Rising Inequality and Spatial Social Segregation due to Urbanization and Increasing Housing Prices

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Abstract

Globally, housing markets in urban areas have seen significant increase in prices over the past years. These developments are of relevance for the local population as well as social processes that underline the urban cohabitation. Increasing income inequality can impede social mobility, economic opportunities and lead to rising social segregation. While the effect of rising housing prices and social segregation are commonly subject of interest, the effect of capital income on inequality through the channel of housing prices is less investigated in current research. This paper provides empirical evidence from Sweden that urbanization through the channel of housing markets leads to segregation and inequality. Urbanization causes housing prices to rise disproportionately to income. Consequently, segregation of social strata takes place as well as an overall rise in capital income for those high-income urban residents. Therefore, increasing housing prices extend the inequality in wealth and capital income. The capital income distribution trend in turn leads to rising inequality, as measured by the Gini coefficient. The presented analysis indicates that increasing housing prices may potentially have adverse effects on social equity, even in highly developed welfare state like Sweden.

The distribution of income is a widely discussed topic and its economic effects have been recognized for many countries.[1,2,3] In recent times, an increase of inequality has been observed in the majority of the world' s largest economies.[4,5]

Rising income inequality is seen critically and its drivers are being investigated, because, among other things, it can indicate a deficiency of social mobility and economic opportunities for marginalized populations.[3,6] Economic opportunities partly depend on the place of residence as an important factor of getting access to public goods[7], networks[8] and jobs.[9]

Recently, the income segregation, i.e., the spatial sorting of individuals by income level, has amplified.[4,10]

Due to rising inequality and a higher stake of high-income earners, the spatial segregation of housing and population strata has been significantly influenced. Increasing housing prices (also described as real estate prices and used synonymously in this paper) displace lower income earners from higher priced areas to subordinated ones.[11]

This effect is based on and promoted by urbanization. The ease of access to various daily services enhances the attractiveness of cities compared to rural areas resulting in high urbanization rates globally.[12,13,14]

An excess demand for dwellings in the city is joined by lagging housing and land supply leading to rising real estate prices and rents. Higher price levels require more financial resources to get access to a place to live, which promotes inequality and the displacement of lower-income groups, who then often face affordability problems.[14,15]

High-income earners are less affected by the growing housing costs caused by urbanization. However, low- and moderate- income earners are increasingly limited in following their locational preferences.[16,17]

Research on the relationship between income inequality and increasing housing prices revealed several times a strong correlation and concluded that inequality leads to higher housing prices,[3,18,19,20,21,22] for example caused by an top-income-induced housing demand increase.[23] However, despite vast literature in this field and the linkage between increasing housing prices and inequality as its underlying cause, less is known about the reverse impact.

This paper explores whether urbanization and rising housing prices lead to increasing inequality as well as to social segregation and redistribution.

Sweden was chosen as the area of study, in particular because of two relevant circumstances that are conducive to the study's objective.

(1) For a long time, Sweden's welfare state was considered a social democratic role model, which is based on benefits and support in numerous sectors for more equality among the population through different policy programs. However, Sweden has seen a sharp rise in inequality over the past years.[24,25] The country experienced a rise in inequality (measured by the Gini coefficient) and ranks the most unequal country in the Nordics in 2019, while being the most equal 15 years prior in 2004 (see Fig.1).[26,27]

(2) The second circumstance relates to the housing market in Sweden and its characteristics (see Fig.2).[27,28] Among other things, the strong political regulatory support of homeownership, e.g., strong tax benefits combined with a reduction of public housing from around the 1970s to the 90s has led to an extremely high share of Swedes who are living in their own dwellings.[29] In Sweden's rural areas, on average 94.17 % of the population lived in their owned dwellings in 2019. In urban areas the share is on average 64.01 %, but still comparatively higher than in other countries.[27] A predominant share of owner-occupied dwellings in dense, high demand and under supplied city areas, driven by persistent urbanization (see Supplementary Note 1), results in a strongly competitive situation of getting access to those areas and affects the housing price level significantly.[14] A substantial quantity of media reports state that people in Sweden must apply many years in advance to get access to rentable dwellings in city areas. It varies by geographical location, but the effect is most apparent in Sweden's capital Stockholm. Whereas the average waiting time in the capital was around 9 years in 2016, it could take more than twice as many years depending on the neighborhood. Around 500,000 people were on the waiting list.[30,31]

In this paper, a two-fold analysis is applied, namely investigation 1 and investigation 2:

In investigation 1, the variation of average income and average housing prices across areas with different degrees of urbanization is quantified.

For investigation 2, the relationship between urbanization, housing prices, income inequality and social segregation is analysed.

By examining the data set as well as performing regression models (OLS), the paper provides evidence that urbanization leads to segregation and inequality through the channel of housing markets. The mechanism is the following: Urbanization leads to rising real estate prices, this in turn leads to rising financial barriers of getting access to urban areas due to a disproportionate increase in housing prices relative to income. In consequence, segregation of social strata takes place. Moreover, rising housing prices increase the inequality in wealth and capital income. The capital income distribution trend in turn leads to rising inequality, as measured by the Gini coefficient.

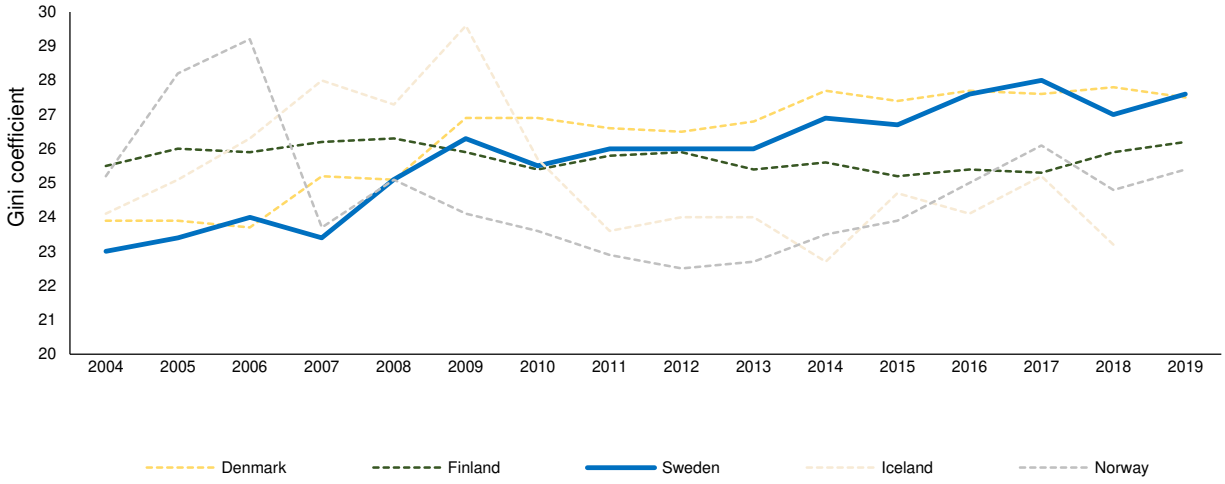

Fig.1 Gini coefficient. Sweden (blue line) accounts the strongest inequality increase compared to all Nordic states over a period of 15 years (2004-2019). Sweden ranked first as the most equal country among the Nordics 2004, while being the most unequal one 2019.[26]

