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# Housing inequalities

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# Housing inequalities: The space-time geography of housing policies

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## ABSTRACT

Changes in policy over the last thirty years, particularly within advanced economies, have allowed for increased financialization, deregulation and globalisation of housing. What differentiates real-estate from other financial markets is that it possesses a salient socio-spatial geography. Housing inequalities are often framed as an outcome of macro-economic structural changes or as a product of local socio-spatial conditions, but the interactions between the two are less understood. To address this gap, we develop a descriptive methodology to connect the analysis of national housing policy trends in the Netherlands with local socio-spatial trajectories of neighbourhood change using nearly 20 years of historical data across a range of socio-spatial dimensions from the City of Rotterdam. Whilst nationally there has been an increasing policy preference for home ownership associated with a narrative of social upliftment, the spatial-temporal analysis reveals that the wealthiest neighbourhoods have benefitted significantly more from capital gains and increased rates of home ownership over time. Through descriptive analysis, the results highlight the role of divergent neighbourhood characteristics and path dependencies, suggesting that housing policies could benefit from the adoption of a more localised approach. Overall, the study sheds light on housing inequalities by integrating macro socio-economic factors with micro-level neighbourhood conditions.

## 1. Introduction

According to the World Inequality Report (2022:3), the share of total global wealth owned by the bottom 50 % is 2 %, contrasted against the top 10 % who own 76 % of total global wealth. The rise in total private wealth and vast increases in wealth-to-income ratios in the 21st century can largely be attributed to growth in the value of capital gains through housing (Fuller et al., 2020). This is reinforcing a growing divide among those who cannot afford to purchase a home, those who can buy their own home and multiple property owners (Adkins et al., 2020; Mezaroş & Paccoud, 2022).

Housing inequalities are structural in nature in that they reflect persistent disparities in the distribution of housing across population groups (James et al., 2022). They may indicate differences in levels of home ownership (Bonnet et al., 2018; Hochstenbach, 2018; Lowies et al., 2022; Smith et al., 2022), disparities in capital gains over time (Mayock & Malacrida, 2018; Wind & Hedman, 2018) and availability of housing in centrally located and well connected areas (Martínez et al., 2018; Rokem & Vaughan, 2019). Housing inequalities are rooted in multiple causes. On a structural level they are exacerbated by both high price inflation, periods of economic instability and recession (Forrest,

2021) and can be driven by historical policy processes, such as the discriminatory practice of redlining in the United States which excluded predominantly Black neighbourhoods from accessing loans to purchase homes (Faber, 2021). They are also related to local geographic factors like access to job opportunities and transportation (Martínez et al., 2018) and social disparities in income (Boelhouwer, 2020), race (Sharp & Hall, 2014) and migrant status (Kolb et al., 2013; Wind & Hedman, 2018). Housing wealth accumulation is a cumulative process which happens over both space and time (Fuller et al., 2020; Modai-Snir & van Ham, 2020). What separates housing from other global financial markets is that it is physically embedded within a local neighbourhood context that is shaped by particular demographic, economic and spatial conditions.

Housing inequalities are often conceptualised either as an outcome of macro-economic processes, such as the financialization of the housing market (Aalbers et al., 2017), or local spatial-temporal conditions through the lens of neighbourhood change, but few studies systematically connect the two. An approach which places emphasis exclusively on either the micro or the macro context is at risk of ignoring the wider system within which housing inequalities emerge and supporting solutions that do not address underlying structural issues, systemic barriers,

or trade-offs (refer to Section 2.3 which expands on this statement). Recognizing housing inequalities as a complex issue entails moving away from conventional scientific frameworks that prioritise linear "cause and effect" (de Roo et al., 2020). It involves acknowledging that these inequalities arise from interactions among numerous interconnected factors at both micro and macro levels, which undergo dynamic changes and evolution over time. Therefore the focus of this paper is on descriptively connecting micro and macro-level factors through the analysis of spatial-temporal neighbourhood trajectories across a wide range of socio-spatial dimensions and their detailed links with macro changes that are differentiated by distinct housing policy phases, employing Rotterdam in the Netherlands, as a case study.

Neighbourhoods are theorised as an important spatial unit in which both decision making from the *bottom-up* (individual and local) and *top-down* (centralised, higher-level authorities) meet (Sampson, 2019). The 'neighbourhood effects' literature suggests that local contexts matter and impact the collective social lives of communities (Suss, 2023:3). Conceptualising policies within a trajectory framework of neighbourhood change has the potential to increase our understanding of how they contribute to shaping present conditions. To gain a multidimensional understanding of the socio-spatial context of neighbourhoods, one can apply geo-demographic classification, a dimension reducing technique that helps condense large data sets (Voas & Williamson, 2001) and in this study multiple urban and socio-economic characteristics of neighbourhoods. Policy is not independent from geography and in the same way neither can geographical trajectories of neighbourhood change be divorced from institutional changes within the policy landscape. We specifically focus on changing distributions in home ownership, capital gains, levels of social housing and income-to-house value ratios. The Netherlands, whilst possessing relatively low income inequality, when internationally compared has one of the highest levels of wealth inequality in the world with the top 10 % estimated to own almost 50 % of all wealth (World Inequality Database, 2023). The remainder of the structure of the paper is as follows, Section 2 develops a theoretical framework for this study through a review of related literature, Section 3 outlines the Methodology, followed by the presentation of the results in Section 4, a Discussion of the key findings in Section 5 and Conclusion with key contributions and avenues for future research in Section 6.

## 2. Housing inequalities

### 2.1. Macro-economic processes

Scholarly interest in housing inequalities through macro-economic processes tends to highlight the profound structural changes associated with the deregulation and liberalisation of advanced economy banking systems implemented in the 1980s (Arundel & Ronald, 2020; Byrne, 2020; Christophers, 2021). These changes are linked to significant decreases in public spending through increasing reliance on private companies for the delivery of major infrastructural development and investment (Graham & Marvin, 2001). This was coupled with policy that prioritised home ownership through the deregulation of housing markets and increasing financing of mortgage loans to enable greater access by individuals (Ryan-Collins, 2021:480).

