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City skew and homeowner subsidy removal

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City Skew
and Homeowner Subsidy Removal

– May 10th, 2020 –

Alexander Daminger and Kristof Dascher

Abstract: Many countries subsidize homeownership, and Germany is no exception. However, for an interlude of 12 years Germany also *paused* its subsidy. Over these twelve years most of the country's 100 largest cities saw their central city population expand. We explore subsidy removal's role in center revival. We assemble a large data set of population strata for a fine partition of city rings. Then we exploit the design of the subsidy (which benefited more affordable places more, and also which never benefited the young) to identify its effects on urban spatial structure. We will find that homeowner subsidy removal has strongly driven the skew of the distribution of commuting distance up. In doing so subsidy removal has also, so we will suggest, contributed to strong recent growth in both, urban rent and female labor force participation.

Keywords: Commuting Distribution, Skewness, Homeownership Subsidy, Reurbanization
JEL-Classifications: R12, D72, R52

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1 Introduction

Many countries subsidize homeownership, and for most of its post-WW-II history Germany has been no exception. But Germany also *paused* its homeownership subsidy, between 2006 to 2017. This provides us with one rare opportunity to learn about a homeownership subsidy's effect on tenure choice and urban spatial structure, given that homes owned tend to be peripheral and apartments rented tend to be central. We first assemble a large data set of population strata for a fine partition of the city area into concentric rings. Then we exploit the subsidy's design (having benefited households in more affordable cities more, and nowhere having benefited the young), to identify the effects of its removal on the *skew* of the city's commuting distribution. We find that subsidy removal has forced skew up, and substantially so.

Germany's recent experience is remarkable enough. It also has, so we document, no counterpart in US metro areas' recent experience. City center population had begun to drop as early as 1950 (Ehrlich/Hilber/Schöni (2018)). Suburbanization often entails sprawl, and interest in sprawl has grown (e.g., Brueckner (2000), Burchfield et al. (2005)). First, sprawl has commuters travel longer, and hence increases the burden imposed on co-travellers, or on those living along the city arteries. Second, sprawl likely contributes to global warming, as more spacious suburbian homes and larger cars imply larger carbon dioxide emissions (Glaeser/Kahn (2010a, 2010b), Glaeser (2011)), and because those living further out are more likely to oppose a carbon tax (Holian/Kahn (2015)). Also, third, sprawl makes it more difficult to provide for "eyes on the street" (Jacobs (1961)).

Many of the culprits behind sprawl are well-known. Rising incomes drive household demand for private space up, while an ever-expanding network of roads accommodates the widespread ownership of the car that makes moving out possible (Baum-Snow (2007)). Also, advanced suburbanization begets even more suburbanization, as when suburban interests become entrenched (Thurston/Yezer (1994)). And then, of course, there are governmental incentives. It has long been argued that government subsidies to homeownership contribute to sprawl, too. For the US, Muth (1967, 272) early on suggested that

> " ... governmental programs, such as the federal income tax advantage to owner-occupied housing ..., have probably encouraged decentralization.".

In the same vein, Glaeser (2011) has argued that if owner-occupied housing is peripheral, subsidizing it contributes to city centers' hemorrhaging residents further.

Any assessment of the homeownership subsidy will want to depart from a change in policy that (i) is substantial, (ii) is exogenous, and (iii) applies to at least some households while sparing like-minded others. Germany's homeowner subsidy recess promises to offer just that. For a quick assessment of how wide-spread and how

generous homeowner support really was, note that federal government's aggregate yearly expenditures on homeownership subsidies had attained a staggering 11 billion Euro by 2004. By then expenditures on homeownership promotion had become the single largest subsidy in the federal budget. Next, the political decision to phase out the subsidy was clearly beyond any individual household's control. And to complete, the subsidy's benefits never were evenly distributed across households. And so neither were the effects of the subsidy's withdrawal.

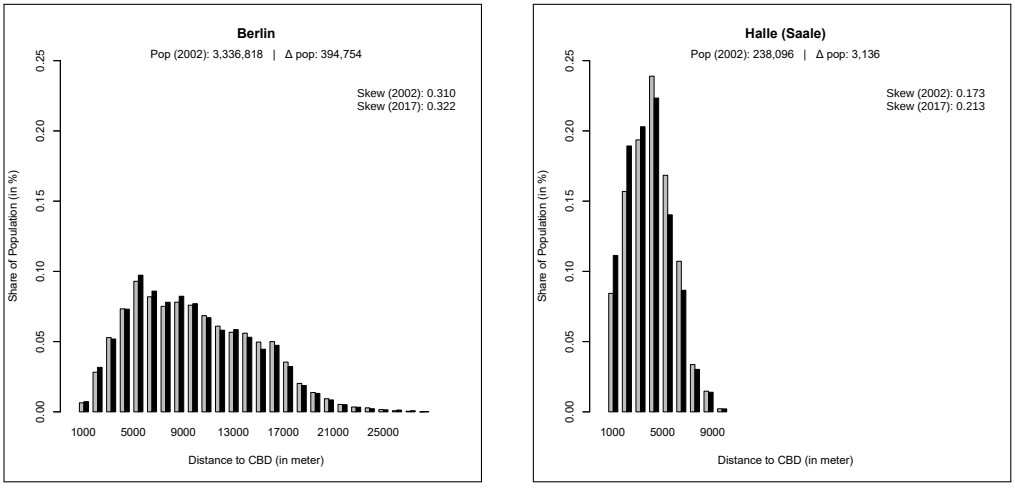
Not only was a substantial component of the subsidy (e.g. the fixed bonus awarded for each child) fixed in nominal, rather than real, terms. Affordable city residents were bound to forego greater real benefits from subsidy withdrawal than citizens of expensive cities (where the subsidy had less real value to begin with). Also (and almost trivially), subsidy withdrawal only hurt those who were young at the time of withdrawal, but not not those who were middle-aged then. It was the middle-aged who had built up sufficient funds for buying a home, and so had qualified for the subsidy prior to its removal. For the period following subsidy removal, we expect to have suburbanized less both: (i) households in more affordable cities and (ii) age cohorts that were young at the time of withdrawal.

These comparisons (affordable vs. expensive, old vs. young) offer two complementary ways in which the impact of homeownership subsidy removal (and hence of the subsidy) should make itself felt in our panel data. We will test for, and find convincing evidence in favor of, both of these. Had it not been for subsidy removal, skew would have *fallen* in most cities. Subsidy removal more than offset the larger, ongoing trend of suburbanization. Now, exploring two different types of treatment not only brings added robustness. It also permits us to rule out age-cohort specific, unobservable trends as reurbanization's driver. In particular we show that the popular notion of "millennials having greater taste for urban living" cannot have driven reurbanization in Germany. Such explanations fail to explain why reurbanization actually is *stronger* in affordable cities – in which the population tends to be *older*.

Our data are built from a large, finely graded sample of various urban demographics indexed by city, distance to the central business district (CBD), and year. We then match official population statistics to city district level shape files (embodied in GIS information), then approximate various population strata for the full set of 1 km-wide rings around the city center.[1] This we are able to do for 79 of the 100 largest German cities, and for all years (2002 through 2017) available. The ring data we thus obtain extend from 4 years before, to 12 years after, subsidy removal. They permit us to trace the distribution of various demographics across city rings from well before, to long after, the reform.

Fig. (1)'s two diagrams show histograms for Berlin and the (substantially smaller, more affordable) Eastern city of Halle, with the grey (black) histogram indicating

[1] While micro data are unavailable to us, we inspect the effect of subsidy removal on those strata that are particularly susceptible to the policy change (e.g., households with and without children, middle-aged vs. young individuals).



Berlin, 2002-2017 Halle, 2002-2017

Figure 1: Distribution of Commuting Distance by Affordability

the fraction of 2002 (2017) population residing in each concentric $[r, r+1)$-km urban ring around the city's CBD. These histograms show frequencies of commuting distance, and may be referred to as "city shape" (Arnott/Stiglitz (1981)). Keeping in mind that overall population rose, central rings appear to have gained weight in either city. At the same time, population shares in peripheral rings often went down. We will refer to this realignment in population shares as "reurbanization", or "recentralization". We early on emphasize a poignant property of these diagrams – being an increase in the *skew* of city shapes. For our choice of indicator (an indicator confined to the interval $[0, 1]$), skew has risen by app. 0.01 points in Berlin, and by even 0.04 points in Halle.[2] More generally, and quite remarkably, almost all of our sample's cities have seen their skew go up in the sample period.

The raw increase in skew appears more pronounced in affordable Halle than in more expensive Berlin. Table (1) takes these observations slightly further. Table (1) first shows the sample average increase in skew by affordability. We see that the average change is larger if cities are "affordable" (here defined as having a price of land in the lowest quintile of the distribution, prior to the sampling period), and this is just what we might expect from a first rough look at the data. As "control", Table (1) also documents the corresponding changes in skew for the sample of US metropolitan areas, over a roughly comparable time span (i.e. 2000-2010), and here we do not see any difference in the change of skew across cities of varying affordability. From our perspective this is intuitive, given no attendant change in homeownership subsidy provision in the US.

There are a number of reasons for assessing homeowner subsidy removal through the lens of city shape *skew* (as opposed to via selected points on the graph of the commuting distribution). From a descriptive perspective, changes in skew condense changes in many different rings into a succinct summary measure (rather than a set

[2]Interpretation and motivation for our choice of indicator of skew we delegate to section 5.

	Affordable	Expensive
σ_{02}	0.299	0.266
σ_{17}	0.329	0.281
$\sigma_{17} - \sigma_{02}$	+ 0.030	+ 0.015

Germany: 2002 - 2017

	Affordable	Expensive
σ_{00}	0.056	0.021
σ_{10}	0.036	0.004
$\sigma_{10} - \sigma_{00}$	– 0.020	– 0.017

US: 2000 - 2010

Table 1: Changes in City Shape's Skew

of numbers). From an analytical perspective, changes in skew directly connect to changes in prominent urban aggregates and urban political economy. We first briefly point to the more straightforward implications of the observed rise in skew, as when seen from within a simple closed-city framework (as in Mohring (1961)). Landlords benefit both from shorter commutes (if they themselves move closer to the center) and from higher rent (if their tenants do).[3] At the same time, average aggregate commuting distance, and the global warming externalities associated with it, recede as skew rises.[4]

Moreover, suppose for the moment that multiple-property-owning landlords are resident (rather than absentee), and that they divide into centrists (whose properties on average are closer to the CBD) and decentrists (owning properties whose average distance is closer to the city fringe). Then under fairly mild conditions[5] skew can be shown to bound the share of centrists among all landlords from below (Dascher (2019)). As skew rises, landlords can be expected to become more "centrist". Landlords now more often side with those who reject peripheral shopping centers or building height controls, and with those who support a federal carbon tax (Dascher (2020)). In short, subsidy removal has implications that go beyond its more immediate effects on "just" the shape of the city.