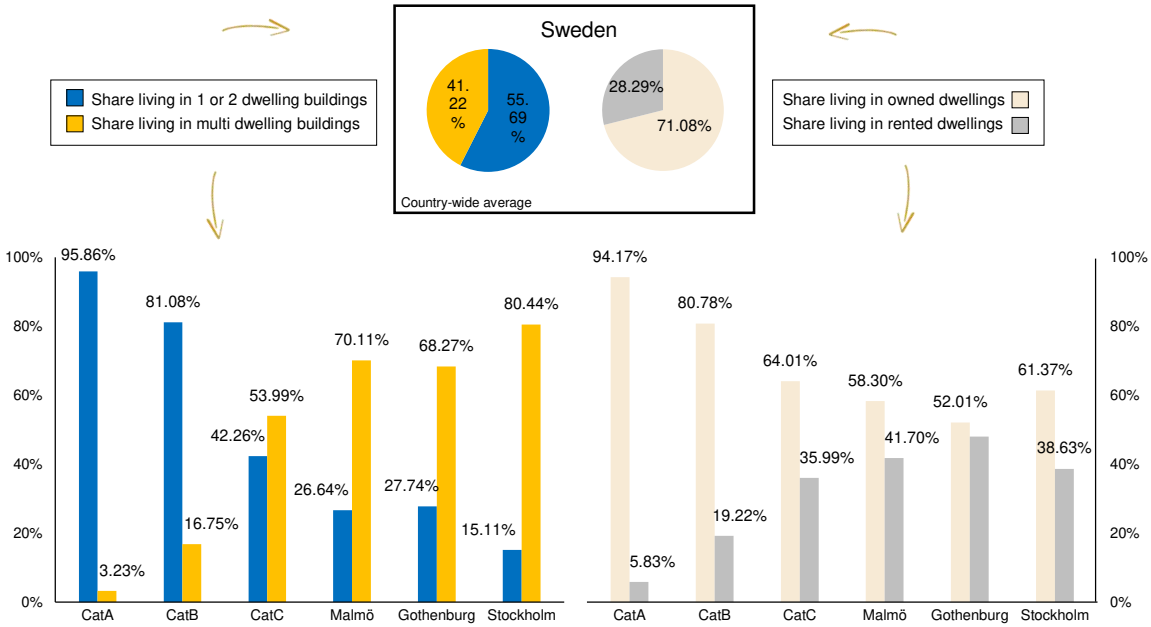

Fig.2 DeSO zones. Statistical delimitation of the so-called DeSO zones based on Sweden's official statistical bureau. Divided into three main groups: (1) out-of-town zones (category A, light terracotta), (2) city-region zones (category B, blue), (3) inner-city zones (category C, red). Focus on Sweden's three biggest cities: Stockholm, Gothenburg and Malmö.[20,27,32]

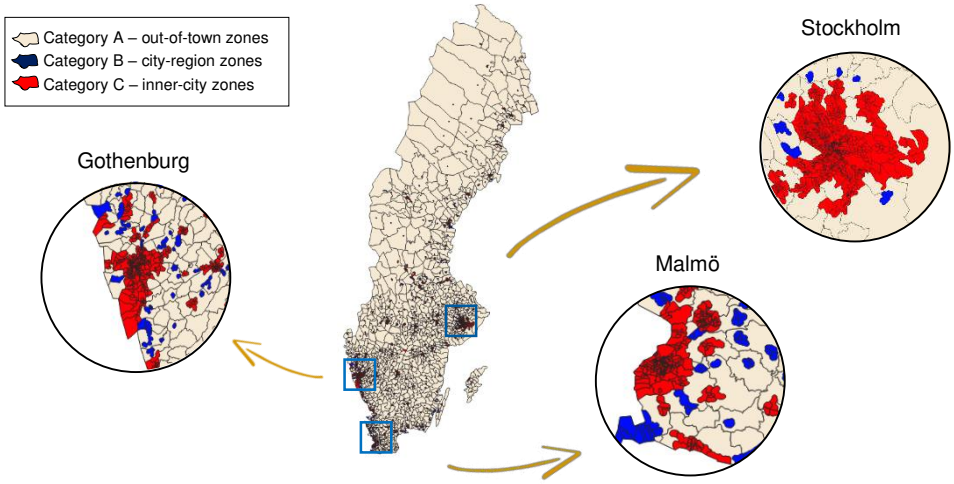

Fig.3 Sweden's housing characteristics. Sweden's housing characteristics structured according to the DeSO classifications as well as the three biggest cities. The left-hand side displays the distribution of the share of people living in 1 or 2 dwelling buildings (blue) versus living in multi dwelling buildings (orange). Almost a contrary movement between suburban and urban regions is recognizable. Category A is the most suburban and accounts for the highest share of people living in 1 or 2 dwelling buildings compared to the lowest share in Stockholm. The right-hand side displays the share of people living in owned dwellings (light terracotta) and the share living in rented dwellings (grey). There is the same, almost contrary movement with a higher share of people living in owned dwellings in more rural region versus the lower in more urban regions. The pie charts in the middle represents the country-wide averages of the titled considerations.[27,32]

Results

Study area. The statistic office "Statistics Sweden" divides the country of about 10.33 million people into 5,984 so-called *DeSO zones*, which cover between 663 and 5,291 people, and are categorized according to their degree of urbanization. Overall, 18 % of the population is settled in DeSO zones category A (out-of-town area, short: cat. A), 10 % in B (city-region area, short: cat. B) and 72 % in C (inner-city area, short: cat. C).[32]

The municipality level is a decomposition on a larger scale. There are a total of 290 municipalities in Sweden (see Supplementary Note 2).[27]

Income data. The used income data corresponds to a person's total earned income, pre-taxed, and consists of all taxable income from employment, business income, pension, sickness benefit and other taxable transfers. Capital income data was only available on municipality level, but not on DeSO level. Therefore, capital income could only be included in parts of investigation 2, but not in investigation 1.[27]

Housing data. Housing data was partially taken from Statistics Sweden. One data set consists of data regarding the building type and tenure type. Another data set contains actual real estate transactions to reflect price levels of people's residence. Since Statistics Sweden does not publish statistics regarding housing transactions at the DeSO level, 452,112 country-wide data from Sweden's biggest residential portal called *Hemnet*[33] were used. Detailed insight into how the Hemnet data was used is displayed in the Supplementary Note 3. The underlying idea behind this approach was that higher purchase prices correspond to higher rents, and consequently, purchase prices per sqm of actual transactions can be used as an indicator reflecting rent price structures. Noticeable, it was not possible to address the reason for the transaction or the type of buyer (private, institutional investor, et cetera). The assumption was made that the purpose of the buyer is trivial for the investigations on hand.

Real estate prices are not the only determinant of rent levels at specific locations, for example, Swedish housing prices increased more sharply compared to rent levels.[28,34] Several factors, related to characteristics of the real estate market, make the relationship between real estate prices and rent levels complex. Such factors, like time-lags, divergence in property characteristics (e.g. location, condition, furnishing, age) or prices (e.g., mortgage rates, maintenance costs), taxes or the current market situation impact the ratio between real estate price level and renting prices. However, the assumption was made that this issue is negligible.[35,36,37]

Investigation 1. In the paper´s first investigation, the objective is to find out how income and housing price level differ in varying geographical locations, especially rural versus urban areas. The idea was to assess the coincidence of income levels and housing prices with urbanization.

The calculation of the arithmetic mean was applied first as displayed in the methods section (Eq.1). The country-wide mean income in 2019 was 326K Swedish krona (for the sake of clarity the abbreviation SEK for Swedish krona is being

used and large number are shortened by "K" which reflects the unit 1,000). The out-of-town zones' (cat. A) mean income is below the national average with 311K SEK and the city-regions zones' mean income (cat. B) is also below the national average with a mean income of 317K SEK. The DeSO zones located in inner-city regions (cat. C) have a mean income of 331K SEK, that is above the country's average. Looking at Sweden's three biggest cities (Stockholm, Gothenburg and Malmö), the zones in Stockholm account for the highest mean income level (396K SEK), followed by Gothenburg (329K SEK). Both cities are above the national average income level. Malmö is below the total average with 290K SEK.

In relative terms, people living in cat A zones earn on average 4.69 % less than the national average, people in cat B zones 2.62 % less and people cat C zones earn 1.52 % more than the average income earner. Stockholm's mean income is 21.35 % above the national average, Gothenburg's is 0.85 % higher than the country's average and the mean income in Malmö is 11.05 % lower than the mean income in Sweden. An overview of the income distribution is presented in Supplementary Note 4 & 5.

The average real estate price level throughout the entire country amounts 27,650 SEK per sqm. The out-of-town areas (cat. A) have a mean real estate price per sqm of 15,652 SEK, the city-region areas (cat. B) 17,583 SEK. Both spatial categorizations are below the average in Sweden. The inner-city zones (cat. C) have a higher average real estate price level per sqm (32,137 SEK). SEK. Stockholm accounts for the highest price level with 67,157 SEK per sqm, Gothenburg is set at 43,966 SEK and Malmö accounts for an average residential price per sqm of 29,754 SEK. Supplementary Note 6 & 7 give more insight on Sweden's hosing prices.

In relative terms, the real estate prices per sqm in out-of-town regions (cat. A) are 43.35 % below the national average. DeSO zones in cat. B (city-regions) are 36.35 % below the average, while zones in inner-city areas (cat. C) are 15.73 % above the average national price level. On the city level, Stockholm lies 139.22 % above Sweden's average, followed by Gothenburg with 54.43 % and Malmö with 6.97 %.