Various authors provide insights into the political motivations associated with these structural reforms. Forrest (2021) determines that these changes were initially politically driven by social, rather than investment considerations. New wealth would be generated through home ownership, creating more egalitarian and socially inclusive societies. Arundel and Ronald (2020) reflect on a political vision across North America, Europe and Australia, which espoused widespread and equitable home ownership in the future, that would lead to a reduction in inequalities and overall improvement in the well-being of families and individuals. Ronald et al. (2017) argue that lowering the barriers in accessing home ownership across societies was linked to a wider project of asset-based welfare, that encompassed state supported access to a raft

of assets built up at the individual level, offsetting dependency on public funds and infrastructure. State support would be reduced and replaced by the benefits of owning a home. These benefits include drawing on the equity a house provides as collateral for loans or as a financial asset to tap into during retirement (Fuller et al., 2020), increased housing security (Berry et al., 2017; Forrest, 2021) and passing the home on as an item of value to children (Kolb et al., 2013:1010; Ronald & Lennartz, 2018).

Despite evidence proposing that these structural changes were initially part of a wider social project, their long term outcomes have been transformed through the commodification and financialization of real estate, which has become integral to global financial portfolios and a driver of economic instability and crisis (Aalbers et al., 2020; Dewilde, 2017; Fields & Uffer, 2016). This undermines the capacity of a building to function as a home and an item of security for families and individuals (Forrest & Hirayama, 2018; Ronald & Kadi, 2018). Madden and Marcuse (2016) in their book, *In Defense of Housing*, observe three prominent, interconnected and mutually reinforcing trends of *deregulation, financialization* and *globalisation* of housing that are reshaping housing systems. The *deregulation* of housing has resulted in the weakening or removal of the regulations, customs, and rules governing residential property (Madden & Marcuse, 2016:37). As an example, the retreat of regulation in New York between 1981 and 2011, resulted in the number of rent-controlled apartments decreasing from more than 285,000 to fewer than 39,000 (The Furman Centre for Real Estate and Policy, 2012). According to the organisation Living Rent,[1] since 1979 in the UK, 4.5 million council homes have been lost to privatisation and demolition, with many tenants being evicted and effectively zoned out of centrally located areas. *Financialization* is a generic term to describe the increasing power and prominence of actors and firms that engage in profit accumulation through the servicing and exchanging of money and financial instruments (Madden & Marcuse, 2016:39). As a consequence, Wall Street and other global financial investment markets have become key players in real estate investment.[2] The third trend is the *globalisation* of housing. Real estate may be fixed in place, but it is increasingly dominated by economic networks that are global in scope (Madden & Marcuse, 2016:42). In many ways, the Financial Crisis of 2008, illustrates the profound convergence of these three trends. The deregulation and financialization of housing through subprime lending of mortgage loans, resulted in mass devaluation of homes which had global reach and caused major economic crisis (Renaud & Kim, 2008).

Home ownership levels across a number of societies, such as Japan, the United Kingdom, the United States and Australasia are declining (Arundel & Ronald, 2020; Forrest & Hirayama, 2018). In the United Kingdom the rise in "buy-to-let landlordism" is documented, leading to the term "generation rent" that represents a group of younger people who are not only more vulnerable to exploitative practices in private renting, but limited in their capacity to acquire their own homes (Ronald & Lennartz, 2018:787). In Sydney, Australia, research suggests that investor landlords are growing with an increasingly financialised mindset (Pawson & Martin, 2020). In Dudeland, Luxembourg, Paccoud (2020) shows how the production of housing is concentrated and controlled by a small group of landlords and property developers. García-Lamarca (2020) illustrates that the private rental sector in Barcelona, Spain is playing an increasing important role. These studies support the notion that a new generation of global institutional investors is emerging, edging out individuals from the market (Smith et al., 2022; Christophers, 2021). Furthermore, weak regulation of tenure rights and rental prices enhance investment opportunities in purchasing homes for rental purposes (Hochstenbach et al., 2020:1626) and in this way no longer prioritise the general interests of urban society, but those of the

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[1] https://www.livingrent.org
[2] https://www.nytimes.com/2020/03/04/magazine/wall-street-landlords.html

market, as they seek to enhance private investment (Cassiers & Kesteloot, 2012:1917).

In summary macro-economic perspectives emphasise housing inequalities as an outcome of wider political, institutional, and economic processes. Whilst we do not dispute that these structural processes are integral and supported by evidence across a number of case studies, they tend to overlook the role of local contextual dynamics. Thus, in the subsequent section we focus on research that conceives housing inequalities within a framework of local spatial-temporal processes of neighbourhood change.

## 2.2. Local spatial-temporal neighbourhood processes

It is well established that poverty and inequalities converge in certain neighbourhoods (Delmelle, 2016; Vaughan, 2018). Whilst people may be initially sorted out into neighbourhoods by wider socio-economic processes (Cheshire, 2012), such as through the distribution of affordable housing across different zones (Nieuwenhuis et al., 2020), evidence suggests that the distribution of economic and social opportunities enhances polarisation between neighbourhoods over space and time. Localised opportunities, such as access to affordable and efficient transportation (Power, 2012), educational opportunities (Owens & Candipan, 2019), economic opportunities (Chen et al., 2012), social opportunities (Tóth et al., 2021; Kim et al., 2022), healthcare (Mayaud et al., 2019) and characteristics of the spatial configuration of neighbourhoods such as spatial connectivity (Modai-Snir & van Ham, 2018; Su et al., 2019) may contribute to persistent and increasing inequalities.