It is our intention to extract the extent to which the observed growth in sample raw skew can be attributed to subsidy removal, and for this we directly or indirectly address a number of (known or unknown) potential confounders, among them the 2008-2009 financial crisis, the influx of refugees in 2015-2016, a growing urban wage premium (Dauth et al. (2018), de la Roca/Puga (2017), Michaels et al. (2018)), the rise of the service sector (deindustrialization), or rising female labor market participation (joint with the implied extra demand for child care facilities more easily satisfied in the city center), even as other trends surely also have reduced

[3]We suggest that this predicted increase in average rent corresponds well with the empirically observed growth in average urban rent (Mense/Michelsen/Kholodilin (2019)). Rising average rent reflects tenants moving into more central locations, and not just rents going up. We also note that, incidentally, strong rental growth is also attributed to subsidy removal's implications in Glaeser (2011).

[4]Arguably not everyone commutes to the city center, and it is certainly true that Germany's average commuting distance has actually gone up (Dauth/Haller (2019)), and that local concentration of pollutants has actually risen (Borck/Schrauth (2019)). Yet for those who do commute to the city center, commutes have, on average, become shorter along with greater skew.

[5]These are (in addition to the assumptions that underlie the closed monocentric city) that housing consumption is set to 1, and that each landlord owns two flats (one of which she rents out).

skew, e.g. the continuous construction of new peripheral roads.

Our results play into three distinct literatures. First, our results contribute to the controversy over whether (or not) homeownership subsidies improve welfare. Homeownership confers benefits on homeowners' neighbors, as argued by a large literature before and since Glaeser/diPasquale (1999), and the social distancing that sprawling suburbs make possible during the 2020 Covid-19 epidemic will certainly add to them. Yet inasmuch homeownership also contributes to sprawl, aggregate travel costs and related environmental externalities go up also. From an urban economics perspective, next, we tie city shape skew to well-established urban aggregates. And third, we also add to the literature on how city shape affects female labor market participation. As argued by Farré et al. (2020), if women are the primary care givers, more compact (or in our parlance, more skewed) cities – cities in which the average commute is shorter – provide greater incentives to work.

The paper has six sections. Section 2 lays out the subsidy's design. Section 3 details the assembly of our geospatial city-ring-year panel, and presents some preliminary and coarse observations on urban structure. Section 4 sets out the much finer city ring population as a spline of distance to the CBD, and interacts changes in city shape with affordability (subsection 4.1) and age cohort (subsection 4.2) to identify subsidy removal's impact on rings. Section 5 introduces skew, then decomposes the sample average rise in skew of 0.03. This rise we break down into (i) a subsidy removal contribution of more than 0.11, (ii) an increase of 0.03 due to rising female labor force participation, and (iii) a contribution of almost -0.12 from unobservable trends. Germany's cities would have suburbanized further, too, had the homeownership subsidy not paused. Section 6 concludes.

2 Subsidy Design

Germany's homeownership subsidies start with the housing shortage following WW II. One can distinguish roughly four phases here. In a first phase (1949 to 1995), investment into owner-occupied property was income tax deductable, by way of a tax depreciation option. In the second phase (1996 to 2005), investment into owner-occupied property was subsidized lump-sum instead (*Eigenheim-Zulage* in German, and EZ for short). EZ was terminated by the end of 2005. In the following third phase, extending from 2006 up until 2017, the homeownership subsidy paused. Finally, and only as recently as 2018, federal government temporarily (for now) restored the homeownership subsidy, by introducing a variant of EZ for another three years (the fourth, and current, phase).[6] This paper exploits the transition from phase 2 to phase 3.

[6]This variant is the so-called *Baukindergeld*, or BK below. The state of Bavaria tops up BK by an extra 300 Euros. We will return to the issue of BK in section 6, when assessing our results on EZ.

			1996-2003	Amendments 2004/2005
New construction	Beneficiary	Recipient	Income tax liable individuals	
		Maximum 2-year taxable income	81,807 Euros (singles) / 163,614 Euros (couples)	70,000 Euros (singles) / 140,000 Euros (couples)
		Threshold increase per child	30,678 Euros	30,000 Euros
	Object	Subsidized property	Owner-occupied property (house or condo)	
	Subsidy	Funding start	Year of completion	
		Funding period	7 subsequent years	
		Assessment basis	Property price: q_3	
		Yearly subsidy amount (baseline)	**5% of q_3, but max. 2,556 Euros**	**1% of q_3, but max. 1,250 Euros**
		Child allowance	**767 Euros per child**	**800 Euros per child**
Existing property	Beneficiary	Recipient	Income tax liable individuals	
		Maximum 2-year taxable income	81,807 Euros (singles) / 163,614 Euros (couples)	70,000 Euros (singles) / 140,000 Euros (couples)
		Threshold increase per child	30,678 Euros	30,000 Euros
	Object	Subsidized property	Owner-occupied property (house or condo)	
	Subsidy	Funding start	Year of acquisition	
		Funding period	7 subsequent years	
		Assessment basis	Property price: q_2	
		Yearly subsidy amount (baseline)	**2.5% of q_2, but max. 1,278 Euros**	**1% of q_2, but max. 1,250 Euros**
		Child allowance	**767 Euros per child**	**800 Euros per child**

Table 2: EZ-Design: Prerequisites, Recipients, Payments, etc.

Table (2) provides an overview over essential features of the homeownership subsidy as they applied in phase 2. The subsidy in fact split into two separate prongs. Newly built homes (see Table (2)'s upper panel) were subsidized more than existing homes (lower panel). Let q_3 (q_2) denote the price of a newly built (existing) home (where we reserve the price q_1 for the rental housing introduced further below). Then, for every year over a period of eight years altogether, subsidy payments amounted to $\min\{0.05 \cdot q_3, 2\,556\}$ Euro per newly built home, as opposed to only $\min\{0.025 \cdot q_2, 1\,278\}$ Euro for an existing home.[7] Common to all specifications for phase 2, households with children were always entitled to another 767 Euros per child and year.[8]

Transition from phase 2 to phase 3 was gradual. Those who had applied for the subsidy by the end of 2005 remained entitled to receiving it up until eight years later.[9] As mentioned, subsidy payments were highly similar across cities. This was especially true if there were children. Take, as one not overly contrived example, a married couple with two children (and with combined 2-year taxable income of no more than 163,614 Euros) buying a new home in 2003 at the price of 200,000 Euros (i.e. in an "expensive" city). This family would have received $2,556 + 2 \cdot 767$ a year,

[7] Our term "home" here applies to condos, apartments, detached or semi-detached housing alike, as long as they are owner-occupied. – The distinction between newly built and existing homes was eventually lifted, in 2004. Then, and in year 2005, the subsidy was reduced to $\min\{0.01 \cdot p, 1250\}$ Euros, $p \in \{q_2, q_3\}$ for either type of property.

[8] Subsidies applied to first homes, but couples were eligible for second homes, too.

[9] In fact, subsidy pay out period could be pushed back even further if, for example, applications for subsidy and building permission had been in by 2005 while construction was only completed by 2009.

or a total 32,720 Euro over all eight years. That same family would have received the identical total of 32,720 Euro when buying a newly built home in an "affordable" city in which that same home cost only half as much.[10]

Terminating EZ meant terminating subsidies to *both*, existing and newly constructed homes. A minimum framework to sort out the net impact of this joint removal must allow for three types of housing: owner-occupied new housing and owner-occupied existing housing (the two subsidized types of housing) and rental housing (the single non-subsidized type). The effect of simultaneously removing both of these subsidies (themselves of unequal size) is not obvious. We build on a multi-quality, Sweeney (1974)-type framework, and introduce three qualities of housing, with newly built owner-occupied homes (in the periphery) the best, existing owner-occupied homes (also in the periphery) the second best, and rental housing (in the city center) the lowest quality.[11] We assume fully elastic supply of peripheral new housing at construction cost $\overline{q}_3$, and we denote subsidies to existing and newly constructed housing as σ_2 and $\sigma_3 = 2\sigma_2$, respectively.

Twin subsidy removal then changes the structure of equilibrium prices. Specifically, Appendix A shows how joint subsidy removal implies $0 < dq_1$. The rise in equilibrium rental price has us conclude that if government removes its twin subsidy on new and existing owner-occupied housing, rental housing population (near the city center) goes up. Correpondingly, the two segments of owner-occupied housing recede, given the induced filtering into rental housing. These observations underlie our subsequent strategy of discussing removal *as if* a single subsidy had been scrapped.

3 Data

Much as we would prefer to analyze a micro panel of EZ beneficiaries, this type of detailed information is not available, as noted above.[12] But we are able to analyze strata of the urban population that are particularly (un-)susceptible to subsidy removal (i.e. households with vs. without children, and different age cohorts), and at the level of the very narrow ring. Let $2\pi r$ give the approximate area of the 1 km wide concentric ring around the CBD starting at distance r. If $D(r)$ is population density at distance r, then $g(r) = 2\pi r D(r)$ approximates the share of population inhabiting the 1-km-wide ring starting at r km away from the CBD. Let $\widetilde{r}$ denote the

[10] Generally, for any two homes costing more than the threshold 51,120 Euro (a threshold rarely not passed) subsidy payments would have been the same.

[11] Such a tenure-quality-hierarchy may be justified by appealing to informational asymmetries in housing (e.g., as in Arnold/Babl (2014)). Regarding the link between housing tenure and city location, see Hilber (2014) who finds that an apartment in a multi-family building is substantially less likely to be owner-occupied than a detached house, holding occupant and location characteristics constant, and see Ahlfeldt/Maenning (2015) who suggest that close to 80% of one- and two-family houses are owner-occupied, whereas more than 80% of dwellings with three or more families are inhabited by renters.

[12] Though a federal subsidy, EZ was not administered centrally. Instead, local tax offices screened applications and supervised subsidy payout. According to the Federal Ministry of Finance, nowhere were data consolidated. This lack of information may help explain the dearth of studies on EZ.