Fig.4 & 5 display the average income and real estate prices across Sweden. They illustrate how the housing costs to income ratio is higher in urban areas compared to more rural areas.

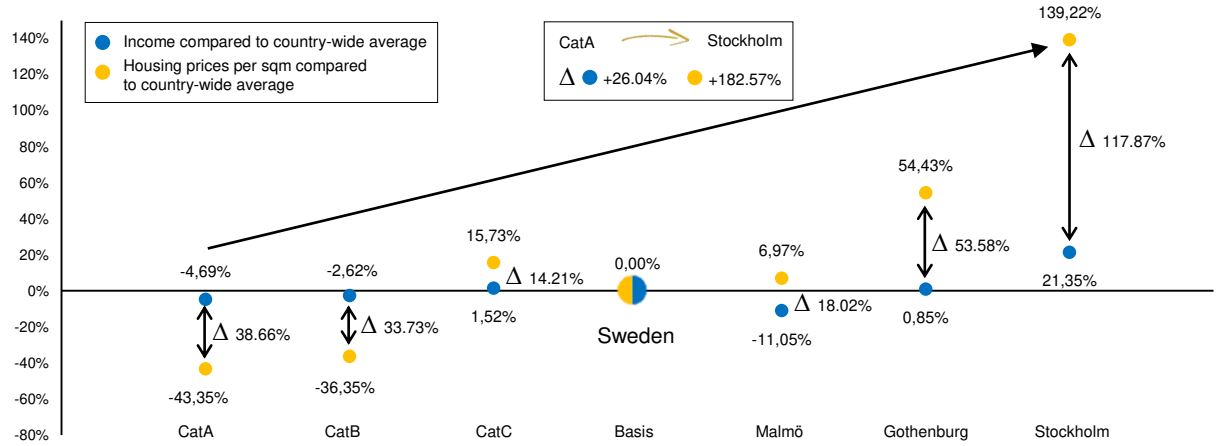

Fig.4 Divergences of the income- and real estate price level in comparison to the country-wide level. Divergences are calculated by taking the country-wide average as the basis and comparing it with the average of each class classification by the official statistical bureau (DeSO zones) as well as the biggest three cities. The income level is displayed as the blue dot. The orange dot refers to the housing prices per sqm. From rural to urbanized zones, income as well as housing prices rise, however, the housing prices rise disproportional. Whereas in cat. A and cat. B the income is slightly below the total average, the real estate prices are far lower than average. This effect can be considered in favor of the inhabitant. In contrast, there are reversed deviations from the average in urbanized areas, and the reversal is most significant in Stockholm where the income is 21.35 % higher than the country-wide average, however, the real estate price is 139.22 % above the average. Stockholm is, therefore, the city where average people have to pay the most for housing, relative to their income. By a theoretical change in localization from cat. A (out-of-town) to Stockholm the income level increases by 26.04 %, at the same time, the real estate level would rise by 182.57 %.[27,32,33]

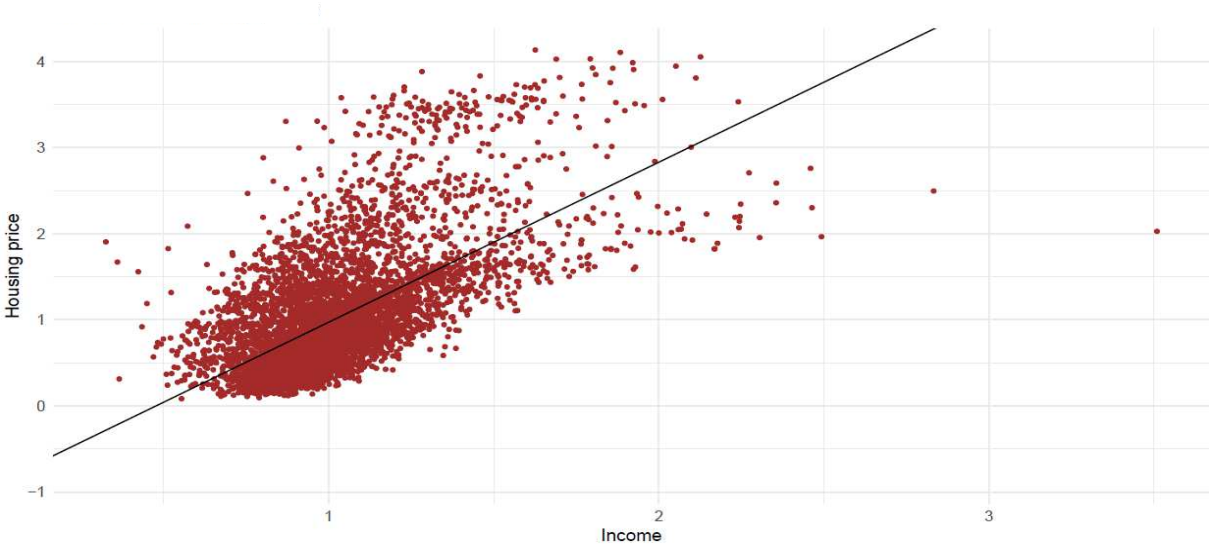

Fig.5 Income and housing prices. The figure displays the 5,984 DeSO zones with their relative deviations from the average national income and housing prices. A red dot at the point (1,1) would represent a DeSO zone which is average in both dimensions. In fact, it can be seen that most of the zones are located roughly in an elliptical pattern around the country's average. But it can also be seen that some zones are clearly above the major clustering. This shows the clash from the mismatch between incomes and housing prices. Where incomes are above the average up to twice the national average (scaling between 1.0 and 2.0 on the x-axis), the zones are in turn located at a housing price level of 3 and 4 times compared to the average (scaling between 3 and 4 on the y-axis).[27,32]

Investigation 2. For the paper's second investigation the aim is to analyze whether urbanization and increasing housing prices are a reason for the rising inequality (Gini coefficient, Fig.1) on national level and a cause for social segregation.

The arguments and the presented evidence are structured in five parts: (1) At the relatively close DeSO level, urbanization reduces inequality by displacing the relatively poor from expensive DeSO zones. (2) At municipality level, capital income is a predictor of inequality growth. (3) Municipality zones' capital income is partly explained by the local housing price level. (4) The housing prices level in a municipality is increased by the local urbanization. (5) In recent times the more urbanized municipality zones attracted more people and grew faster, in other words, the urbanization process is ongoing. While part (1) evaluates the effects of urbanization on inequality at the close DeSO level, parts (2)-(5) together form an evaluation of the effects at the more distant municipality level.

In part (1), an OLS regression was applied to estimate the relationship between income inequality and urbanization at the DeSO level (Supplementary Note 8). For the persistence of income inequality and its historical reasons, lagged inequality was included as an explanatory variable for current income inequality. This inclusion should reduce potential problems with omitted variable bias. The main explanatory variables of interest are the mean scaled income (scaled income means the DeSO zone's deviation from the national mean) and the scaled mean real estate price per sqm (scaled in the same sense). Both have statistically significant effects, showing that DeSO zones are on average more equal, when real estate prices are higher or income levels are lower.

Does this mean, that higher housing prices reduce income inequality? The evaluation at the municipality level in the next four parts suggests otherwise for the bigger picture. A reducing effect at DeSO level but an increasing effect at municipality level can be explained: Since DeSO zones are relatively small, containing only between 663 and 5,291 people, leaving the DeSO zone is relatively easy and lower income levels as well as higher housing prices both represent, ceteris paribus, a stronger relative burden for local low-income earners. A displacement of the relatively poor to other DeSO zones can explain the effects of housing prices on inequality at the DeSO level, since out-moving lower strata induce a homogenization of the remaining population.