The study of neighbourhood change is a well-established area of research, but until recently the mapping of neighbourhoods beyond two points in time was limited (Delmelle, 2016:37). The advantage of a longitudinal approach is that it is more likely to shed light on the structural mechanisms which contribute to widening inequalities which may facilitate or negatively impact processes of upward social mobility and socio-spatial polarisation. For example, Mayock and Malacrida (2018:92) study transaction histories for homes between 1990 and 2013 across 9 metropolitan areas in the USA, showing that neighbourhoods occupied by the lowest income families are limited in capital gains. This increases divisions between the housing markets of different neighbourhoods, making it difficult for lower income families to relocate. An analysis of the housing pathways of one Swedish birth cohort (1970–1975), based on population-wide register data (GeoSweden), is used to explain differences in capital gains between different social groups in the period of 1995–2010 (Wind & Hedman, 2018). The results indicate more capital gains for individuals with higher incomes and lower capital gains for migrant populations, suggesting that native swedes are able to use their economic and cultural capital to profit in the housing market.

With recent advancements in the availability of multi-dimensional data sets and increases in computational power, new techniques are being adopted from data science and applied to the study of neighbourhood change. Two particularly promising methods are statistical clustering and sequencing techniques. Statistical clustering, when applied to neighbourhood characteristics, aid in the segmentation of neighbourhoods into a set of discrete categories across multiple spatial and social dimensions (Singleton and Longley, 2009). Sequence analysis, when applied alongside clustering, allows for the mapping of neighbourhood transformations as they change between discrete categories over time (Kang et al., 2020). Instead of measuring numerical changes to specific variables across neighbourhoods, sequence analysis evaluates and compares neighbourhoods as holistic trajectories of urban transformations shedding light on the social and spatial processes which allow neighbourhoods to move through social hierarchies over time.

## 2.3. A framework for housing inequalities: a complex problem at the intersection between micro and macro-level factors

In summary, housing inequalities are characterised by disparities in the distribution of characteristics of the housing market across population groups and geographical regions, with greater equalities observed when these disparities are reduced. Housing inequalities include discrepancies in the distributions of tenure types and levels of home ownership (Bonnet et al., 2018; Hochstenbach, 2018; Lowies et al., 2022; Smith et al., 2022), house prices and capital gains (Mayock & Malacrida, 2018; Wind & Hedman, 2018) and availability of housing in well-connected areas (Martínez et al., 2018; Rokem & Vaughan, 2019). Housing inequalities may reflect the varying needs of different population groups and may not be considered inherently "unfair" or inequitable, depending on the way one defines "fairness". However, reports such as the *The Role of Land in Achieving Adequate and Affordable Housing* (UN Habitat, 2020) and *The World Inequality Report* (2022) express growing concern for rising wealth and housing inequalities, highlighting that they place certain regions and people at a systemic disadvantage, threatening sustainable social and economic development.

Scholarly research from macro-economic perspectives tends to rest in explanatory frameworks for rising housing inequalities within wider political, institutional, and economic structural processes (Aalbers et al., 2017; Smith et al., 2022). Although specific case studies may be employed, local contextual factors are often placed beyond deeper interrogation. Whereas evidence from "neighbourhood-effects" literature shows that despite radical transformations of institutional, economic, and political structures over time, uneven development patterns across neighbourhoods can persist, emphasising the role of local characteristics of place (Sampson, 2019; Sharkey & Faber, 2014).

If we adopt a systemic perspective, housing inequalities can be conceived as a complex real-world phenomenon that emerges from the interactions between both macro-level factors such as globalisation, deregulation and financialization and micro-level factors such as house price, local employment opportunities and demography of residents. Studying complex problems requires moving away from a reductionist and traditional scientific mindset that emphasises linear "cause and effect" (de Roo et al., 2020) and incorporating multiple perspectives to develop an appropriate analytical strategy that reconciles both the micro and macro. Increasingly organisations, policymakers, academics, and practitioners are acknowledging the complexity of societal challenges, encountered in the economy, society, and the environment, such as housing inequalities (Calenbuhr, 2020). A complex systems approach offers an alternative scientific paradigm that recognises that complex real-world problems are characterised by non-linear, dynamic, and interconnected relationships that defy simple cause-and-effect explanations. The purpose of this paper thus lies in advancing our understanding of the systemic nature of housing inequalities by developing an explorative methodology to connect and contextualise institutional structural shifts in macro-economic housing policy with micro-level socio-spatial factors in trajectories of neighbourhood development using Rotterdam in the Netherlands as a case study.

## 3. Methodology

In this paper we propose a comparative trend analysis between changes in housing policy and trajectories of neighbourhood development over time, employing Rotterdam, in the Netherlands as a case study (see Section 3.5 for an introduction to the case study). The overarching aim of the comparative trend analysis is to engage with both the wider structural and local contextual factors which drive housing inequalities. This requires the implementation of an interdisciplinary methodology that combines the analysis of macro-economic changes in housing policy with the spatial-temporal analysis of neighbourhood development. We define three stages within our methodological process, refer to Fig. 1.
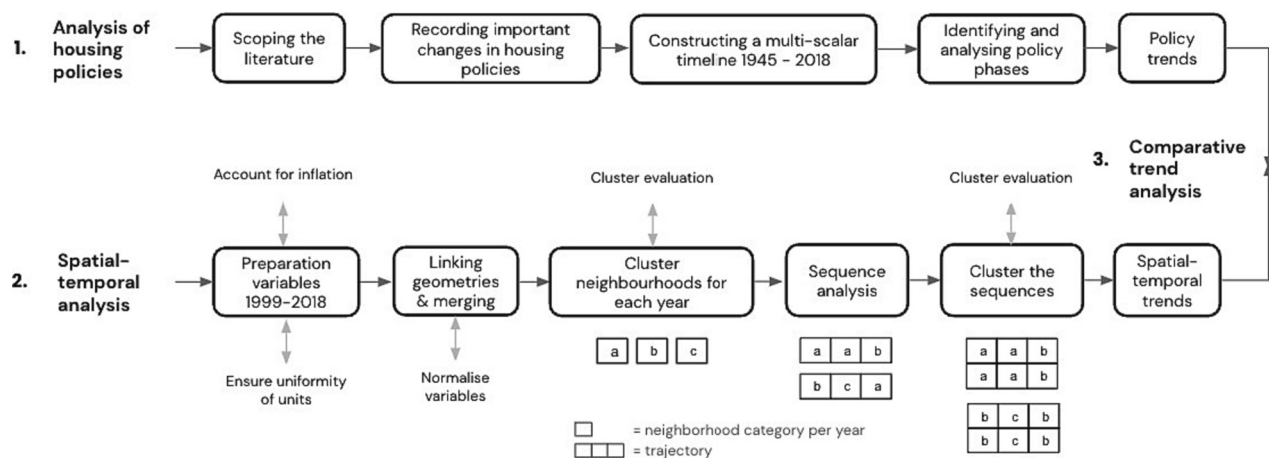
**Fig. 1.** Methodological framework: A diagrammatic representation of the three stages of the methodological process, *Analysis of housing policies, Spatial-temporal analysis* and *a Comparative trend analysis.*