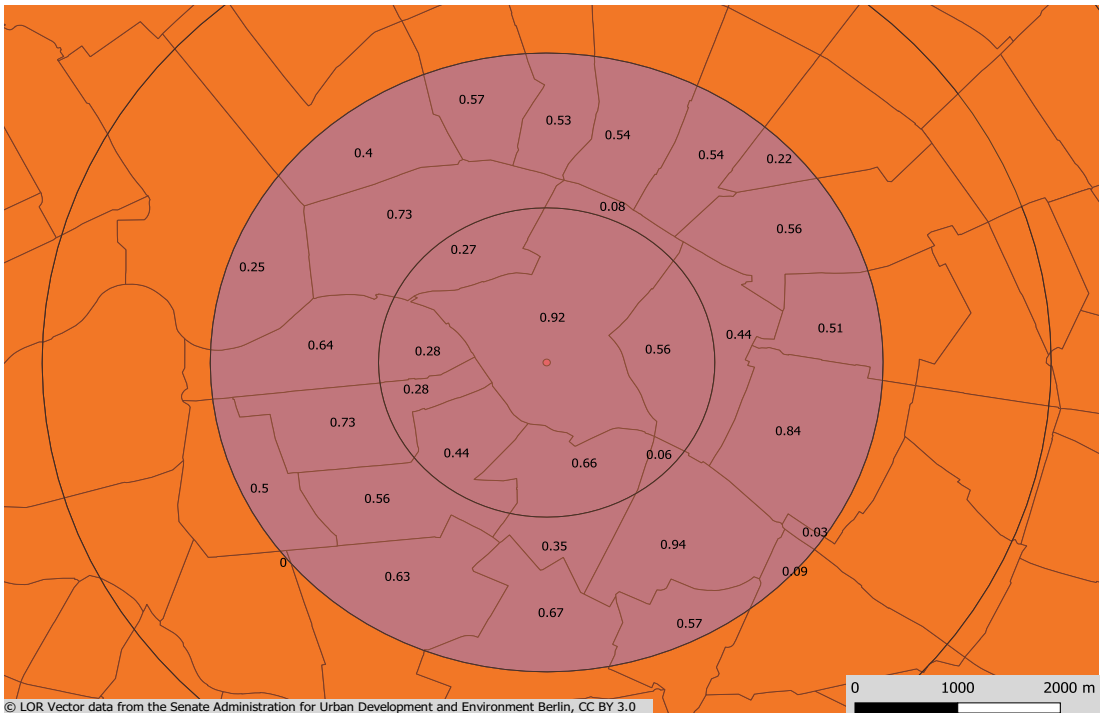


Figure 2: Shares α_{11} and α_{12} for Berlin's first two rings

maximum distance from the CBD to the city's administrative boundary, i.e. "city size". Then as r ranges from 0 to $\widetilde{r}$, function $g(r)$ captures the city's "shape" (again, Arnott/Stiglitz (1981)) or "distance profile" (Lee (2020)).

Data on city shape g are not available for Germany, and so we infer them from available population data on cities' administrative subdivisions, resorting to standard geospatial techniques.[13] Highly detailed subdivision data are provided by BBSR[14] and KOSTAT[15] for the 100 largest German cities[16], and (in most cities) for all years 2002 through 2017. As the city's CBD we often (i.e. whenever possible) choose city hall.[17] Given the CBD's geo-coordinates, we next equate $\widetilde{r}$ with the maximum length of all rays extending out from the CBD. We partition the city into 1 km wide concentric rings around the CBD, and then intersect this partition with the city shapefile polygons.[18] Fig. (2) gives one example of the procedure, for Berlin's first

[13]Below we briefly also make use of US data, where g actually *is* available on 1 mile wide rings around the city center and for years 2000 and 2010, see Wilson (2012) and Dascher (2019).

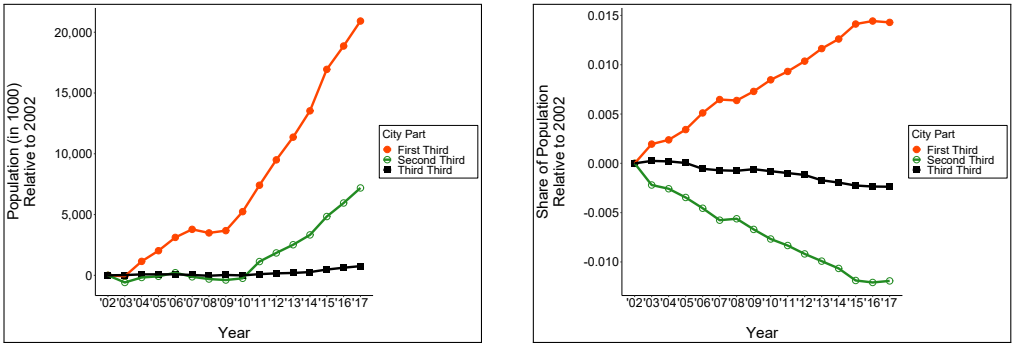
[14]BBSR: Bundesinstitut für Bau-, Stadt- und Raumforschung.

[15]KOSTAT: KOSIS-Gemeinschaft Kommunalstatistik.

[16]We had to omit 21 cities from this list, because for these cities shapefiles (see below) and/or data on population are missing. These cities are Osnabrück (48th in a list ordered by city size), Leverkusen (49th), Paderborn (56th), Heilbronn (62nd), Bottrop (66th), Bremerhaven (70th), Hildesheim (79th), Cottbus (80th), Kaiserslautern (81th), Gütersloh (82th), Hanau (84th), Ludwigsburg (87th), Esslingen am Neckar (88th), Iserlohn (89th), Düren (90th), Flensburg (93th), Gießen (94th), Ratingen (95th), Lünen (96th), Marl (99th) and Worms (100th).

[17]When city hall no longer exists, we pick the central market square or any other significant building or square (a cathedral, for example) that could justifiably be considered part of the CBD.

[18]City shapefiles indicate subdivisions' polygonal boundaries. Where shapefiles are not publicly available we contacted municipal cadastral offices.



2002-2017, Population

2002-2017, Population Share

Figure 3: Recentralization in Germany

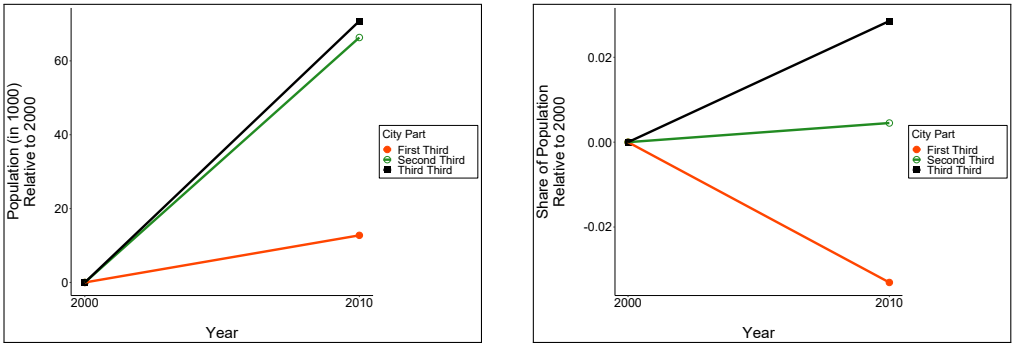
two concentric rings around the historical city hall (itself shown as a small circle at the center of the map).

For each of city i's subdivisions $s = 1, \ldots, S_i$ we first use GIS to identify the area of the intersection of that subdivision with ring j, A_{sj}. Then $\alpha_{sj} = A_{sj}/A_s$ is the share of city ring j in subdivision s's area A_s. Of all n_s residents in subdivision s we next apportion $\alpha_{sj} n_s$ individuals to ring j.[19] Repeating this procedure for all subdivisions and summing over respective contributions, we estimate total population in city i's ring j at $n_{ij} = \sum_{s=1}^{S_i} (A_{sj}/A_s) n_s$. Repeating this procedure for every city in the sample yields the full set of city shapes, $\{g_i\}$. Fig. (2) highlights the procedure for the first two rings. For example, 92% of the centralmost subdivision's population, for instance, are assigned to the first ring, while 8% are assigned to the second, ring.

Whenever possible we will make use of the full sample of 79 cities. Data are not always available for the full sixteen years 2002-2017, and this is why our (unbalanced) panel comes to somewhat less than the full number of observations. Altogether our sample cities account for slightly over 22 million individuals (in 2002), and represent nearly one fourth of the country's population. For now we aggregate every city's set of rings into consecutive subsets of thirds. We coarsely equate the 1st third of rings with the empirical counterpart of the previous section's rental housing (quality 1), the 2nd third with the counterpart of existing homes (quality 2), and the 3rd third with the remaining segment hosting newly built homes (quality 3). The first panel in Fig. (3) shows the change in the sample average of ring thirds' population over time. On average, the 1st third of rings (graph in red on screen) grows by over 20,000 residents between 2002 and 2017. Residents in the 2nd third of rings (green graph) on average also become more numerous, if only later and less so. Average population in the last third of rings (black graph) essentially stagnates.

Taking averages conceals strong heterogeneity across cities. For example, while 58% of Berlin's residents inhabit the 1st third of rings, and the share of those who populate the 2nd third is 40%, in the small city of Weimar the 1st and 2nd thirds

[19] This is an exact procedure only if residents are uniformly distributed across space – which of course they are not. We consider it a reasonable approximation.



2000-2010, Population

2000-2010, Population Share

Figure 4: No Recentralization in the US

of rings host 73% and 25%, respectively.[20] So we alternatively cast our diagrams in terms of ring thirds' shares in city population (Fig. (3)'s second panel). Here we see that the 1st third's share grew by 1.5 percentage points almost; while the 2nd and 3rd thirds' shares both *shrank*. These observations starkly illustrate the extent to which Germany's larger cities underwent reurbanization.

A small but growing literature asserts gentrification, and even a degree of city center renaissance, for certain population strata in US metro areas' urban core (Baum-Snow/Hartley (2019), Couture/Handbury (2017), Owens/Rossi-Hansberg (2020)). To relate to this literature, we have also recomputed Fig. (3) for the US, for the period 2000 to 2010 (see Fig. (4)).[21] We comment on trends in absolute numbers first. Average population in the 1st third of US rings did rise. However, average population in the 2nd and 3rd third of rings also grew, and by *more*. Fig. (4)'s second panel also displays changes in the averages of city thirds' population shares. In contrast to what we saw for German cities, the average share of US urban population in the 1st third of rings *dropped* dramatically, by nearly 3 percentage points; whereas the 2nd and the 3rd third's shares actually *grew*. For all the emphasis on US urban revival for narrow population strata (e.g. "young professionals") in the vicinity of the city center, i.e. 1 or 2 miles near the CBD, here we see (e.g., much as does Lee (2020)) that the share of residents' *total* in the most central third of rings unambiguously *falls*.