Coming to the four parts at the municipality level, in part (2), another OLS regression was performed to estimate the effect of urbanization on income inequality. The following regression was applied:

$$\begin{aligned}\ln(Gini_{gr,11\_19}) = {} & \beta_0 + \beta_1 I_{\tilde{x},s,2019} \\ & + \beta_2 REsqm_{\tilde{x},s,19} + \beta_3 Cap_{\tilde{x},s,19} \\ & + \beta_4 PopCat2 + \beta_5 PopCat3 \\ & + \beta_6 PopCat4 + \beta_7 PopCat5 \\ & + \beta_8 REsqm_{\tilde{x},s,19} Cap_{\tilde{x},s,19}\end{aligned} \quad (3)$$

The above displayed equation (Eq.3) describes the growth of the Gini coefficient over the years 2011 to 2019 ($Gini_{gr,11\_19}$) as the dependent variable and scaled mean income 2019 ($I_{\tilde{x},s,19}$),

scaled mean real estate price per sqm 2019 $(REsqm_{\tilde{x},s,19})$, scaled (in relation to the total country-wide income) mean capital income 2019 $(Cap_{\tilde{x},s,19})$, as well as population density categories (quintiles, while category 5 being the one with the highest population density).
The results are presented in Tab.1.

Tab.1 Estimation of the relationship between Gini growth and real estate prices and income (eq. 3)

	Dependent variable: Gini growth 2011-2019 $(\ln(Gini_{gr,11,19}))$	
	Coefficient	Error
(Intercept)	0.008321	0.01730
Mean real estate price per sqm 2019 scaled	-0.000902	0.00260
Mean income 2019 scaled	0.002355	0.01416
Mean capital income 2019 scaled	0.001104***	0.00023
Population cat. 2	-0.003884	0.00284
Population cat. 3	-0.006975*	0.00287
Population cat. 4	-0.002984	0.00306
Population cat. 5	-0.008392*	0.00370
Mean real estate price per sqm 2019 scaled × mean capital income 2019 scaled	-0.000265***	0.00007
Number of observations	287	
R^2	0.1742	
Adjusted R^2	0.1505	

*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

The results of estimation specified in Eq.3 presented in Tab.1, show no significant correlation between the recent change in a municipality's Gini coefficient and its current real estate price level or its income level. However, there is a significant positive correlation between the Gini coefficient growth and the municipality's current scaled capital income (scaled by being divided by the municipality's other income). Even though there is a negative interaction effect between housing price level and capital income level on Gini coefficient growth, this effect only weakens the overall effect of capital income. It can be only weakening since the scaled real estate price level reaches the value of 1.39 in the extreme case of Stockholm (Fig.4). Only the most extreme outliers, the much smaller DeSO zones, reach the value of around 4. However, this value would be necessary for the whole municipality to reach an overall reducing impact of capital income on inequality growth. Altogether, the municipality's amount of capital income has a less positive effect on the Gini coefficient growth rate where real estate prices are higher. This is plausible since in an expensive municipality more people are expected to have a share in capital income.

In part (3), the impact of real estate price level on capital income was estimated. The previous estimation of Eq.3 suggested that the real estate price level has no impact on inequality growth apart from the channel of interacting with capital income. Since house owners gain capital income i.e., from renting their houses, there must be an effect from real estate price levels on capital income. The correlation of housing prices and capital income on the municipality level was estimated in an OLS regression framework with the following equation:

$$\ln(Cap_{\tilde{x},s,19}) = \beta_0 + \beta_1 REsqm_{\tilde{x},s,19} \qquad (4)$$

In equation 4 (Eq.4), the scaled mean capital income in 2019 $(Cap_{\tilde{x},s,19})$ is set as the dependent variable and scaled mean housing prices per sqm in 2019 $(REsqm_{\tilde{x},s,19})$ as the independent variable. The result is presented in Tab.2.

Tab.2 Estimation of the relationship between capital income and real estate prices (eq. 4)

	Dependent variable: Mean capital income 2019 $(\ln(Cap_{\tilde{x},s,19}))$	
	Coefficient	Error
(Intercept)	0.15990	0.10981
Mean real estate price per sqm 2019 scaled	0.84010***	0.09289
Number of observations	287	
R^2	0.2212	
Adjusted R^2	0.2185	

*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

The mean real estate price level is significantly positively correlated with higher capital income of the municipality. The estimated effect size is almost certainly positively biased by an omitted variable bias, since richer people tend to live in more expensive areas and increase the areas capital income. However, when trying to generalize from the results to national inequality, there is also a negative bias, since some capital receivers do not live in the municipality, where their capital generating houses are located. Since a causal effect from real estate values on capital income is necessary for purely mechanical reasons, at least when a moderate share of the rented houses is owned by owners residing in the same municipality, these biases are neglected.

In part (4), is the impact of urbanization on the housing price level is evaluated. Here, it can be drawn from investigation 1 and from theoretical arguments: In investigation 1 it was shown at the DeSO level, that more urbanized areas have on average higher housing prices (see Fig.4 and Supplementary Note 6). Since the factor land is fixed and building high comes at significant costs[38], rising housing prices are the logical consequence of the urbanization process.

In part (5), the effect of a municipality's past urbanization on its current urbanization is estimated. Since Sweden faces an ongoing urbanization process and the more urbanized areas have higher housing prices (Investigation 1), then the more expensive areas should face

higher population growth. To show that the urbanization process is measurable at the municipality level, another OLS regression is applied on the following formula:

$$\ln(Pop\_dense_{11\_19}) = \beta_0 + \beta_1 REsqm_{\tilde{x},s,19} \quad (5)$$

The change of population density between 2011 and 2019 ($Pop\_dens_{11\_19}$) as the dependent variable and scaled average housing prices 2019 ($REsqm_{\tilde{x},s,19}$) as the independent variable are chosen to perform the OLS regression displayed in Eq.5.

The results, displayed in Tab.3, show that an ongoing urbanization process is observable at the municipality level. Since the real estate price level is a proxy for the aggregated previous urbanization (Investigationv1), then the estimate shows that in fact the more urbanized municipalities faced on average larger increases in population density in the last decade.

Tab.3 Estimation of the relationship between population density and real estate prices (eq. 5)

	Dependent variable: Population density diff. 2019-2011 ($\ln(PopDense_{11\_19})$)	
	Coefficient	**Error**
(Intercept)	0.064113***	0.002857
Mean real estate price per sqm 2019 scaled	0.069900***	0.004513
Number of observations	287	
R^2	0.4545	
Adjusted R^2	0.4526	

*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

The role of this causal chain is supported by the structure of capital income: According to the official statistical bureau in Sweden, 60.29 % of Sweden capital income is generated by real estate income.[39]

The development of the overall capital income distribution in Sweden is presented in the Supplementary Note 9 & 10.

Discussion

This paper explored how urbanization is associated with housing prices and indirectly with income inequality. It provides evidence supporting the claim that urbanization - by increasing housing prices - leads to social inequality in the wider picture (i.e., municipality level) and to more equality by gentrification in the narrow picture (i.e., DeSO level). The results add to the literature, because previous research regarding the relationship between urbanization and inequality deals in very overwhelming number with low and middle income countries.[40,41,42,43,44] and does not consider housing prices as a channel.[45,46] There is literature regarding the connection of income inequality and housing prices, mostly suggesting effects from inequality on housing prices,[21,22,23,47,48] furthermore regarding the connection between housing prices and capital income share,[49,50] and regarding the effect of urbanization on housing prices.[51] This paper suggest that urbanization causes inequality by increasing housing prices.

The results indicate implications not only for Sweden's future: Since urbanization is a global trend[52], within-country inequality is increasing[3,53], and since rising inequality can have adverse effects[54,55], a better understanding of the role of urbanization as a driver of inequality can help to prevent the adverse effects. If the urbanization increases inequality and segregation even in Sweden, a long held social democratic role model[25] with relatively high degree of homeownership, then it is likely to be even more influential in countries with less social redistribution.

Some limitations remain and might be fruitful objects of future research:

Firstly, for the limited scope of this paper, the importance of the identified process for the ongoing process of rising inequality could not be put into proportion to other drivers of inequality. For example, the reduction and privatization of social welfare services is another driver identified for Sweden,[24] labor market flexibilization and globalization have been identified as other inequality drivers.[56,57]

Secondly, causality cannot be proven, and the complexities of urbanization and inequality dynamics can produce overlapping and disturbing effects contributing to the measured correlations. For example, inequality growth can positively affect housing prices[22,23,48] as well as capital accumulation.[58] However, this paper provides an argument for one further explanation of the relationship between urbanization, housing prices and inequality, which has seen little attention before as a single nexus.

Thirdly, the empirical evidence investigated in this paper rather measured short run dynamics. While the urban population increase tightens the local housing market and appreciates the capital stock of relatively rich real estate owners in the short run, long run dynamics might distort the captured picture. For example, people immigrating to the city might face some delay before unleashing all beneficial income effects of their new urban location. In principle, this dynamic would be similar to that measured for immigrants in Sweden, whose employment rates and wages are converging to those of Swedish natives, although this takes decades.[59] Other examples for long term effects of urbanization on inequality would be an elastic but slowly responsive supply at the housing market, effects out of ongoing wealth redistribution from tenants to house owners.