- Analysis of historical housing policy phases in the Netherlands
- Analysis of spatial-temporal trends of neighbourhood change in Rotterdam
- A comparative trend analysis

### 3.1. Analysis of historical housing policy phases in the Netherlands

The overarching goal is to gain insights into the structural landscape of housing inequalities through a descriptive analysis of changing housing policy phases between 1945 and 2018 in the Netherlands. By focusing on changing housing policy phases, as opposed to specific housing policies, the intention is to shine light on the relationship between national housing policies, macro-economic shifts, and demographic changes in Rotterdam, in line with the conceptual framework developed in Section 2.3. The identification of housing policy phases for analysis involves scoping literature to identify, record and visualise them in a multi-scalar timeline. The methodology developed is documented in more depth below:

#### 3.1.1. Scoping the literature

The primary purpose in scoping literature is to utilise it as a database to extract and analyse important developments related to housing policies in the Netherlands. This includes developments which effect the composition of the population, as demographic changes lead to changing demands in housing (Mulder, 2021) as well as wider macro-economic changes, such as the Global Financial Crisis of 2008, which had a global impact on housing markets. The literature is primarily scoped through backwards and forwards snowballing, which is a process of identifying relevant literature through using the reference list and citations in a relevant paper. The starting point for this process is the paper: *The unlikely revival of private renting in Amsterdam: Re-regulating a regulated housing market* by Hochstenbach and Ronald (2020). Each paper is scanned for relevance, and this leads to a total of 56 papers.

#### 3.1.2. Recording important changes in housing policies

The literature is scanned to extract important developments related to housing policy, such as the implementation of the *Landlord Levy* placed on Housing Associations in the Netherlands in 2014 (van Gent and Hochstenbach, 2020) and the publication of the *Memorandum for Housing in the Nineties* in 1989 (Dieleman & van Kempen, 1994). Each development is logged as an entry in a Spreadsheet with their name, date of occurrence and a brief description. In addition, each housing policy/memorandum is specifically recorded in a table with the year of implementation/publication, name, target areas, target groups and

policy instruments utilised (refer to Table AI in Appendix A). Target areas and groups refer to the geographical regions and population groups/organisations the policies were intended for. Whereas the policy instruments refer to the tools or mechanisms that were used to implement public policies and achieve specific objectives, such as subsidies, grants, and/or specific regulations.

#### 3.1.3. Constructing a multi-scalar timeline 1945–2018

Each important development/policy is mapped into a multi-scalar timeline at either Global, National or City scales to get a sense of the housing policy landscape (refer to Fig. 2). For example, the Bilateral agreements to attract migrant workers implemented in the 1960s were implemented nationally, whereas, in Rotterdam, where many of the migrants came to work, specific policies focusing on their integration into Dutch society were developed and implemented locally (Dekker and van Breugal in Crul et al., 2019).

#### 3.1.4. Identifying and analysing the policy phases

Through an examination of the multi-scalar policy timeline, three overarching phases are inductively identified:

- 1945–1989: Highly regulated housing in the Netherlands with an emphasis on public social housing.
- 1989–2008: Significant decrease in regulation with an emphasis on home ownership.
- 2008–2018: Increase in regulation with an emphasis on home ownership.

An analysis of the housing phases is conducted through mapping changing institutional relationships between institutional actors, examining the defining policy objectives of each phase and the level to which these objectives were achieved. It is important to recognise that public policies are usually generated within networks in which multiple actors are interrelated in a systematic way (de Bruijn & ten Heuvelhof, 2018; Kenis & Schneider, 1991). We conceive each policy phase as a multi-actor process and identify the main institutional actors as those who may influence or be influenced by housing policy as: the Housing Associations, private owners, renters, private landlords, State actors and the Bank as a source of financing, refer to Fig. 3.