No recentralization can be observed for the US, certainly not up until 2010. For this it appears difficult to cast Germany's recent recentralization experience as a reflection of a broader international trend towards city center revival (as may have been brought about by a general resurgence of the central city labor market). Of course, this observation relies on mere sample averages for ring thirds, which themselves are coarse measures of city spatial structure. We next turn to our full panel of finer city shapes g to disentangle subsidy removal's effect on city shape and skew from that of those many conceivable confounders.

[20] This is why we consistently add city fixed effects later.

[21] Underlying data are from Wilson (2012), see Dascher (2019) or Holian (2019).

	Ring Residential Population	
	log(Pop)	
	(1)	(2)
Intercept	8.989***	9.376***
	(0.029)	(0.047)
Distance	0.384***	0.232***
	(0.007)	(0.007)
(Distance - $\tilde{r}/3$) × Peri	−0.808***	−0.660***
	(0.010)	(0.009)
(1 - Peri) × Post	0.213***	0.055***
	(0.024)	(0.019)
Peri × Post	−0.141***	0.001
	(0.025)	(0.018)
City FE	No	Yes
Observations	14,939	14,939
R^2	0.554	0.787
Note:		*p<0.1; **p<0.05; ***p<0.01
		Huber-White robust standard errors in parentheses.

Table 3: Benchmark Model: Ring Population as a Spline Function of Distance

4 Results

Consider the following small empirical model that forms the core of all our analysis below. According to eq. (1), the conditional expectation of the population (or some stratum thereof further down) inhabiting city i, ring j and period t is a simple spline of the ring's distance DIST to the CBD, where μ_i is the city i fixed effect, PERI is a city periphery dummy (1 if ring belongs to the the last two thirds of rings), and POST is the treatment period dummy (1 if year t dates to after 2005, the year of subsidy removal), such that

$$\begin{aligned} E(y_{ijt}|x_{ijt}) &= \alpha_0 + \mu_i + \alpha_1 \,\mathrm{DIST}_j + \alpha_2 \,(\mathrm{DIST}_j - \widetilde{r}/3) \times \mathrm{PERI} \\ &+ \beta_1 \,(1 - \mathrm{PERI}) \times \mathrm{POST} + \beta_2 \,\mathrm{PERI} \times \mathrm{POST}, \end{aligned} \tag{1}$$

and where x_{ijt} is shorthand for the full list of covariates. We motivate including a spline by recalling the city's typical hump-shaped form and positive skew as illustrated in Fig. (1). Ring population first increases, then decreases, in distance from the CBD. This of course is because the CBD is predominantly commercial, and also because building height recedes as one moves out further (e.g. Fujita (1989)). We set a single fixed knot, at distance $\widetilde{r}/3$.[22]

Table (3) provides OLS estimates for the population regression equation (1), with and without fixed effects. Going by the first three estimates in our preferred specification in column (2), average population (conditional on distance etc.) prior to subsidy removal is credibly non-linear in distance to the CBD. Both slope coefficients exhibit the predicted sign, and are significant. Moreover, going from before, to after, the year of subsidy removal has the upward sloping segment of the spline shift

[22] One may endogenize this knot, e.g. by making it equal the distance at which the (negative of the) growth rate of population density equals that of available land. I.e., differentiate $g(r) = 2\pi r D(r)$ with respect to r, rearrange and set equal to zero. This gives $1/r = -D'/D$, and this locates the r for which g is maximal. In the interest of parsimonious modeling we have decided against endogenizing the knot.

upwards, with no complementary downward shift of the downward sloping segment. Each of the most central rings sees its residents grow by 5.7%. We must be careful not to equate this effect with the effect of subsidy removal. To properly assess the effect of subsidy removal next, we augment equation (1) by suitable sets of dummy interactions that implement the two comparisons set out in the introduction. We implement one comparison exploring inter city differences in (real estate) affordability in subsection 4.1, and another exploring inter cohort differences in (subsidy) accessibility in subsection 4.2.

4.1 Affordable Cities vs. Expensive Cities

Subsidy removal should drive city center revival in affordable cities more, as discussed. For now we partition our cities into the categories of "affordable" and "expensive", and pursue the continuous treatment case below. Expected ring population in affordable cities should be allowed to undergo a post-subsidy-removal experience that differs from that of expensive cities. In eq. (2) we augment our baseline specification in eq. (1) by interacting either spline segment with dummy AFF, which equals 1 if the ring belonged to the most affordable quintile of cities (where cities are ranked according to their average price of land in 2002). Thus,

$$\begin{aligned} E(y_{ijt}|x_{ijt}) &= \alpha_0 + \mu_i + \alpha_1 \,\mathrm{DIST}_j + \alpha_2 \,(\mathrm{DIST}_j - \widetilde{r}/3) \times \mathrm{PERI} \\ &+ \beta_1 \,\mathrm{POST} \times (1 - \mathrm{PERI}) + \beta_2 \,\mathrm{PERI} \times \mathrm{POST} \\ &+ \gamma_1 \,\mathrm{AFF} \times (1 - \mathrm{PERI}) \times \mathrm{POST} + \gamma_2 \,\mathrm{AFF} \times \mathrm{PERI} \times \mathrm{POST}. \quad (2) \end{aligned}$$

Affordable cities' extra experience is captured by coefficients γ_1 and γ_2. Here γ_1 indicates the possible extent to which the 1st third of rings expands more in affordable, than in expensive, cities, while γ_2 achieves the opposite by capturing the extent to which the last two thirds of rings may expand less in affordable, than in expensive, cities. We consider the stratum of families with dependent children first, which is the household type that should respond to subsidy removal strongest.

Table (4) shows the corresponding estimates.[23] The first two columns of the table give the results for estimating eq. (2). Estimates for our coefficients of interests equal $\widehat{\gamma}_1 = 0.433$ and $\widehat{\gamma}_2 = -0.173$, respectively, and are statistically significant. Hence in the wake of subsidy removal, in affordable cities households with children grew by an extra 54% in every central ring, while they contracted by 16% in every peripheral ring. As subsequent columns (3) and (4) in Table (4) also account for average household income[24], estimates of our coefficients of interest continue to retain their predicted sign and significance.

Columns (5) and (6) go on to include women's labor force participation rate. We expect rising female labor force participation to drive households into the city center,

[23] We now also document estimates for Poisson MLE, an alternative estimator that accounts for the count data nature of our ring resident figures, even as we will restrict our comments to often very similar OLS estimates.

[24] INCOME and further variables introduced below are defined in the Appendix.

	Ring Households with Children					
	log(HHwC)	HHwC	log(HHwC)	HHwC	log(HHwC)	HHwC
	OLS	*Poisson*	*OLS*	*Poisson*	*OLS*	*Poisson*
	(1)	(2)	(3)	(4)	(5)	(6)
Intercept	6.950^{***}	7.354^{***}	6.948^{***}	7.695^{***}	6.834^{***}	7.624^{***}
	(0.063)	(0.051)	(0.086)	(0.074)	(0.082)	(0.072)
Distance	0.244^{***}	0.153^{***}	0.241^{***}	0.149^{***}	0.244^{***}	0.150^{***}
	(0.010)	(0.008)	(0.011)	(0.008)	(0.011)	(0.008)
Peri × (Distance - $\bar{r}/3$)	-0.657^{***}	-0.469^{***}	-0.661^{***}	-0.475^{***}	-0.662^{***}	-0.475^{***}
	(0.012)	(0.009)	(0.013)	(0.009)	(0.013)	(0.009)
(1 - Peri) × Post	-0.151^{***}	-0.097^{***}	-0.066	-0.021	-0.053	-0.019
	(0.033)	(0.023)	(0.043)	(0.030)	(0.043)	(0.030)
Peri × Post	0.036	0.122^{***}	-0.004	0.034	0.007	0.047^{*}
	(0.031)	(0.023)	(0.036)	(0.025)	(0.036)	(0.025)
Aff × (1 - Peri) × Post	0.433^{***}	0.232^{***}	0.428^{***}	0.214^{***}	0.175^{**}	0.138^{**}
	(0.071)	(0.050)	(0.073)	(0.051)	(0.076)	(0.055)
Aff × Peri × Post	-0.173^{**}	-0.219^{***}	-0.181^{**}	-0.211^{***}	-0.075	-0.141^{***}
	(0.071)	(0.048)	(0.072)	(0.049)	(0.073)	(0.051)
(1 - Peri) × Household Income			-0.120^{***}	-0.128^{***}	-0.973^{***}	-0.428^{***}
			(0.033)	(0.022)	(0.099)	(0.084)
(1 - Peri) × Female Labour					3.079^{***}	1.131^{***}
					(0.341)	(0.293)
City FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	7,125	7,125	6,244	6,244	6,244	6,244
R^2	0.789		0.787		0.789	
Log Likelihood		-1,952,712		-1,722,199		-1,716,045

Note: *p<0.1; **p<0.05; ***p<0.01
Huber-White robust standard errors in parentheses.

Table 4: Households with Children and Affordability

or at least make them refrain from moving out. In the center, commutes are shorter (allowing more precious time to spend with one's children), and population density D is greater (alternatively permitting families to share child minding cost more easily). Accounting for this channel reduces the coefficient of AFF × PERI down to 0.175, and brings the coefficient of the interaction AFF × PERI × POST up to −0.075. At least the first of these estimates continues to be significant. We also consult column (5) on coefficient estimates pertaining to expensive cities. These estimates are found in rows (1−PERI)× POST and PERI × POST, and are essentially insignificant. Following subsidy removal, expensive cities do not see any family gains (or losses) in central (or peripheral rings), and this is precisely what we should expect.

Fig. (5) illustrates these effects, going by the estimates in column (5) of Table (4). According to the diagram on the left, removal had no effect on families in expensive cities, while according to the diagram on the right, in affordable cities removal did attract families to central rings, and repel families from peripheral rings. We note that the coefficient estimate for female labor force participation itself is positive, and signals families' risen demand for living in a more central location (assuming we could rule out endogeneity here). As Farré/Joffre-Monseny/Torrecillas (2020) have pointed out, female labor force participation may well follow, rather than determine, urban spatial structure. Then estimates in columns (5) and (6) would be inconsistent.[25] We return to this issue shortly.