For all the limitations presented, drawing political implications is not straight forward. The ongoing urbanization process is a global trend which is not expected to end in the next decades[52]. However, even if urbanization is inevitable, urban planners can shape this process.

A first option might be to mitigate the increase of real estate prices by damping urban concentration: One way to achieve such damping could be the improvement of mobility options. Another way could be the smart promotion of decentral business location and sub-centers. The motivation for this option is a contribution of this paper, since it is only visible when the housing prices are identified as a causal channel through which urbanization increases inequality. However, the overall consequences of urban concentration are under dispute[60] and there might be no smart way that prevents the potential drawbacks of too low urban concentration. Urban sprawl is associated with higher income inequality, but no direct causal effect has been suggested.[45,46]

A second option might be the increase of housing supply: Governmental provision has to deal with crowding out effects on private investors when using the scarce factor *land*. The government can build high and cautiously allow higher building for the private sector in consideration of a potential effects on the cities' character. The public provision of affordable housing has been proposed before, where the effect of housing prices on inequality was recognized.[19] Another way might be the subsidization of housing. However, depending on the price elasticities of demand and supply side, subsidies might mainly benefit house owners and thereby increase social inequality.

A third option to prevent a rise in real estate prices might be price regulation measures. But this comes with inefficiencies as well: The highly regulated housing market of Stockholm currently demonstrates this, since renters have to wait almost 10 years before getting a rental home.[31]

A fourth option, one that does not try to mitigate the rise of housing prices, is the taxation of capital income from housing. However, the tax incidence depends on the elasticity of supply and demand at the housing market. Furthermore, the supply of housing would probably decrease as well as future investments.

A fifth option might be the promotion of owner-occupied housing. However, this is becoming increasingly difficult when prices already rose substantially and this measure would mostly help the relative rich and thereby not decrease inequality.

Methods

To calculate the arithmetic mean[61] for the income level, the following equation was used.

$$I_{\tilde{x},i} = \frac{I_{x1,i} + I_{x2,i} + \ldots + I_{n,i}}{n} \quad (1)$$

The $I_{\tilde{x},i}$ stands for the mean income described by the sum of all relevant observations in the respective area i divided by the total number of observations taken into account (n).

The arithmetic mean[61] for the real estate prices was calculated using the following equation.

$$REsqm_{\tilde{x},i} = \frac{REsqm_{x1,i} + REsqm_{x2,i} + \ldots + REsqm_{n}}{n} \quad (2)$$

$REsqm_{\tilde{x},i}$ indicate the mean real estate price per sqm calculated by the sum of n real estate prices of all relevant observations in the respective consolidation and subject $(REsqm_n)$ divided by the total number of observations taken into account (n).

For the second half of the study, Ordinary Least Square (OLS) was chosen as the regression model. The Ordinary Least Square regression is used to determine dependencies between two or more variables based on the assumption of a linear correlation between the dependent variable and the independent variable and is described in equation 6.[62]

$$\ln(y_1) = \beta_0 + \beta_1 x_{1,i} + \beta_2 x_{2,i} + \beta_3 x_{1,i} x_{2,i} \; .. + u_i \quad (6)$$

In the equation above, y_1 is the dependent variable which is explained by the independent variable x_i in infinite (n) observations, known due to the data set. Contrary, β_0 and β_1 [...] are unknown and there is a need to be estimated. The estimation shall be based on a linear function to describe the dependent variable. Most likely, there is no perfect linear correlation between the variables, hence deviation, called residuals (u_i) occur. Any interaction effects between independent variables are described with the term $(\beta_3 x_{1,i} x_{2,i})$.[62,63]

Information on the used real estate/housing data is described in Supplementary Note 3.

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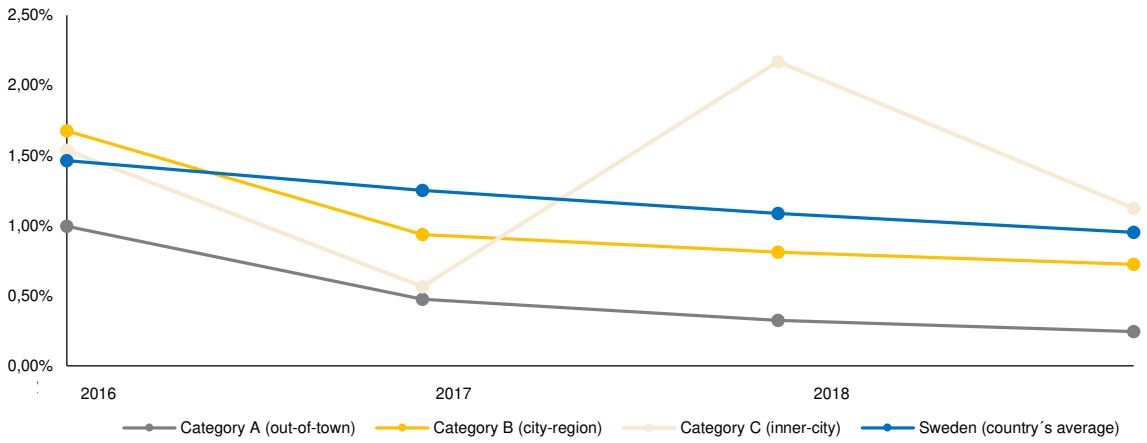
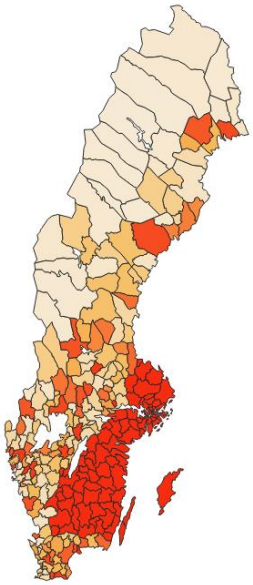
Supplementary Information for Rising Inequality and Spatial Social Segregation due to Urbanization and Increasing Housing Prices

Supplementary Note 1: Population growth rate year-to-year in Sweden and by regions



Supplementary Fig.1: Population growth rate year-to-year in Sweden and by regions. By taking a look at the annual population growth rate in a time frame of four years (2016 - 2019) the nationwide trend (blue) respectively shows a positive growth rate, albeit with a steady slight decrease in the annual growth per year. On a regional basis, the lowest annual growth is seen in category A (grey) across all years. Category C (light terracotta) shows the greatest growth with a clear swing from 2017 to 2018. Category B (orange) is in between.[27]

Supplementary Note 2: Overview of the municipal level delimitation and population density



Supplementary Fig.2: Municipal level delimitation and population density. At the Municipal level, the country is divided into 290 zones. Furthermore, the population density is displayed. The darker the area is colored red, the more densely populated it is.[1,2,3]

Supplementary Note 3: About the housing price data

Regarding the data pool of the paper, the major share of the data is already processed by the official statistic office of Sweden. It describes data related to income, housing situation, categorical and geographically spatial constraints, etc. However, to get more insight on the real estate market, the officially available data was not sufficient and especially not available on DeSO or municipal level. Therefore, it was necessary to collect data by other sources. The data was collected from Sweden's biggest residential real estate portal called Hemnet[2] with a broad archive of transactions all over Sweden.

Through this process, the focus was set on standard residential buildings like one or two dwelling buildings or any kind of multi-dwelling buildings. Special buildings or buildings for other purpose, rather than residential use were cleared. The raw data was processed by using the coordinates of the localization of every object by performing an algorithm using QGIS—a free geographic software for analyzing spatial data to match the object locations with the layer of the official statistic zones delimitations.[3] In total, it was possible to allocate 452,112 objects.

The data set was also cleared by duplicates, i.e., if the same property was sold/bought multiply times. The zone coverage with a sufficient number of objects is also given. Measured by the smallest statistical delimitation (DeSO zones) only 169 zones have 9 or fewer objects. The remaining 5,626 zones consist between 10 and 517 objects per zone. It is also notable that the data set is based on transactions between the years 2008 and 2021. To match the income data all transactions are either upscaled or downscaled to 2019 by using Sweden's official real estate price index[4] to adjust the price developments throughout the country.