### 3.2. Spatial-temporal analysis of neighbourhood change in Rotterdam

The overarching goal is to shed light on the local spatial-temporal mechanisms associated with housing inequalities in Rotterdam. This analysis utilises multi-dimensional data sets composed of social, eco-
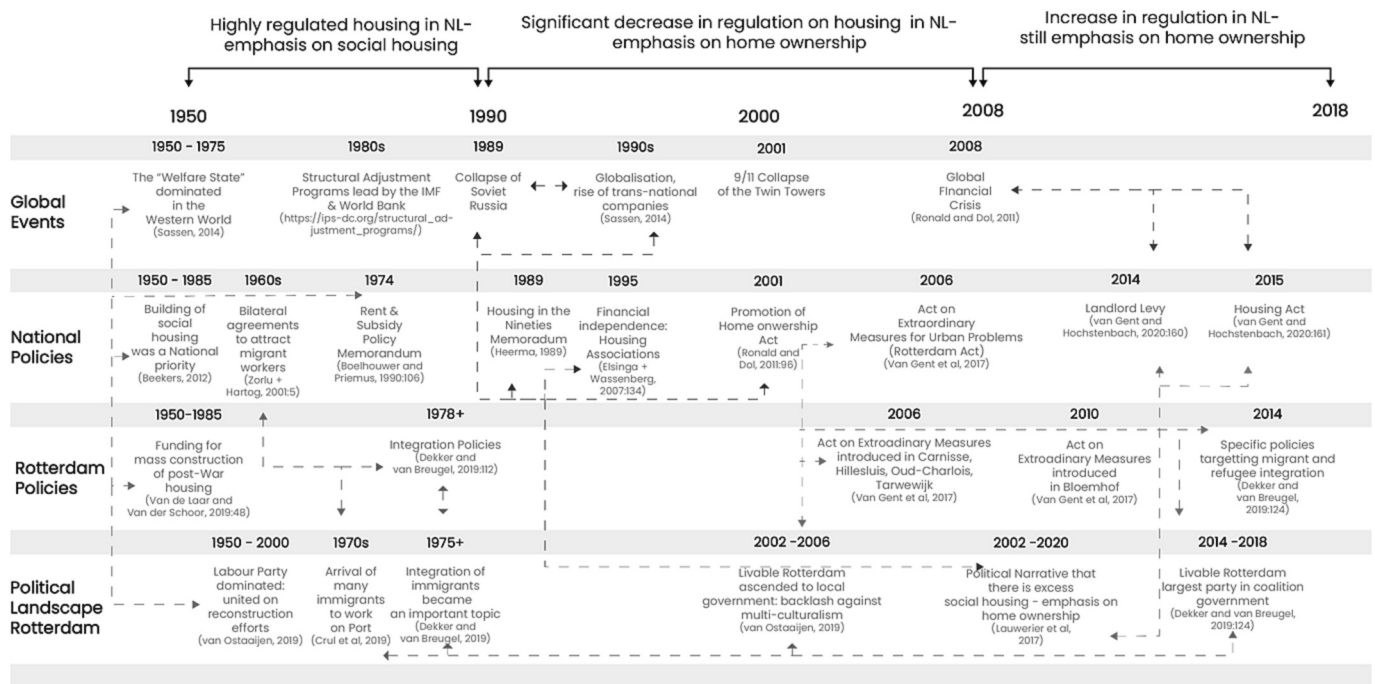
**Fig. 2.** Historical housing policy landscape: a multi-scalar timeline of the housing policy landscape with connections between the local, national, and international levels depicted with arrows.
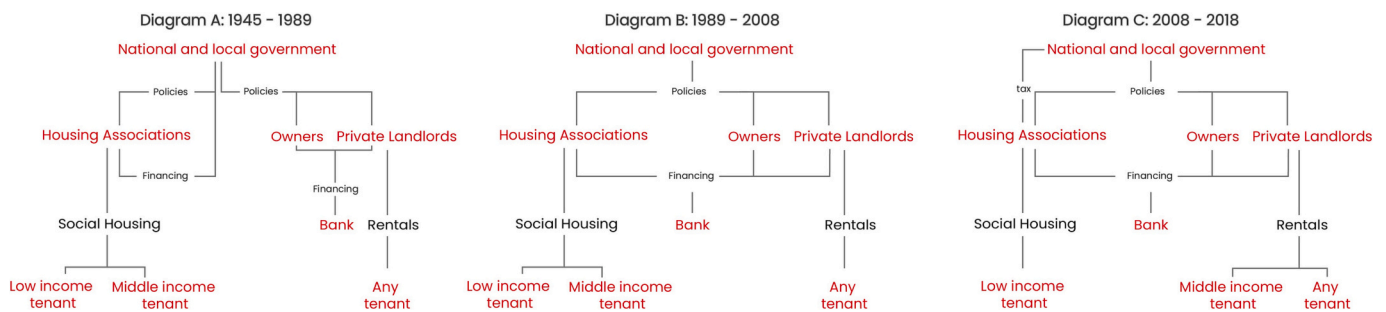


**Fig. 3.** Institutional relationships: diagrammatic visualisations of changing institutional relationships across the phases between multiple actors and stakeholders involved in the formation of housing policies.

nomic and urban variables at the administrative boundary of the neighbourhood in Rotterdam from 1999, 2001, 2003, 2005, 2007, 2009, 2011, 2013, 2015 and 2018. This methodology broadly draws on the work of Delmelle (2016); Lee et al. (2017) and Patias et al. (2022) and firstly classifies the neighbourhoods for every year into a set of discrete categories, utilising K-means clustering, yielding a temporal sequence for each neighbourhood of discrete types and then secondly applies sequencing analysis methods to provide insights into these local urban transformations. The spatial-temporal analysis is composed of three phases: *Data preparation of neighbourhood variables, Linking geometries and merging the data sets* and *Trend analysis*.

*3.2.1. Data preparation of neighbourhood variables*

Each year of the analysis possesses multidimensional *demographic, economic* and *urban* variables at the administrative boundary of the neighbourhood in Rotterdam as defined by the Central Bureau of Statistics (CBS) . The majority of the variables are derived from the CBS and South Holland Open Data Portal, but for a detailed explanation of each variable, how they are calculated, why they are included and how we address missing data, refer to Appendix 1. The specific *demographic variables* are the total population, percentage of native and non-native Dutch and different age groups. Specific *economic variables* are mean

income, mean house value and percentages of owned and rental units. Specific *urban variables* include the number of residential, non-residential land uses, mean integration and betweenness centralities of the street network and access to metro and tram. The process of data preparation is as follows:

1. *Ensuring uniformity of variable units:* this allows for relative comparison across the years. For example, if in one year the variable is in the form of an absolute number, but in percentages for all other years, the variable is transformed to a percentage. Furthermore, as part of the data cleaning process it is insured that there is uniformity in the way each variable and neighbourhood is named and spelled across the data sets.

2. *Addressing missing data:* ensuring that any missing data was appropriately addressed, refer to the Supplementary material for further details.

3. *Adjusting all monetary variables:* the monetary variables are firstly adjusted for inflation according to rates as denoted by the International Monetary Fund to enable comparison across the years. In conducting this process, we find that the monetary variables have increased significantly beyond rates of inflation. Thus, to allow for the identification of where relative wealth and poverty have

persisted over time, the monetary variables are normalised for each year individually. The normalisation process enables the values to be placed on a scale with a range between 0 and 1. Thus for example, it transforms the highest income values across all years to 1. For a comprehensive description of the normalisation process, refer to Appendix 2.