[25]This may also explain why the coefficient on female labor force participation is so large in absolute value. An increase in the (general) female labor participation rate of ten percentage points

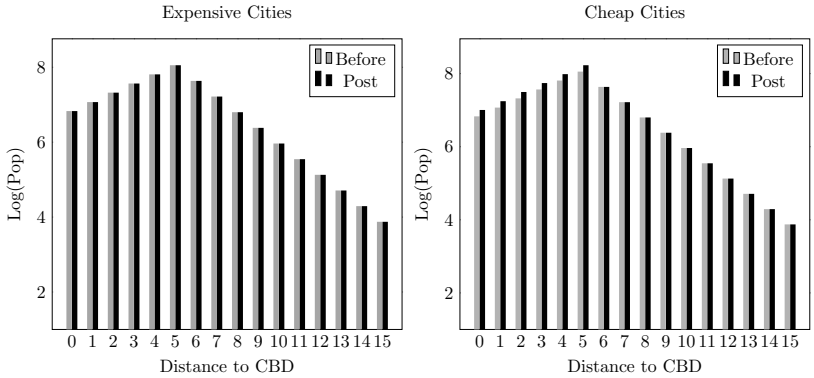


Figure 5: Predicted Effect of Removing Homeowner Subsidy

We next allow for a continuous treatment, and now also address total ring population (rather than families with children). In eq. (2) our continuous treatment is $\overline{\text{PRICE}}-$ PRICE. This is the extent to which the local average price of land back in 2002 fell short of that in the most expensive city in the sample, Munich. This gives the modified specification

$$\begin{aligned} E(y_{ijt}|x_{ijt}) &= \alpha_0 + \mu_i + \alpha_1 \,\text{DIST}_j + \alpha_2 \,(\text{DIST}_j - \widetilde{r}/3) \times \text{PERI} \\ &+ \beta_1 \,\text{POST} \times (1 - \text{PERI}) + \beta_2 \,\text{PERI} \times \text{POST} \\ &+ \gamma_1 \,(\overline{\text{PRICE}} - \text{PRICE}) \times (1 - \text{PERI}) \times \text{POST} \\ &+ \gamma_2 \,(\overline{\text{PRICE}} - \text{PRICE}) \times \text{PERI} \times \text{POST}. \end{aligned} \tag{3}$$

We identify the effect of subsidy removal on expected ring population as the sum of the last two lines of eq. (3), while we equate the combined impact of all other (essentially unobservable) trends with the changes we observe for Munich, as given on the equation's second line. Table (5) has the coefficient estimates. Here certainly peripheral rings' contraction, if not central rings' growth, is driven by subsidy removal. Finally, we also note that all cities appear to have experienced a strong undercurrent of suburbanization. This is best seen when consulting our estimates on the only city where subsidy removal cannot have mattered, i.e. Munich. Munich's peripheral rings always continued to grow.

4.2 Young vs. Old

Instead of focusing on individuals' differential treatment by city, we now explore the effects of individuals' differential treatment by age. Scrapping the homeowner subsidy meant scrapping it for those too young in 2005 to have bought a home, for lack of income. It did not mean scrapping it for those old enough to have bought a home, and applied for the subsidy, by then. We define as "young" in any given year those who are between 15 and 29 years, as "old" all middle-aged individuals in brackets 30-44, and as "very old" those who are 45 through 59. For the course

implies a 21% rate of change in the number of families (and hence essentially women with children) in the city center.

	Ring Residential Population					
	log(Pop)	Pop	log(Pop)	Pop	log(Pop)	Pop
	OLS	*Poisson*	*OLS*	*Poisson*	*OLS*	*Poisson*
	(1)	(2)	(3)	(4)	(5)	(6)
Intercept	9.495***	9.846***	9.343***	9.965***	9.237***	9.942***
	(0.046)	(0.046)	(0.067)	(0.057)	(0.065)	(0.057)
Distance	0.208***	0.131***	0.209***	0.131***	0.216***	0.132***
	(0.008)	(0.006)	(0.009)	(0.007)	(0.009)	(0.007)
Peri × (Distance - $\tilde{r}/3$)	−0.638***	−0.430***	−0.629***	−0.426***	−0.634***	−0.426***
	(0.010)	(0.007)	(0.011)	(0.007)	(0.011)	(0.007)
(1 - Peri) × Post	−0.496***	−0.058	−0.354***	−0.028	−0.049	−0.0003
	(0.069)	(0.047)	(0.074)	(0.050)	(0.077)	(0.052)
Peri × Post	0.435***	0.348***	0.352***	0.295***	0.256***	0.281***
	(0.061)	(0.041)	(0.063)	(0.043)	(0.063)	(0.043)
($\overline{\text{Price}}$ - Price) × (1 - Peri) × Post	0.725***	0.119*	0.550***	0.082	0.131	0.042
	(0.093)	(0.063)	(0.098)	(0.065)	(0.102)	(0.067)
($\overline{\text{Price}}$ - Price) × Peri × Post	−0.576***	−0.457***	−0.482***	−0.399***	−0.326***	−0.371***
	(0.086)	(0.054)	(0.090)	(0.056)	(0.090)	(0.056)
(1 - Peri) × Household Income			−0.025	−0.018	−0.831***	−0.144***
			(0.024)	(0.016)	(0.069)	(0.048)
(1 - Peri) × Female Labour					2.782***	0.441***
					(0.224)	(0.157)
City FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	13,933	13,933	11,022	11,022	11,022	11,022
R^2	0.784		0.775		0.778	
Log Likelihood		-33,071,377		-28,734,332		-28,710,020

Note: *p<0.1; **p<0.05; ***p<0.01
Huber-White robust standard errors in parentheses.

Table 5: All residents and Affordability

of the 15 years that followed the year 2002, the young turned old as the old turned very old. We reasonably expect the initially old to move out into the home they had bought just in time prior to subsidy removal, and the initially young to stay put. Empirically, we match up age cohorts in our data set by essentially setting up the 2002 number of young (old) against the 2017 figure of old (very old).

Let dummy OLD equal 1 (zero) if the stratum in city i ring j is 30 to below 45 (15-29) in 2002 and 45 to below 60 (30-44) in 2017. The baseline equation we estimate is

$$\begin{aligned} E(y_{ij}|x_{ij}) &= \alpha_0 + \mu_i + \alpha_1 \,\text{DIST}_j + \alpha_2 \,(\text{DIST}_j - \widetilde{r}/3) \times \text{PERI} \\ &+ \beta_1 \,\text{POST} + \beta_2 \,\text{OLD} + \beta_3 \,(1 - \text{PERI}) \\ &+ \gamma_1 \,\text{POST} \times \text{OLD} + \gamma_2 \,\text{POST} \times (1 - \text{PERI}) + \gamma_3 \,\text{OLD} \times (1 - \text{PERI}) \\ &+ \delta \;\text{POST} \times \text{OLD} \times (1 - \text{PERI}). \end{aligned} \tag{4}$$

In conditional expectation (4), coefficient δ identifies the extent to which the old reurbanize *more* (or *less*, if negative) than the young, over the 15 years under scrutiny. Coefficient δ provides a complementary way of capturing the impact of subsidy removal. We here hope to remove any inconsistency in estimation arising due to unobservable trends (e.g., increasingly attractive amenities) that drive *both* cohorts' reurbanization. As shown in the first column of Table (6), our DDD-estimate is $\widehat{\delta} = -0.467$. Reurbanization among the old falls short of what it is for the young.

We again also control for household income and female labor force participation in columns (3) through (6), to nearly identical effect. We also now instrument for the interaction term on labor force participation, using sectoral shares, in column (7).[26]

[26] We omit the first stage regression here for brevity. We document a first stage regression in the following section, with more detail on the instruments also used here.

	Dep.Var: Ring Residential Population						
	log(Pop)	Pop	log(Pop)	Pop	log(Pop)	Pop	log(Pop)
	OLS	*Poisson*	*OLS*	*Poisson*	*OLS*	*Poisson*	*2SLS*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Intercept	7.304***	7.971***	7.241***	8.170***	7.207***	8.120***	7.193***
	(0.093)	(0.091)	(0.142)	(0.136)	(0.138)	(0.132)	(0.142)
Distance	0.213***	0.119***	0.213***	0.119***	0.213***	0.119***	0.205***
	(0.011)	(0.008)	(0.013)	(0.010)	(0.013)	(0.010)	(0.013)
Peri × (Distance - $\bar{r}/3$)	−0.621***	−0.415***	−0.620***	−0.412***	−0.621***	−0.412***	−0.600***
	(0.013)	(0.010)	(0.015)	(0.011)	(0.015)	(0.011)	(0.015)
Post	−0.045	0.004	−0.034	0.007	−0.031	0.011	−0.016
	(0.032)	(0.034)	(0.039)	(0.042)	(0.039)	(0.042)	(0.040)
Old	0.568***	0.479***	0.568***	0.480***	0.568***	0.480***	0.575***
	(0.036)	(0.034)	(0.038)	(0.035)	(0.037)	(0.035)	(0.039)
(1 - Peri)	−0.093**	−0.199***	0.722***	−0.284**	−1.458***	−1.231***	−0.985**
	(0.043)	(0.040)	(0.154)	(0.138)	(0.232)	(0.195)	(0.458)
Post × Old	0.067	0.001	0.065	0.004	0.065	0.004	0.049
	(0.049)	(0.046)	(0.062)	(0.056)	(0.061)	(0.056)	(0.063)
Post × (1 - Peri)	0.370***	0.331***	0.542***	0.303***	0.187***	0.155**	0.246***
	(0.047)	(0.048)	(0.067)	(0.064)	(0.070)	(0.065)	(0.094)
Old × (1 - Peri)	0.023	0.101**	0.022	0.101**	0.022	0.101**	0.026
	(0.055)	(0.048)	(0.057)	(0.050)	(0.056)	(0.050)	(0.058)
Post × Old × (1 - Peri)	−0.467***	−0.455***	−0.464***	−0.456***	−0.464***	−0.456***	−0.445***
	(0.075)	(0.066)	(0.094)	(0.082)	(0.092)	(0.082)	(0.095)
(1 - Peri) × Household Income			−0.578***	0.063	−0.810***	−0.226**	−0.692***
			(0.105)	(0.090)	(0.105)	(0.096)	(0.133)
(1 - Peri) × Female Labour					5.574***	3.040***	4.227***
					(0.482)	(0.406)	(1.224)
City FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	6,986	6,986	4,758	4,758	4,758	4,758	4,446
R^2	0.792		0.790		0.795		0.792
Log Likelihood		-5,429,294.000		-3,713,125.000		-3,661,689.000	

Note:

*p<0.1; **p<0.05; ***p<0.01
Huber-White robust standard errors in parentheses.
Four years included: Before = 2002, 2003; Post = 2016, 2017.
Young = Age 30-44, Old = Age 45-59

Table 6: Old vs. Young Individuals

Then there is barely any change in the DDD-estimate. It is only that the coefficient estimate for the interaction between female labor force participation and $1 - \text{PERI}$ falls, suggesting endogeneity, i.e. suggesting that reurbanization has induced women to work more.