To obtain the real estate transaction price level for each single object (RE_i), the original real estate prices ($RE_{hem,i}$) were multiplied by the percentage slope of the base year ($Index_{base}$), defined as the year of the actual transaction to the index of 2019 ($Index_{2019}$) as the reference.

$$RE_i = RE_{hem,i} * \left(\frac{Index_{2019}}{Index_{base}}\right) \tag{S1}$$

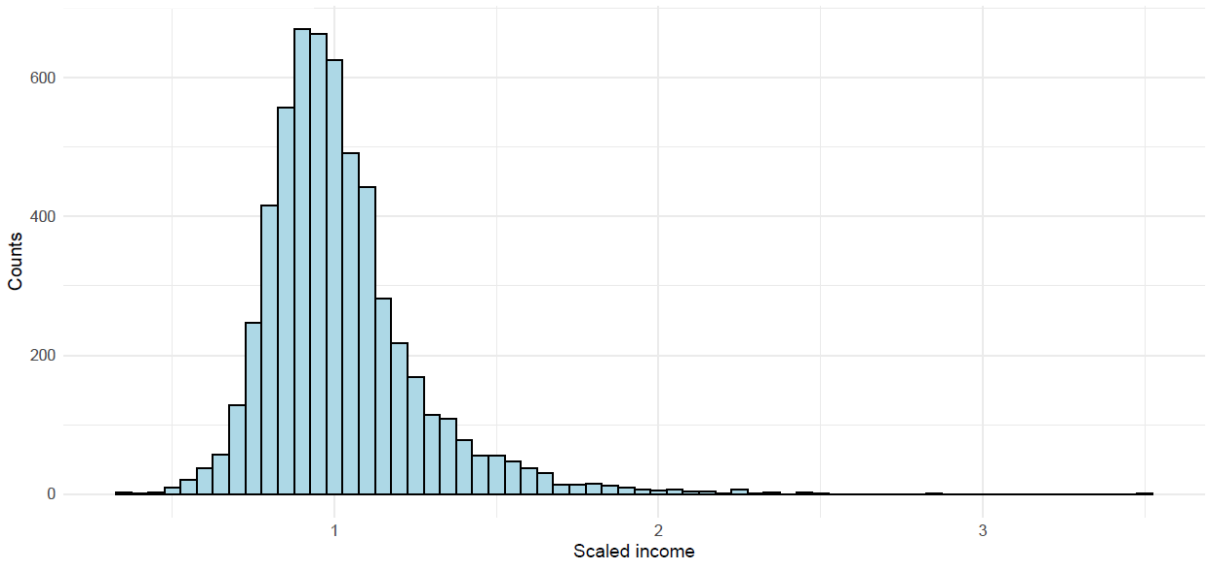
Finally, to ensure that the object prices are comparable and ready for further investigation, the prices per sqm of each object ($RE_{sqm,i}$) were calculated by:

$$RE_{sqm,i} = \frac{RE_i}{LivA_i} \tag{S2}$$

The year-adjusted data of the real estate prices per object (RE_i) were divided by the living area ($LivA_i$) of each respective object.

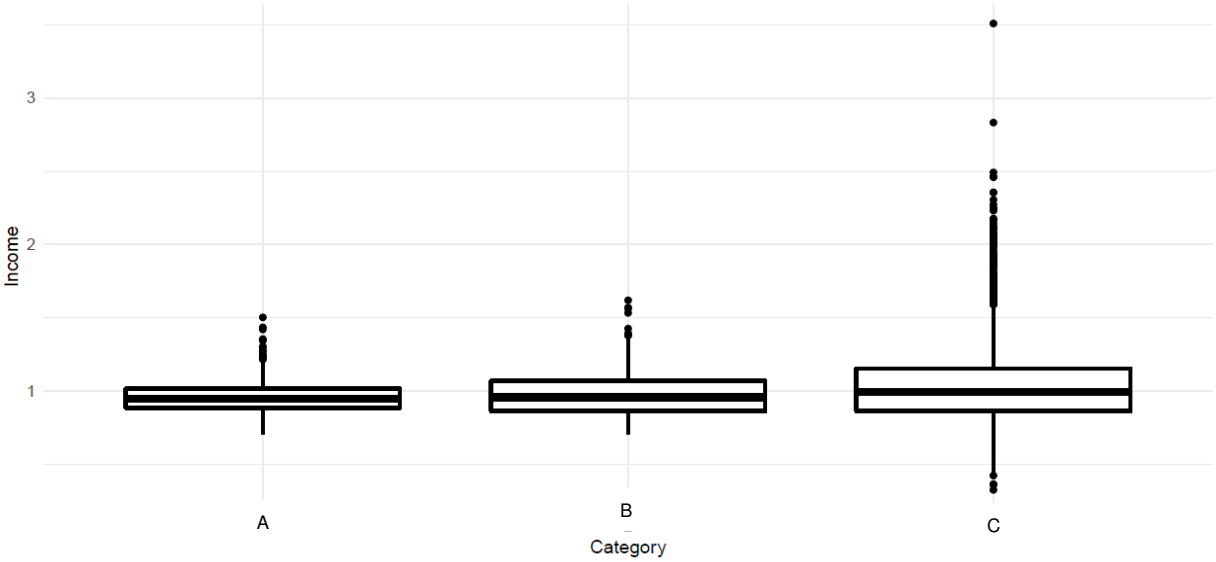
But why was the decision made to collect data of transactions to describe price levels instead of taking rents?
It was not possible to access data on actual rent payments at the DeSO or municipal level. The only way to get an idea of the rent levels in a given zone would be to take current rent offers into account. But the data vary because current rent offers are based on the present and therefore incongruent to the used data in the paper. The offers could also be requested at a much higher level than the actual prevailing rent at the location. Therefore, the actual transactions are reflecting actual purchases in line with supplier and demander. In addition, the special housing situation in Sweden with a major share of people living in owned dwellings is another reason. Even by theoretically taking rent offers into account, the availability is not given. It is reasonable to assume that the coverage is therefore not guaranteed, by not only missing out regions without any data, but moreover cross out any country-wide analyses. Not to mention that it is also important to have a sufficient number of observations per zone for a better fitting and higher expressiveness.

Supplementary Note 4: Income (mean) distribution



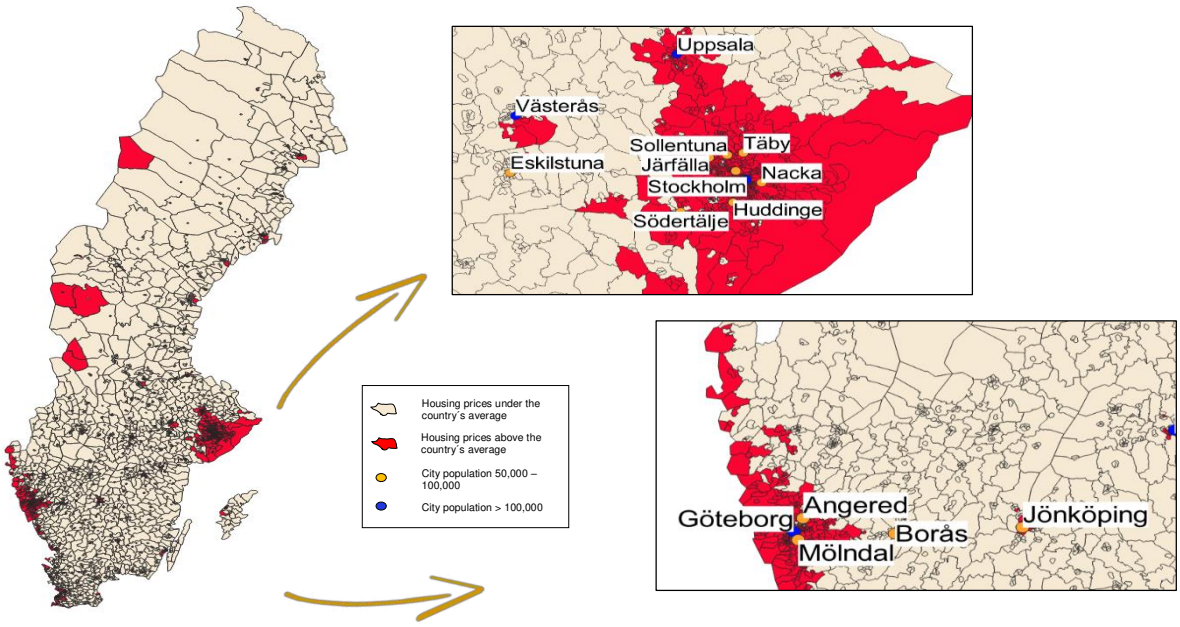
Supplementary Fig.4: Income (mean) distribution. The income distribution measured by the average income in Sweden. The national-wide distribution of income based on the DeSO zones from 2019 is approximately standard distributed when scaled with the nationwide average income. A few zones deviate from the standard distribution on the right side and can be defined as outliers.[1]

