2.244***	3.559***	3.306***	3.847***
	(0.248)	(0.378)	(0.456)	(0.544)	(0.218)	(0.297)	(0.388)	(0.449)	(0.312)	(0.543)	(0.582)	(0.741)
Distance x WFH	0.152***	0.139***	0.152***	0.140**	0.057	0.038	0.068	0.073	0.236***	0.116	0.131	0.069
	(0.034)	(0.044)	(0.050)	(0.057)	(0.049)	(0.056)	(0.059)	(0.063)	(0.088)	(0.139)	(0.141)	(0.185)
Supply			-0.029	-0.006			0.007	0.025			-0.009	0.011
			-0.102	-0.103			-0.109	-0.112			-0.102	-0.104
Distance x Supply			-0.282***	-0.314***			-0.339***	-0.364***			-0.320***	-0.345***
			(0.083)	(0.086)			(0.098)	(0.102)			(0.085)	(0.088)
R2	0.331	0.352	0.389	0.39	0.327	0.348	0.385	0.387	0.327	0.351	0.385	0.387
N° Observations	15752	8845	6175	4958	15752	8845	6175	4958	15682	8793	6138	4921
N° FUAs	207	38	59	38	207	38	59	38	205	37	58	37
N° of countries	16	14	16	14	16	14	16	14	15	13	15	13
FUA-fixed effects	X	X	X	X	X	X	X	X	X	X	X	X

* p < 0.1, ** p < 0.05, *** p < 0.01