It is instructive to decompose the DDD-estimate. On the one hand, for the younger cohort we have $\widehat{\gamma}_2 = 0.370$ in the baseline case in column (1). Central rings' growth exceeded peripheral rings' growth. Yet what is more, we even learn that central rings grew ($\widehat{\beta}_1 + \widehat{\gamma}_2 = 0.325$), while peripheral rings actually contracted, in their young ($\widehat{\beta}_1 = -0.045$). For the cohort of the old, on the other hand, we obtain a log change of $\widehat{\gamma}_2 + \widehat{\delta} = -0.097$, implying that here central rings grew less than peripheral rings did. In fact, consulting the proper coefficient estimates in the Table shows that central rings not just grew less than peripheral rings. Central rings' old became fewer in absolute numbers, too; whereas peripheral rings' old actually became more numerous. It is not just that both age cohorts reurbanized, with the young reurbanizing more. Rather, and plainly, it is that the young reurbanized while the old suburbanized.

The difference between these two urbanization "vectors", equal to our $\widehat{\delta} = -0.467$, we attribute to subsidy removal. As mentioned earlier, one may wonder if this difference could also be due to differences in cohort-specific trends, e.g. millennials' preferential shifts. We briefly explain that such trend differences are not an issue here, by contradiction. We note first that affordable cities tend to be older on average, as Fig. 6 shows. Now, suppose that age-specific shifts drive the differences in reurbanization between young and old. But then these same shifts would have cheaper cities reurbanize *less* than expensive cities. This is in contradiction to what

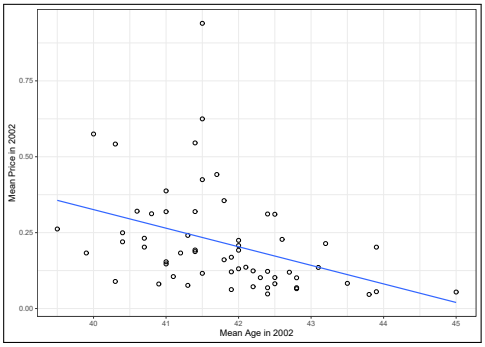


Figure 6: Real Estate Affordability and Average Age

we just learned, in subsection 4.1. Subsidy removal (through its independent impact on affordable cities), in contrast, is well able to also explain the reurbanization pattern laid out in subsection 4.1.

5 Skew Decomposition and Subsidy Removal

We condense the changes in individual ring population predicted in subsection 4.1 into city skew, a single measure. We first offer a conceptual (if partial) framework of which our concept of skew is a natural extension. Then we take this framework to the empirical changes in skew that we observe. Subsection 5.1 ties the observed skew change to changes in average aggregate land rent (ALR) and average aggregate travel cost (ATC), and relates skew to the local preponderance of "centrism", as landlords' propensity to embrace jobs and shops in the city center rather than in the city periphery. Subsection 5.2 identifies the extent to which a city's raw change in skew – joint with its attendant effects on ALR, ATC and "centrism" – can be attributed to subsidy removal.

5.1 Motivation

Allow for a modified perspective now, based on the simplest version of the closed model of the monocentric city (as in Mohring (1961)). We partition its circular area into n (n even) concentric, 1-unit of distance-wide rings about the CBD, where $j = 1, \ldots, n$ indexes rings. Linear commuting cost to the CBD is tr_j, where $r_j = j - 0.5$ is ring j's distance to the center and τ the travel cost incurred per unit of distance. We also assume there is a marginal resident at the city fringe $\widetilde{r}$, and so Ricardian rent becomes $q(r_j) = \tau(\widetilde{r} - r_j)$ at r, as the cost advantage when commuting from r relative to commuting from $\widetilde{r}$. Housing is owned by resident landlords and owner-occupiers alike, with group size left undetermined for now.

Let b_j be the total number of landlords and tenants (i.e. the total of residents)

inhabiting ring j. We define skew σ as

$$\sigma \;=\; \sum_{j=1}^{n/2} \Big(b_j - b_{n+1-j}\Big)\Big(1 - r_j/(\widetilde{r}/2)\Big)\Big/b, \tag{5}$$

where b_j is the number of residents in ring j and b is total city population. Note that σ is a suitable measure of skew. If city shape $g = (b_1, \ldots, b_n)/b$ is symmetric, such that $b_j = b_{n+1-j}$ for all j, then clearly $\sigma = 0$. Next, if g is skewed to the right, then the ring difference $b_j - b_{n+1-j}$ is large for small j yet small for large j, and so then σ is strictly positive. Finally, and conversely, if σ is strictly positive, it must be that early ring differences (for small j) are positive, given the larger weight placed on them. Intuitively, the left tail must be "thicker" than the tail to the right of the distribution, generating a positively skewed appearance. We finally add that $-1 \leqslant \sigma \leqslant 1$ (Dascher (2019)).

Define aggregate travel costs ATC as $\sum_{j=1}^{n} \tau r_j b_j$, and aggregate land rent ALR as $\sum_{j=1}^{n} \tau(\widetilde{r} - r_j) b_j$, as usual. Then it is straightforward to rewrite $\tau\widetilde{r}\sigma$, a multiple of skew, as

$$\begin{aligned}
\tau\,\widetilde{r}\,\sigma \;&=\; 2\tau \sum_{j=1}^{n/2} \Big(g_j - g_{n+1-j}\Big)\Big(\frac{\widetilde{r}}{2} - r_j\Big) \\
&=\; 2\tau \sum_{j=1}^{n} g_j \Big(\frac{\widetilde{r}}{2} - r_j\Big) \\
&=\; \sum_{j=1}^{n} g_j\,\tau(\widetilde{r} - r_j) \;-\; \sum_{j=1}^{n} g_j \tau r_j \;=\; (\mathrm{ALR} - \mathrm{ATC})/b,
\end{aligned} \tag{6}$$

or the difference between aggregate land rent and aggregate travel cost per capita. Here the second equality exploits the fact that $\widetilde{r}/2 - r_j = -(\widetilde{r}/2 - r_{n+j-1})$ for all $j = 1, \ldots, n/2$, and the third equality follows by mere rearrangement.

Even only from a descriptive perspective (descriptive because we model no particular cause for skew change here) can a rise in skew be instructive. Suppose city shape and skew change over, and are differentiable w.r.t., time t. Then if skew is increasing in t, ALR per capita must be increasing, while ATC per capita must be decreasing, in t. To verify this, divide equation (6) by $\tau\widetilde{r}$ and differentiate both sides of the equation with respect to time t. This yields

$$\begin{aligned}
0 \;<\; \frac{\partial\sigma}{\partial t} \;=\; \sum_{j=1}^{n} \frac{\partial g_j(t)}{\partial t} \qquad &- (2/\widetilde{r}) \sum_{j=1}^{n} \frac{\partial g_j(t)}{\partial t}\, r_j \\
&=\; -\,(2/\widetilde{r}) \sum_{j=1}^{n} \frac{\partial g_j(t)}{\partial t}\, r_j \;=\; -\,(2/\widetilde{r})\, \frac{\partial(\mathrm{ATC}/b)}{\partial t}.
\end{aligned} \tag{7}$$

Here the inequality holds by assumption, and the second equality obtains from the fact that changes in density must sum to zero. We conclude that the last expression in (7) is strictly positive. So ATC p.c. must be strictly decreasing, while ALR p.c. must be strictly increasing, in time.

If we are willing to go one step further, then we might assume that landlords own two properties each (not necessarily in the same ring), one of which they inhabit themselves, the other which they rent out to a tenant. Landlords whose properties sit next to each other (are in the same ring) we might then call "owner-occupiers", while all other landlords we might address as "landlords". It can be shown that skew here actually bounds the share of centrists – being those landlords whose average property is closer to the city center – in the total number of landlords from below (Dascher (2019), Proposition 3). Even if rising skew does not imply a rise in the centrist share, rising skew does indicate less scope for the centrist share to go down. It is in this restricted sense that a rise in skew does indicate an increase in centrism.

5.2 Decomposition

Adapting our definition of skew from eq. (5), city i's skew in period t becomes

$$\sigma_{it} \;=\; \sum_{j=1}^{n_i/2} w_{it}\left(g_{ijt} - g_{i,n+1-j,t}\right) \qquad \text{where} \qquad w_{ij} \;=\; \left(1 - \frac{r_j}{\widetilde{r}_i/2}\right), \tag{8}$$

and where n_i is the number of rings around city i's CBD (not indexed by t because definition of city territory did not change over the period under scrutiny).

Decomposing the increase in city shape skewness is slightly more convenient when building on ring population shares (rather than ring population, as in the previous section). Let us return to eq. (3) and substitute the *share* of population in ring j in total city population, g_{ijt}, for y_{ijt}. Next we estimate the resulting equation by both OLS (columns (1) and (3) in Table (7)) and 2SLS (columns (2) and (4)). Columns (1) and (2) of that table report coefficient estimates for the full sample, while columns (3) and (4) report estimates for the sample restricted to cities in Germany's West. Starting in about 2002, East Germany's cities began a huge program of often demolishing the most peripheral flats. We want to rule out inconsistent estimates due to East German (i.e. often affordable) cities demolishing their peripheral rings. Comparing columns (1) with (3), or (2) with (4), shows that demolition is not driving our results on subsidy removal.