Supplementary Note 5: Income per category



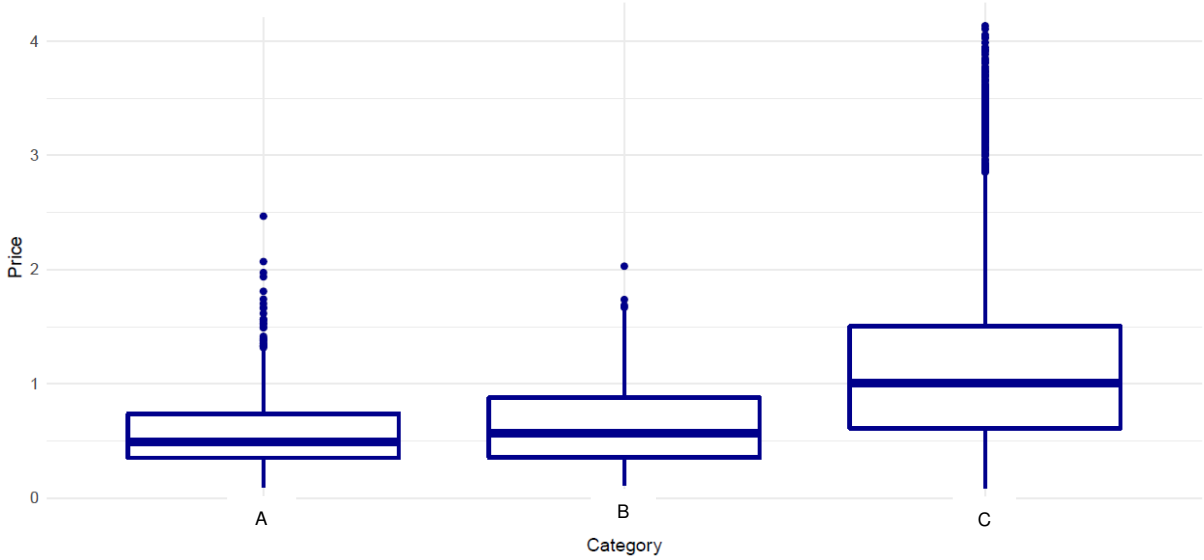
Supplementary Fig.5: Income per category. The income distribution according to the official DeSO delimitation of Sweden shows that the average income, scaled with the national average, increases the more urban the localization becomes. Category A comprises the zones located out-of-town, category B those located in the city region and category C those located in the inner-city. Income increases, but only slightly. Category C has significantly more outliers to a higher income level compared with the rest of the country.[1]

Supplementary Note 6: Heatmap housing prices



Supplementary Fig.6: Heatmap housing prices. The heat map shows the housing price level in Sweden geographically. The boundaries are drawn according to the DeSO delimitation. Zones where the housing price is above the national average are colored red. Zones with a housing price below the average level are shown in light terracotta. In the two individual representations on the right side, cities are also shown. Cities with a population between 50,000 and 100,000 are marked by an orange dot. Cities with more than 100,000 inhabitants are marked with a blue dot. It can already be seen that prices above the national level can be found in the vicinity of large cities. In particular, the Stockholm metropolitan area shows a geographically broad range of above-average real estate. In smaller cities and regions (no mark) the prices are below the national average.[2,3]

Supplementary Note 7: Housing prices per category



Supplementary Fig.7: Housing prices per category. By looking at the housing prices in 2019 categorized by official DeSO delimitations category A (out-of-town), B (city-region) and C (inner-city), the different price levels are clearly evident. From category A, over B, to C the price level of residential real estate is getting higher. Not only the range of prices' increases, but in category C there are also more outliers with extreme price levels noticeable.[1,2]

Supplementary Note 8: Estimation of the relationship between inequality and real estate prices on DeSO level

(S3)

Estimation of the relationship between inequality and real estate prices on DeSO level		
	Dependent variable: Inequality $(\ln(IE_{s,19}))$	
	Coefficient	Error
(Intercept)	0.0152903***	0.0022173
Mean Income 2019 scaled	0.0113534***	0.0023609
Mean real estate price per sqm 2019 scaled	-0.0123306***	0.0014044
Income growth 8 years	0.0018471	0.0077759
Category B	0.0065922***	0.0009231
Category C	0.0074677***	0.0006804
Income Inequality 2018 scaled	0.8453415***	0.0069268
Mean Income 2019 scaled × mean real estate price per sqm 2019 scaled	0.0036926**	0.0011439
Mean real estate price per sqm 2019 scaled × income growth 8 years	0.0152205***	0.0044963
Number of observations	5559	
R^2	0.8551	
Adjusted R^2	0.8549	
*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.		

Supplementary Tab.4: Estimation of the relationship between population growth and real estate prices on DeSO level. The main explanatory variables of interest are the mean scaled income and the scaled mean real estate price per sqm. Both have statistically significant effects, showing that DeSO zones are on average more equal, when real estate prices are higher or income levels are lower.[1,2]

The above displayed regression (Tab.4) is based on the following equation:

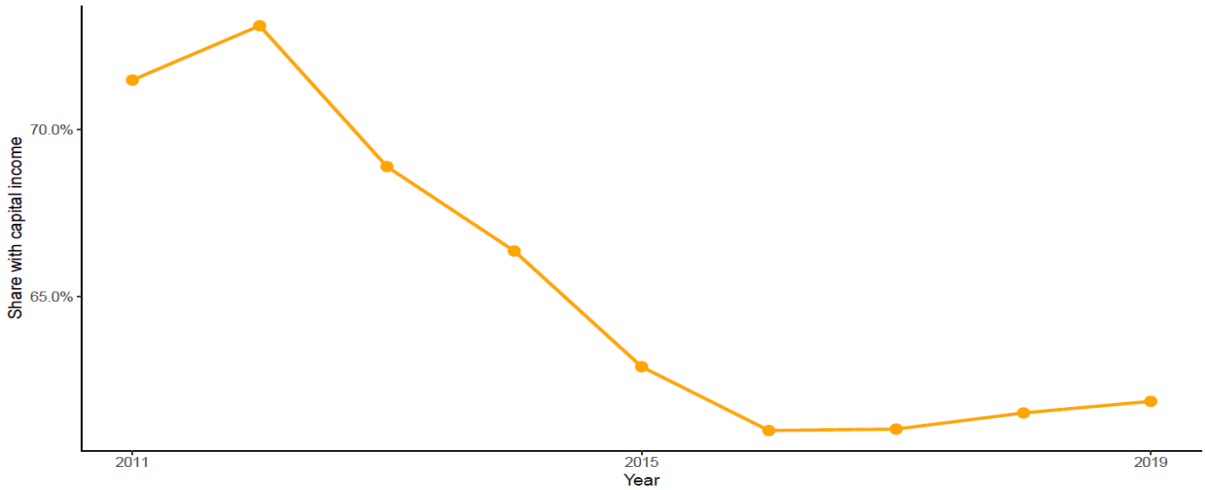
$$\ln(IE_{s,19}) = \beta_0 + \beta_1 I_{\tilde{x},s,19} + \beta_2 REsqm_{\tilde{x},s,19} + \beta_3 I_{gr,8y} + \beta_4 CatB + \beta_5 CatC + \beta_6 IE_{s,18} + \beta_7 I_{\tilde{x},s,19} REsqm_{\tilde{x},s,19} + \beta_8 REsqm_{\tilde{x},s,19} I_{gr,8y}$$

The dependent variable is the scaled measure for inequality 2019 $(IE_{s,19})$ presented in equation S4. The independent variables in this approach are the total scaled mean income 2019 $(I_{\tilde{x},s,19})$, scaled mean real estate price level per sqm 2019 $(REsqm_{\tilde{x},s,19})$, the income growth rate over the past 8 years $(I_{gr,8y})$, the variables for geographical delimitation category B $(CatB)$ and category C $(CatC)$ as well as the scaled inequality 2018 $(IE_{s,18})$. Moreover, interaction terms between the income level and the housing prices $(I_{\tilde{x},s,19}REsqm_{\tilde{x},s,19})$ and between the income growth rate and the housing prices $(REsqm_{\tilde{x},s,19}I_{gr,8y})$ were considered.