### 3.2.2. Linking geometries and merging the data sets

The neighbourhood boundaries remained relatively consistent across the years, but there are slight modifications and thus for ease of comparison all of the data sets are linked by their neighbourhood names with the geometry of the same name from 2018. Once linked to the same geometry, the multiple data sets are merged into one using concatenation in python, resulting in a data set with every neighbourhood (*70 neighbourhoods*) possessing one row of data for each year (*10 years*) and thus a total of 700 individual rows. After the data sets are merged, the variables which had not been normalised previously are normalised in preparation for K-means clustering, refer to Appendix 2 for more details.

### 3.2.3. Trend analysis

#### 3.2.3.1. K-means clustering for each neighbourhood for each year.
Once the data are normalised a K-means clustering algorithm is applied to identify distinct typolo- gies for each neighbourhood for every year. K-means clustering is an established unsupervised machine learning technique which enables the identification of categories within a data set in which unlabelled data is fed into the algorithm and partitioned based on the nearest mean (Géron, 2017:8). It assigns the original *n* objects (700 neighbourhoods) into *k* clusters and each object is assigned to the cluster whose centre is closest to that object. In this case, K-means clustering is chosen over other clustering algorithms, such as K-medians, as it is well suited for data which follows normal distributions and has continuous variables, as is the case with this underlying data. The number of clusters, *k* is predefined and the best *k* value will lead to the strongest cluster groupings. To determine the optimal *k* value, the *Silhouette Score* is applied (Rousseeuw, 1987) and in this case *4 clusters* represent the optimal solution, refer to Appendix 3 for additional information.

#### 3.2.3.2. Sequence analysis.
Sequencing analysis was originally developed to study DNA transformations and subsequently applied to life course analysis (Kang et al., 2020). In the context of this study, it is applied to the neighbour- hood categories derived from K-means clustering to identify similar sequence trajectories. The TraMineR package in the R programming language is employed (Gabadinho et al., 2011) to implement the following steps:

1. A neighbourhood's trajectory is referred to as a *sequence state object* and each sequence state object is composed of the grouping of each discrete category it was assigned in chronological order for each year from the K-means clustering process. We thus have 70 sequence state objects.
2. A pairwise dissimilarity matrix between the sequences is calculated utilising the *Dynamic Hamming Distance* method (DHD) (refer to Lesnard, 2010) to understand how one sequence may be transformed to the other through substitutions. The DHD method is based on the Hamming Distance method, which utilises a constant substitution cost (=1) and an infinitely large cost for insertion or deletion. It differs from the Hamming method in that it accounts for the different timings of each transition between neighbourhood categories by providing different substitutions for each year (Lesnard, 2010).
3. Categories of sequence trajectories are identified through clustering the pairwise dissimilarity matrix to establish groups consisting of similar sequence trajectories. In this case, a Partitioning Around Medoids (PAM) clustering algorithm is applied. PAM is a modification of the traditional K- means and is more appropriate as the dissimilarity matrix is ordinal and not normalised. Various cluster solutions are assessed using *Silhouette Scores* (refer to Appendix 3), resulting in a total of 9 distinct classes of trajectories of neighbourhood change.

### 3.3. Comparative trend analysis

The final stage consists of a descriptive comparison between the spatial-temporal trajectories and housing policy trends. To do this comparison neighbourhood variables that can directly be linked to the changing housing policy phases are examined within each category of sequence trajectories. The specific variables are related to: home ownership, social housing, capital gains and income to house value ratios.

The median value for each variable per year for each sequence trajectory category is plotted across the entire time period and visualised through line graphs. This allows the changing values to be associated descriptively through time to the policy phases.

### 3.4. Data quality issues

The analysis of historical housing policy is able to adopt a much wider timescale, than the spatial-temporal analysis, as the variables included in the neighbourhood data sets are only available from 1999. Further limitations are imposed on the spatial-temporal analysis in relation to the availability of data, for example the exact composition of the non-native Dutch population is only available for later years and thus could not be included across the entire time period. Finally, as we rely primarily on secondary data, we acknowledge that there may be bias or inaccuracies in the manner in which the data was collected, by for example labelling someone as non-native Dutch when they may identify as native Dutch.

### 3.5. The case study of Rotterdam in the Netherlands

Rotterdam is the second largest city in the Netherlands and a major logistical hub, possessing the biggest port in Europe. For many decades it has attracted international migrants (Entzinger & Engbersen, 2014). However, Rotterdam has not achieved the global status of a city like Amsterdam. Whilst "global cities" compete for highly skilled international labour forces, attracting global expats from all with their advanced knowledge-based economies, migration within "secondary cities" is usually based on capital intensive projects which are aimed at reducing production costs (Crul et al., 2019:8). Rotterdam follows this pattern of development: Chinese sailors arrived in the early 20th Century to work on Dutch ships, migrant labourers settled from Morocco and Turkey in the 1960s followed by postcolonial immigrants from Indonesia, Suriname, and the Dutch Caribbean (Entzinger & Engbersen, 2014). As a result, Rotterdam possesses vast economic, social, religious and language differences, with local politics often hinged on issues of multiculturalism and cultural assimilation (Crul et al., 2018:8). Previous research shows that Rotterdam has persistently remained divided along class lines of rich and poor (Musterd et al., 2020). In addition, there is a lack of literature in "secondary" cities and this case study reflects on housing inequalities in such an urban space.