Table (7) instruments for female labor force participation, in its columns (2) and (4), with a vector of yearly city industry structure variables (interacted with (1−PERI)) as instruments. Corresponding first stage regressions reveal sectoral shares to matter, and explain female labor force participation well. Instrumentation, moreover, renders coefficients pertaining to subsidy removal stronger (in absolute size), not weaker. Consider a city having a slightly lower average price of land in 2002, by 0.1 Euro say. Then according to Table (7), the more affordable city would find the share of residents in any of its central rings, post-subsidy-removal, to have expanded by 0.34 percentage points *more*. Instrumentation, at the same time, attenuates, or even wipes out, the coefficient on female labor force participation. Given a Wu-Hausman-statistic that clearly rejects equality of OLS and IV estimates (again see

	Ring Population Share			
	PopShare			
	OLS	*2SLS*	*OLS*	*2SLS*
	(1)	(2)	(3)	(4)
Intercept	0.022***	0.025***	0.032***	0.039***
	(0.004)	(0.004)	(0.004)	(0.005)
Distance	0.014***	0.013***	0.012***	0.012***
	(0.001)	(0.001)	(0.001)	(0.001)
Peri × (Distance - $\tilde{r}/3$)	−0.024***	−0.023***	−0.022***	−0.022***
	(0.001)	(0.001)	(0.001)	(0.001)
(1 - Peri) × Post	−0.023***	−0.027***	−0.012**	−0.024***
	(0.005)	(0.005)	(0.006)	(0.006)
Peri × Post	0.014***	0.015***	0.008**	0.010***
	(0.003)	(0.004)	(0.004)	(0.004)
($\overline{\text{Price}}$ - Price) × (1 - Peri) × Post	0.027***	0.034***	0.015**	0.030***
	(0.007)	(0.007)	(0.007)	(0.008)
($\overline{\text{Price}}$ - Price) × Peri × Post	−0.021***	−0.023***	−0.013***	−0.017***
	(0.005)	(0.005)	(0.005)	(0.005)
(1 - Peri) × Household Income	−0.008*	0.002	−0.021***	0.031***
	(0.004)	(0.006)	(0.008)	(0.011)
(1 - Peri) × Female Labour	0.162***	0.127***	0.195***	0.007
	(0.015)	(0.021)	(0.029)	(0.039)
City FE	Yes	Yes	Yes	Yes
Observations	11,022	10,362	8,517	8,517
R^2	0.623	0.614	0.602	0.598
	First stage results			
	(1 - Peri) × Female Labour			
(1 - Peri) × Share Agriculture		1.654***		1.450**
		(0.442)		(0.537)
(1 - Peri) × Share Production		0.220***		0.229***
		(0.007)		(0.006)
(1 - Peri) × Share Construction		0.722***		0.589***
		(0.046)		(0.045)
(1 - Peri) × Share Hospitality		−0.372***		−0.164***
		(0.015)		(0.021)
(1 - Peri) × Share Financial		0.813***		0.567***
		(0.013)		(0.016)
(1 - Peri) × Share Public Service		0.351***		0.224***
		(0.008)		(0.010)
R^2		0.992		0.994
Weak Instruments		1680.82***		601.23***
Wu-Hausman		15.33***		43.36***
Sargan		285.20***		197.22***

Note: *p<0.1; **p<0.05; ***p<0.01
Huber-White robust standard errors in parentheses.
(3) and (4) exclude all cities located on territory of former GDR.

Table 7: Ring Population Shares

Table 7), we suggest women's participation in the work force to also result from – rather than just to generate – heightened skew. This by itself appears a remarkable side effect to subsidy removal.

Let us turn to ring population shares' implications for skew. Let $\widehat{\sigma}_{it}$ denote the sample counterpart of the σ_{it} defined in eq. (8). Subtracting $\widehat{\sigma}_{i,04}$ from $\widehat{\sigma}_{i,16}$[27]

[27] Observations for early and last years of the sample period are not available. To retain as many cities in our sample, here we analyze the change in skew over the period 2004 to 2016 – which still straddles the year of policy reform, 2005. This leaves us with 51 cities altogether.

deconstructs the change in skew for city i as

$$\begin{aligned}\widehat{\sigma}_{i,16} - \widehat{\sigma}_{i,04} &= \sum_{j=1}^{n_i/2} w_{ij}\Big((\widehat{g}_{ij,16} - \widehat{g}_{i,n+1-j,16}) - (\widehat{g}_{ij,04} - \widehat{g}_{i,n+1-j,04})\Big) \\ &= \sum_{j=1}^{n_i/2} w_{ij}\Big((\widehat{g}_{ij,16} - \widehat{g}_{ij,04}) - (\widehat{g}_{i,n+1-j,16} - \widehat{g}_{i,n+1-j,04})\Big), \qquad (9)\end{aligned}$$

with the sum on the second line following from rearranging the four terms in large brackets. Interestingly, the expression in large brackets on the second line coincides with an "(inter-ring) difference in differences (of ring population shares over time)". Intuitively it is a measure of how strongly growth in the more central tail of the distribution has exceeded growth in its more peripheral tail.

In eq. (9) next substitute the estimated version of best linear prediction (3) (adapted to $y_{ijt} = g_{ijt}$ earlier) for $\widehat{g}_{ijt}$. When appropriately evaluating dummies POST and PERI, a number of explanatory variables (those that are time-constant) drop out. The r.h.s. of equation (9) becomes the change-of-skew-decomposition that we are interested in, i.e.

$$\begin{aligned}\underbrace{\widehat{\sigma}_{i,16} - \widehat{\sigma}_{i,04}}_{\text{skew change}} &= \underbrace{\rho_i\,(\widehat{\gamma}_1 - \widehat{\gamma}_2)\,(\overline{\text{PRICE}} - \text{PRICE})}_{\text{removal}} + \underbrace{\rho_i\,(\widehat{\beta}_1 - \widehat{\beta}_2)}_{\text{all other}} \\ &+ \underbrace{\rho_i\,\widehat{\delta}_1\,\Delta\text{INCOME}_i}_{\text{growth}} + \underbrace{\rho_i\,\widehat{\delta}_2\,\Delta\text{FEMALE}_i}_{\text{female labor}} \qquad (10)\end{aligned}$$

where ρ_i can, given $r_j = j - 0.5$ and after simplifying, be rewritten as

$$\rho_i = \frac{n_i}{3}\left(\frac{\frac{2n_i}{3} - 1}{n_i - 1}\right). \qquad (11)$$

We insert coefficient estimates from the sample conditional mean function according to col. (2) in Table (7)), city level information on PRICE and long changes in INCOME and FEMALE into eq. (10). The resulting decomposition is given for exemplary cities in Table (8). The average increase in (predicted) skew is 0.03 app., as shown at the bottom of the table. This increase is the net outcome of an ongoing trend of suburbanization (reducing skew by 0.115), a nearly offsetting contribution by subsidy removal (raising skew by 0.113), a small contribution by women's increasing desire to work (contributing 0.031) and a negligible impact from rising average incomes (raising skew by a mere 0.002). It is instructive to also briefly inspect selected cities. Munich, as the city with the highest price of land in 2002, gets no "relief" from subsidy removal. More affordable Halle, in contrast, does.

6 Conclusions

Had it not been for subsidy removal, larger German cities would have become substantially less skewed than they actually have. Subsidy removal mattered to skew.

Price	$\widehat{\sigma}_{16} - \widehat{\sigma}_{04}$	Removal	Female	All Other	Income
Munich	−0.108	–	0.033	−0.144	0.003
Heidelberg	−0.029	0.044	0.014	−0.088	0.001
Berlin	0.025	0.178	0.081	−0.238	0.004
Bremen	0.092	0.274	0.061	−0.247	0.004
Halle	0.037	0.090	0.025	−0.079	0.025
Average	0.030	0.113	0.031	−0.115	0.002

Table 8: Skew Decomposition

Moreover, subsidy removal not just mattered to city shape (subsection 5.1), but contributed to prominent societal changes, too (subsection 5.2). In skewing city shape, in inducing households to gravitate to the city center, subsidy removal contributed to rising average rent. This is for the standard Ricardian reason of many people traveling less, and hence being able to pay more.

We also suspect that subsidy removal contributed to an increase in women's participation in the labor market, inducing them to locate closer to where jobs (and child care facilities) are. By removing the length of the average commute, subsidy removal has made society more mobile. Oswald (1996) has famously conjectured that homeownership may impede mobility, and may even raise unemployment. Our discussion of subsidy removal points to a related mechanism, by which foregoing homeownership – and the adverse shift in individual mobility often tied to it – may improve labor market access, improve employment, and reduce unemployment.

We also recall that in 2018 federal government decided to reinstate the homeownership subsidy – for the three-year period of 2018-2020 (*Baukindergeld* (BK)). BK's dominant features resemble those of EZ. Reinstating the subsidy, so we expect when holding everything else equal, reverses its removal's effects. Among other things, BK will return cities to the trajectory of increasing sprawl, rising rents, and growing greenhouse gas emissions. Bavaria offers a top-up to the federal homeownership subsidy, and so these various effects should be even more pronounced in Bavaria. (This also provides more testing ground for the paper's central hypothesis.)

We suggest that our analysis may inform analysis elsewhere. While the current coronavirus crisis appears to merit subsidizing suburban living, developing a powerful vaccine over the course of the next two years may well return us to the pre-crisis structure of benefits and costs. If policy makers' long run aim is to revive urban centers to reduce travel cost and greenhouse gas emissions and to strengthen women's part in the labor market, a forceful way to get there may be to undo the homeownership subsidy. We are not the first to suggest this (again Muth (1967), Glaeser (2011)), and we certainly will not be the last. However, we do hope to offer a convincing building block here for the larger cost-benefit analysis of the homeownership subsidy.

7 Appendix A: Filtering and Subsidy Removal

Utility is $\theta s_i + x_i$, where θ denotes taste for housing quality, s_i indexes housing segment i's quality and x_i is the numeraire. Taste θ is distributed according to cdf F, on support $[a, b]$ with $a < b$. Rent in segment i is $q_i - \sigma_i$, where σ_i is the subsidy that may apply to i. Hence utility becomes $\theta s_i + w - (q_i - \sigma_i)$ when residing in segment i. There are n city residents altogether (where now n is set to 1, for simplicity). Each household picks the quality that suits it best. We identify the threshold tastes $\underline{\theta}$ and $\overline{\theta}$ – owners of which are indifferent between segments 1 and 2, and between 2 and 3, respectively – as

$$\underline{\theta}(q_1, q_2 - \sigma_2) = (q_2 - \sigma_2 - q_1)/(s_2 - s_1) \tag{12}$$

$$\overline{\theta}(q_2 - \sigma_2, q_3 - \sigma_3) = (\overline{q}_3 - q_2 - (\sigma_3 - \sigma_2))/(s_3 - s_2). \tag{13}$$

We let $\underline{\theta}_1$ denote the derivative of $\underline{\theta}$ with respect to q_1, $\underline{\theta}_2$ the derivative of $\underline{\theta}$ with respect to $q_2 - \sigma_2$, and so on. We note that $\overline{\theta}_2 = -\overline{\theta}_3$.

In an interior equilibrium, households with tastes in $[a, \underline{\theta}]$ sort into rental housing, those (with tastes) in $(\underline{\theta}, \overline{\theta}]$ sort into existing homes, and those in $(\overline{\theta}, b]$ opt for a new home. Individual choices translate into aggregate housing demands, equal to $n_1 = F(\underline{\theta})$, $n_2 = (F(\overline{\theta}) - F(\underline{\theta}))$ and $n_3 = (1 - F(\overline{\theta}))$. Let n_{ij} denote the derivative of aggregate housing demand for housing quality i with respect to price j. The following properties apply:

$$n_{11} = f(\underline{\theta})\,\underline{\theta}_1 < 0 \quad \text{and} \quad n_{12} = f(\underline{\theta})\,\underline{\theta}_2 > 0 \tag{14}$$

$$n_{21} = -f(\underline{\theta})\,\underline{\theta}_1 > 0 \quad \text{and} \quad n_{22} = \big(f(\overline{\theta})\overline{\theta}_2 - f(\underline{\theta})\,\underline{\theta}_2\big) < 0, \tag{15}$$

$$\text{and} \quad n_{23} = -f(\overline{\theta})\,\overline{\theta}_3 > 0, \tag{16}$$

to the extent that $n_{11} + n_{21} = 0 > n_{12} + n_{22}$.