The above-mentioned measurer for income inequality on DeSO level was calculated by the difference of the mean and median income level divided by the total (country-wide) mean income level.

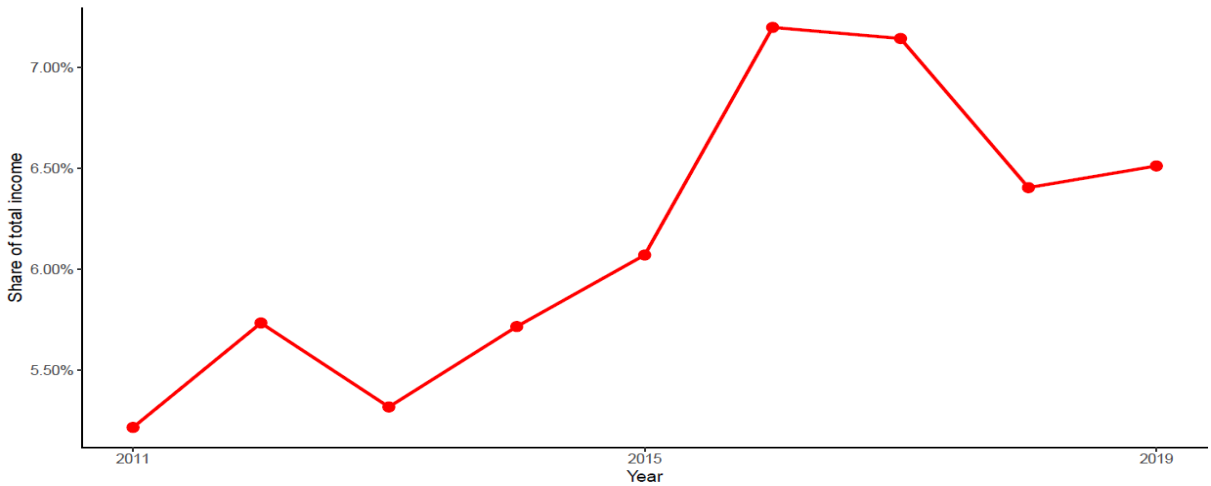
$$IE_{s,i} = \frac{I_{\tilde{x},i} - I_{\bar{x},i}}{I_{\bar{x},total}} \tag{S4}$$

Supplementary Note 9: Share of population with income capital



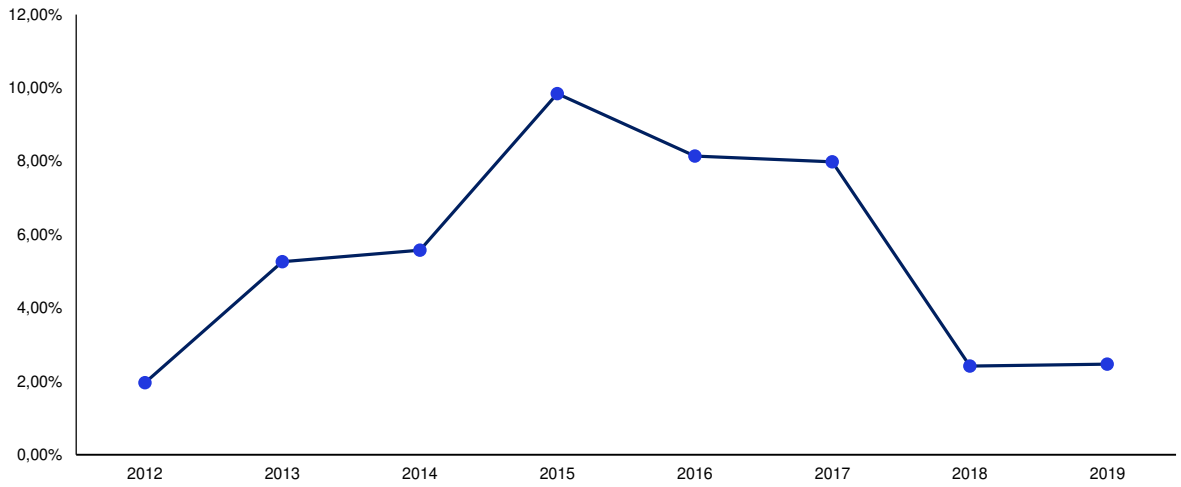
Supplementary Fig.9: Share of population with income capital. The graph shows the development of the share in the population of persons between 2011 and 2019 who received capital income in the respective year under review, irrespective of the amount. A clear downward trend is evident. In particular, the share fell by more than 10 percentage points from 2011 to 2016. Most recently, a slight upward trend can be seen, but not significant, especially in relation to the strong downward trend of previous years.[1]

Supplementary Note 10: Share of income from capital



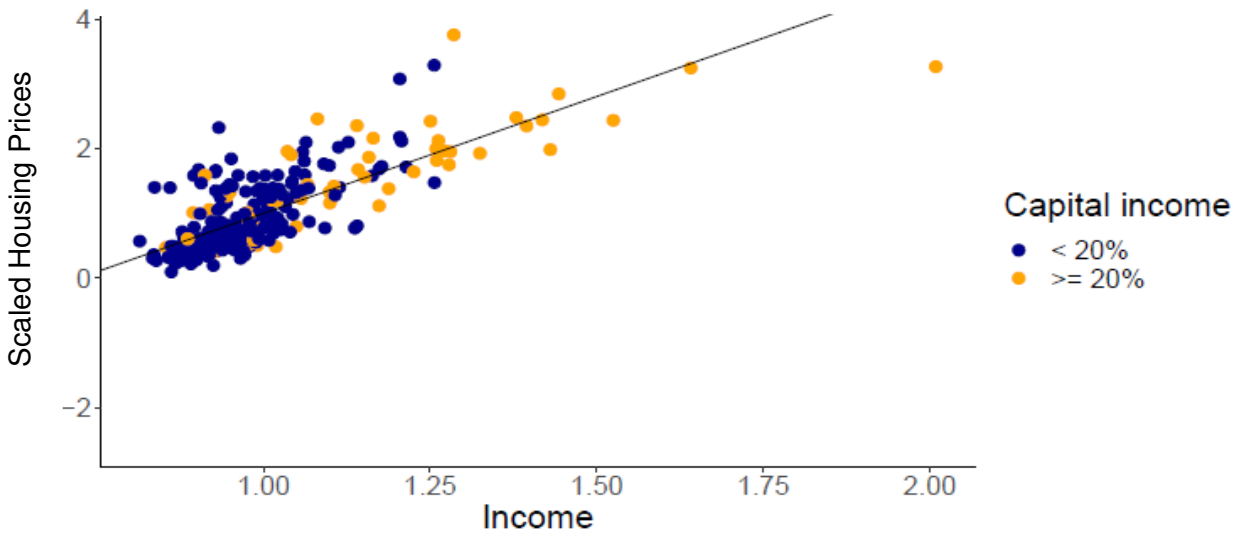
Supplementary Fig.10: Share of income from capital. With the exception of a few individual years, the general trend over time from 2011 to 2019 is that the share of capital income in Sweden's total income has increased. The biggest setback occurred between 2017 and 2018, but the trend is positive back again in 2019.[1]

Supplementary Note 11: Growth rate of housing prices in Sweden year-to-year



Supplementary Fig.11: Growth rate of housing prices in Sweden year-to-year. When considering the year-to-year growth rate of housing prices across Sweden from 2012 to 2019, the growth rate per year is at least 2.00% positive per year. Especially in the 1st half of the observation period from 2012 to 2015 a notable strong growth of the price level took place with up to 10.00% (2015 compared to 2014). From that point on the growth per year gradually levels off.[1]

Supplementary Note 12: Housing prices and income



Supplementary Fig.12: Housing prices and income. Share of population with income capital. It can be seen that the defined classifications of zones/people (municipal level) with a threshold of more than 20% income from capital to find at regions with both high income and high housing price levels. They almost split off and stand out from those below 20% income from capital. These are found almost as a cluster around the average income and average housing price level.[1,2]

References

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