## 4. Results

### 4.1. The analysis of historical housing policy phases

Each historical housing policy phase is derived from an analysis of housing policies in the context of a broader policy landscape, inclusive of wider macro-economic and demographic conditions. The housing policy landscape is mapped according to international, national, and

local levels between the periods of 1945 and 2018 in a multi-scalar timeline (refer to Fig. 2). It is important to ascertain the differences in approach between city and national level policies (Scholten, 2016) as local policies may be driven by different models to national policies (Crul & Schneider, 2010). Fig. 2 reveals that housing policies tend to be implemented at a national level and strongly influenced by global macro-economic attitudes. In closely examining housing policies within the context of this wider policy landscape, three predominant phases are inductively identified and subsequently analysed according to changing institutional relationships, defining policy objectives and the level to which these objectives were achieved in each phase. These phases are:

- 1945–1989: Highly regulated housing in the Netherlands with an emphasis on public social housing.
- 1989–2008: Significant decrease in regulation with an emphasis on home ownership.
- 2008–2018: Increase in regulation with an emphasis on home ownership

The first phase is between 1945 and 1989 and is characterised by a high degree of government regulation and intervention. This phase directly links to ideals espoused by the Welfare State which was the dominant mode of governance across Europe at the time. This era is referred to as the "golden age" for social housing in Europe, output levels were at the highest rate they had ever been and the mass model dominated (Malpass, 2008:17). In the Netherlands, the private and public housing sectors were clearly delineated from each other, refer to Diagram A in Fig. 3. The private housing sector was constituted by owner occupied and privately rented homes, financed either through personal wealth or loans and the public sector was operated by non-profit Housing Associations (HA). The HA were established initially in 1901 through the Housing Act.[3] In response to the severe housing crisis after World War II, the government took a more active role in the delivery of housing through the provision of increased support to the Housing Associations in the form of construction loans and subsidies, alongside increased government control and management, such as the supervision of building construction, decisions on the choice of architect and the tendering of contracts (Beekers, 2012; Aalbers et al., 2017:7). During this phase, Rotterdam experienced a relative period of political stability, as local political parties were united in rebuilding the city, which had been flattened in World War 2 (van Ostaaijen in Crul et al., 2019). The population composition in Rotterdam would begin to change in the 1960s as a result of the new bilateral trade agreements enacted to attract migrant workers, leading to Rotterdam being the first city in the Netherlands to implement policies centred on social integration to enable migrants to better participate in greater Dutch society, through facilitating community meetings to enable better political involvement, education in the Dutch language and a focus on housing improvements (Dekker and van Breugel, 2019).

The defining policy objectives of this phase were centred on solving the acute housing shortage directly after World War II, which deemed the high level of government intervention necessary to meet the needs of both middle- and lower-income populations (Boelhouwer & Priemus, 2014:223). After the initial crisis subsided, the housing agenda was later tied into a cohesive policy of urban renewal (Musterd & Ostendorf, 2021). The aim was to target less financially well off residents in impoverished neighbourhoods, through subsidies provided by the Rent and Subsidy policy (1974). This policy supported both private landlords and Housing Associations to improve existing dwellings and tenants could apply for rental subsidies (Vermeijden, 2001:218). During this phase, the HA received government support to build an average of twenty thousand houses every year nationally and their property doubled in the 1950s to four hundred thousand homes with more than a

hundred institutions each managing more than a thousand, sometimes even thousands, of homes (Beekers, 2012:195). The public sector's share of the total housing stock in the Netherlands grew from 12 % in 1945 to 41 % in 1975 and 44 % by the early 1990s (Boelhouwer & Priemus, 2014:223).

The second phase is between 1989 and 2008 and is characterised by a significant decrease in regulation with an emphasis on home ownership. This results in the financial and administrative independence of the HA from the central government and echoes international trends towards the deregulation and privatisation of public housing that began in the 1980s (Forrest, 2021:3). In Diagram B in Fig. 3, we observe the rising prominence of central banks, with the HA directly receiving funding from them and the State serving only as a third party guarantor (Ronald & Dol, 2011:100). The key differences between renting from a HA versus other private landlords, is that most of the rents are subsidised, regulated and only targeted towards lower and middle-income residents. In Rotterdam local politics entered a more divisive phase, especially during the period of 2001–2006, in which the Liveable Rotterdam party rose to power. Their election campaign was centred on Islam, safety and immigration and they were also key in the implementation of the *Act on Extraordinary Measures for Urban Problems*, also known as the *Rotterdam Law*, which was approved by national government (van Gent et al., 2018). The *Rotterdam Law* targets specific neighbourhoods by allowing the municipality to deny citizens under a certain income limit from moving into those neighbourhoods, and has been applied to specific neighbourhoods in Rotterdam, all of which are located in the South of the city. Whilst the *Rotterdam Law* does not specifically target non-native Dutch populations, low-income earners are highly correlated with non-native Dutch residents. It is important to acknowledge this policy in the context of housing, as it restricts certain citizens from living in specific neighbourhoods and thus affects the housing, they are able to access. During this phase, the HA received government support to build an average of twenty thousand houses every year nationally and their property doubled in the 1950s to four hundred thousand homes with more than a hundred institutions each managing more than a thousand, sometimes even thousands, of homes (Beekers, 2012:195). The public sector's share of the total housing stock in the Netherlands grew from 12 % in 1945 to 41 % in 1975 and 44 % by the early 1990s (Boelhouwer & Priemus, 2014:223).

The defining national policy objectives of this era were focused on releasing the heavy burden that public housing imposed on the State through promoting market efficiency of the housing sector through deregulation, decentralisation and self-sufficiency (Boelhouwer & Priemus, 2014; Ronald & Dol, 2011). This shift in institutional goals represents an intention to stimulate increased levels of home ownership. The HA would be able to sell off parts of their existing stock to tenants, alongside other measures such as the Promotion of Home Ownership Act which offered subsidies and low interest loans to first time buyers from low-income families (Ronald & Dol, 2011:96). Statistical evidence shows that after 1992, the share of stock owned by HA declined and reached a share of approximately 31 % in 2012, previously being 44 % in 1990, in line the policy objectives (Boelhouwer & Priemus, 2014:223). However, an unforeseen outcome was the global boom in housing prices is that it allowed the HA to reap sizable financial benefits, allowing them to use their real estate – often worth billions of euros – as collateral for new loans and investments (Aalbers et al., 2017:10). Many associations started developing housing for profit and several of them adopted more complex financial techniques, such as lending money to other associations, borrowing on global capital markets and buying derivatives (Aalbers et al., 2017:10). Furthermore, the transferal of stock from housing associations to tenants did not take place at the rate envisioned, due to an unwillingness by the HA to sell off stock and prices often being too high for the average social housing tenant to afford, with subsidies offered usually for mortgages well below the average market rate (Ronald & Dol, 2011:95).