New homes are supplied outside the city center, in the periphery, only.[28] Space constraints have much less of a role in the periphery, and so we will take the liberty to assume that new homes are supplied perfectly elastically at constant marginal cost $\overline{q}_3$. In this segment suppliers satisfy any demand at price $\overline{q}_3$. The cum-subsidy (i.e. consumer) price becomes $\overline{q}_3 - \sigma_3$. We set out the equilibrium conditions for the inter-connected segments of apartments and existing homes as follows.

$$\begin{aligned} n_1(q_1, q_2 - \sigma_2) &= s_1(q_1) \\ n_2(q_1, q_2 - \sigma_2, \overline{q}_3 - \sigma_3) &= s_2(q_2), \end{aligned} \tag{17}$$

where s_i is supply in segment i (never at risk of confusion with quality s_i as we suppress the quality index in what follows). For consistency, increases in s_2 (following increases in q_2) come about as existing vacant housing is supplied more; while increases in s_3 (following increases in q_3) we interpret as new construction. Let s_{ii} denote supply i's (strictly positive) derivative with respect to its own price below.

We translate Germany's full EZ-subsidy removal into policy changes $d\sigma_2 = -\sigma_2 < 0$ and $d\sigma_3 = -\sigma_3 < 0$, where $\sigma_2 < \sigma_3$.[29] We are interested in these policy changes' effects on qualities' prices and quantities, and on the distribution of city population

[28] Glaeser (2011) suggests as much, emphasizing the coincidence of owner-occupied housing with peripheral location for the US. Ahlfeldt/Maennig (2015) observe strong positive correlation between a ring's share of owner-occupiers and its distance to the city center for Berlin.

[29] These changes are not "small", and so our emphasis below is on direction, and not so much size, of the endogenous changes implied.

across all three qualities. Removing the subsidy for new homes reduces equilibrium demand in that segment. But changes in the neighboring two segments are less obvious. To sort out the filtering flows involved, totally differentiate the equilibrium, keep in mind $d\overline{q}_3 = 0$, and rearrange to give

$$\begin{pmatrix} n_{11} - s_{11} & n_{12} \\ n_{21} & n_{22} - s_{22} \end{pmatrix} \begin{pmatrix} dq_1 \\ dq_2 \end{pmatrix} = \begin{pmatrix} n_{12}\, d\sigma_2 \\ n_{22}\, d\sigma_2 + n_{23}\, d\sigma_3 \end{pmatrix} \tag{18}$$

or $A\, dq = db$ for short. Immediately we see that $|A| = (n_{11} - s_{11})(s_{22} - s_{22}) - n_{21}n_{12}$ is ambiguous in sign, and so with no further assumption nothing can be said about the sign of dq_1.

And then, the coefficient matrix A has three features we have not exploited yet. The first of these is its dominant diagonal, easily verified by summing all elements of a column and exploiting eq. (14) or (15). Already we conclude that A's inverse has negative entries only (Sweeney (1974)). Two more of A's properties obtain once we rewrite matrix inverse A^{-1} as $G = (g_{ij})_{i,j=1,2}$. For G it must be true that $g_{11} < g_{12}$ as well as $g_{22} < g_{21}$. To these inequalities we refer to as "Sweeney's first and second property" below.[30]

Write the solution to the differentiated system of equilibrium equations as $dq = A^{-1}db$. The price change in segment 1, dq_1, can then be rewritten as

$$\begin{aligned} dq_1 &= g_{11}\, n_{12}\, d\sigma_2 \;+\; g_{12}\, n_{22}\, d\sigma_2 \;+\; g_{12}\, n_{23}\, d\sigma_3 \\ &= \underbrace{f(\underline{\theta})\, \underline{\theta}_2\, d\sigma_2}_{-}\, \underbrace{(g_{11} - g_{12})}_{-} \;+\; \underbrace{g_{12}\, f(\overline{\theta})\, \overline{\theta}_2}_{+}\, \underbrace{(d\sigma_2 - d\sigma_3)}_{+} \;>\; 0, \end{aligned} \tag{19}$$

where the first and last term on the first line of (19) are positive, while the second term on that line is negative. And yet we are able, after signing all individual terms on the second line of (19), to also sign dq_1 as positive nonetheless.

Replacing n_{12}, n_{22} and n_{23} on the first line of (19) by making use of (14) through (16), exploiting $\overline{\theta}_2 = -\overline{\theta}_3$, and also rearranging translates into the second line of (19). Given Sweeney's first property, i.e. $g_{11} < g_{12}$, the first term on the r.h.s. of the second line of (19) must be positive. Moreover, given the structure of subsidy phase-out, i.e. $d\sigma_3 < d\sigma_2$, the second term on the r.h.s. of (19) is positive also. Thus $0 < dq_1$.

Lifting both of EZ's component subsidies does raise the price of rental housing. (Note how this result hinges on being able to sign $(d\sigma_2 - d\sigma_3)$.) Now, because $s_{11} > 0$, apartment supply must have risen, too, as must have equilibrium rental housing demand. Hence $\underline{\theta}$. Yet $d\underline{\theta} > 0$ in turn implies that $dq_1 < d(q_2 - \sigma_2)$. Recalling $-d\sigma_2 < -d\sigma_3$, we conclude that all three qualities' (consumer) prices have gone up, and that

$$0 \;<\; dq_1 \;<\; d(q_2 - \sigma_2) \;<\; d(\overline{q}_3 - \sigma_3). \tag{20}$$

8 Appendix B: Data

We use Regional Database Germany, provided by the Statistical Offices of the Federation and Lander, GENESIS-Database by the German Federal Statistical Office and the INKAR database by the Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR) to obtain the following variables.

[30] These inequalities are implied by Sweeney's (1974) general "commodity hierarchy"-type preferences (of which ours are a special case). They are easily shown when recalling that $A^{-1}A = I$ and exploiting the two component equations corresponding to the two zero entries of the identity matrix. For example, $g_{21}(n_{11} - s_{11}) + g_{22}n_{21} = 0$ and hence $g_{21}/g_{22} < 1$.

Statistic	Years	Mean	St. Dev.	Min	Pctl(25)	Pctl(75)	Max
Land Price per sqm (in 1,000 Euros)	2002	0.20	0.16	0.05	0.09	0.23	0.94
Disposable Household Income (in 1,000 Euros)	2002 - 2016	1.55	0.23	1.12	1.38	1.69	2.46
Female Employment Rate (in %)	2002 - 2017	0.47	0.06	0.34	0.43	0.51	0.63
Sectoral Share Agriculture (in %)	2002 - 2017	0.003	0.004	0.00	0.001	0.004	0.02
Sectoral Share Production (in %)	2002 - 2017	0.17	0.09	0.03	0.10	0.21	0.56
Sectoral Share Building (in %)	2002 - 2017	0.04	0.01	0.02	0.03	0.05	0.08
Sectoral Share Hospitality (in %)	2002 - 2017	0.25	0.04	0.14	0.23	0.28	0.34
Sectoral Share Financial (in %)	2002 - 2017	0.19	0.05	0.08	0.15	0.22	0.36
Sectoral Share Public Service (in %)	2002 - 2017	0.34	0.07	0.15	0.30	0.40	0.49

Table 9: Descriptive Statistics

PRICE The variable PRICE is "price per square meter of building land". This is the average of the square meter prices of (undeveloped) building land sales in 1995 and 2000 in 1,000 Euros. The price per square meter of building land in city i and year t is calculated as the sum of all purchase prices in i at t divided by the aggregate land area sold in i at t. We use the average of the years 1995 and 2000 for reasons of data availability, and to mitigate the issue of outliers.

INCOME The variable INCOME is the average monthly disposable household income per inhabitant in 1,000 Euros. Disposable income should be understood as the amount available to households for consumption or saving. It is obtained by adding social benefits (pensions, unemployment benefits, child benefits, etc.) and other current transfers to primary income, and deducting social contributions and other current transfers as well as income and other taxes payable by households. Primary income includes income from employment and property received by domestic private households (e.g. income from self-employment, compensation of employees). Household income in city i and time t is calculated as the disposable income of private households in i at t divided by the number of residents in i at t.

FEMALE The variable FEMALE is the share of female employees subject to compulsory social insurance in all women of working age. Employees subject to social insurances are manual and non-manual workers and persons in vocational training who are compulsorily insured under statutory pension, health and/or unemployment insurance schemes, i.e. excluding civil servants, self-employed persons, family workers, and marginally employed persons. The female employment rate in city i in year t is calculated as the number of female employees subject to compulsory social insurance at place of residence i at t divided by the number of female residents between ages 15 and 65 in i at t.

AGRICULTURE The variable AGRICULTURE is the share of working population working in the agricultural industry in city i in year t. The agricultural industry comprises production in agriculture, forestry and fisheries.

PRODUCTION The variable PRODUCTION is the share of working population working in the manufacturing industry (without the building industry) in city i in year t. This industry includes the following sections: "Mining and quarrying", "Manufacturing", "Electricity, gas, steam, and air conditioning supply", and "Water supply, sewerage, waste water treatment and remediation activities, waste management and pollution abatement".

BUILDING The variable BUILDING is the share of working population working in the building industry (general and specialized building and civil engineering activities) in city i in year t. This industry includes the following sections: "New construction", "Restoration", "Extension and conversions", and "Building of prefabricated buildings or structures on the site".

HOSPITALITY The variable HOSPITALITY is the share of working population working in trade, transport, hospitality, and information & communication industries in city i in year t. This industry includes the following sections: "Sale, maintenance and repair of motor vehicles and motorcycles", "Transport and storage", "Hotels and restaurants", and "Information and Communication".

FINANCIAL The variable FINANCIAL is the share of working population working in financial, insurance and corporate service, and land and housing industries in city i in year t. This industry includes the following sections: "Financial and insurance activities", "Real estate activities', "Professional, scientific and technical activities", and "Other business activities".

PUBLIC SERVICE The variable PUBLIC SERVICE is the share of working population working in public and other service, education, and health industries in city i in year t. This industry includes the following sections: "Public administration, defense and compulsory social security", "Education', "Health and social work", "Arts, entertainment and recreation", "Other services not elsewhere classified", and "Households with domestic staff".

9 Literature

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