The third phase is between 2008 and 2018 and represents an increase

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[3] https://www.eerstekamer.nl/plenair/20210706/talsma

in regulation with a continued emphasis on home ownership. The global financial crisis in 2008 directly shapes this phase, revealing the financial mismanagement of many of the HA and led to the bailing out of one of the largest Housing Associations, Vestia, costing the State more than 2 billion Euros (Boelhouwer & Priemus, 2014:229). Two major reforms were introduced, the first being that the Dutch parliament required the HA to explicitly provide housing to lower income target groups only, restricting it from middle income earners (van Gent & Hochstenbach, 2020:161). Secondly, a new tax targeting the rental income of the HA is introduced in 2014 (van Gent & Hochstenbach, 2020:160), to claw back the extra rental income HA could collect by introducing new rent increases for households with a higher income in the social rented sector. Refer to Diagram C in Fig. 3 for a diagrammatic representation of changing relationships.

This phase is imbued with a strong motivation to reduce the power of the housing associations, through limiting their target group and ensuring any extra rental income which could be used to reinvest and increase stock is taxed (Aalbers et al., 2020:548). In recent years there is growing media attention in relation to rising rents and national housing shortages, although a narrative that excess social housing both nationally and locally in Rotterdam continues to persist (van Gent & Hochstenbach, 2020:162; Lauwerier et al., 2017). In the past, HA have been central in anti-cyclical responses to market downturns. However, while they still control approximately 31 % of housing stock, they have been constrained in their abilities to offset falling private supply and demand with increased rental housing development (Ronald & Dol, 2011:108).

### 4.2. Spatial-temporal analysis of neighbourhood trajectories in Rotterdam

In this section the case study of Rotterdam is examined to understand how housing inequalities manifest locally. Due to data availability, the spatial-temporal analysis commences at the beginning of the second phase identified in the analysis of housing policy in 1999, following the privatisation of the Housing Associations in 1995.

The neighbourhood data sets are merged and clustered, leading to the multi-dimensional categorisation of each neighbourhood for every year of data. A four-category solution is found to be optimal, based on the *Silhouette Score*. Each cluster is described below, refer to Figs. 4 and 5

for visual depictions of the cluster solutions.

#### 4.2.1. Cluster 1 - affluent native Dutch

*Cluster 1* is characterised by a high percentage of affluent native Dutch families. Out of all four categories, this category possesses the highest levels of home ownership, mean incomes and real estate of the greatest estimated value. These neighbourhoods possess reasonable access to the tram system and the highest mean betweenness centrality, indicating that they are well connected to roads with high through movement potential and thus able to access routes which can quickly get them into the city.

#### 4.2.2. Cluster 2 - native Dutch

*Cluster 2* is characterised by a high percentage of native Dutch population, with a significant percentage of residents above 65 years of age. These neighbourhoods possess larger populations than the *Affluent Native Dutch* neighbourhoods and lower average incomes, reduced levels of home ownership and weak access to both the tram and metro underground train system.

#### 4.2.3. Cluster 3 - diverse young professional

*Cluster 3* neighbourhoods are the most demographically diverse and possess an almost equal combination of both non-native and native Dutch populations, dominated by the age groups between 25 and 44 years old. More residents reside in rental homes than owned properties, although they do have higher levels of income than the *Native Dutch* neighbourhoods, the income levels are still significantly less than the *Affluent Native Dutch* neighbourhoods. They are spatially integrated with the highest access to tram, metro and non-residential land-use.

#### 4.2.4. Cluster 4 - non-native Dutch

*Cluster 4* neighbourhoods have the highest proportion of non-native Dutch families. Out of all the categories, these neighbourhoods have the lowest mean incomes, mean house values and the majority of their residents reside in rental properties. They have decent access to the tram system and non-residential amenities, but weak access to the metro.

A sequencing analysis is conducted utilising the designated cluster categories for each neighbourhood for every year to construct



**Cluster 1:**
Affluent Native Dutch families
- Predominantly native Dutch families.
- Highest levels of home ownership, income and housing values.
- Reasonable access to the tram system and well connected to roads that have high through movement potential - thus can easily access city.

**Cluster 2:**
Native Dutch
- High percentage native Dutch population, significant percentage elderly.
- Lower mean incomes, reduced home ownership and real estate values.
- Weak access to both the tram and metro.

**Cluster 3:**
Diverse young professionals
- Almost equal combination of non-native and native Dutch populations.
- More rental homes than owned homes, but higher levels of ownerships & income than in Cluster 2 neighbourhoods, still significantly less than Cluster 1.
- Spatially integrated with highest access to tram, metro and non-residential land use.

**Cluster 4:**
Non-native Dutch
- Dominated by non-native Dutch families.
- Lowest average incomes, house values and highest percentage of rentals.
- Spatially integrated with decent access to tram and non-residential amenities, but weak access to the metro.
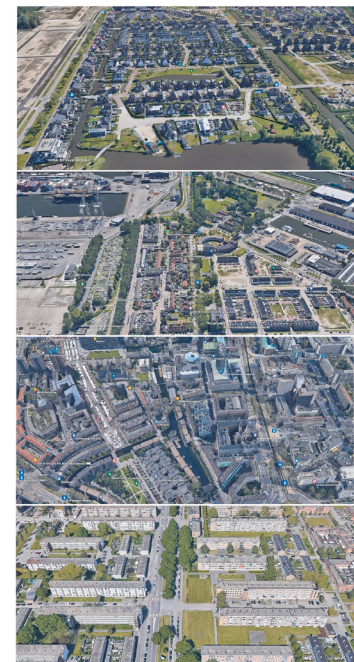
**Fig. 4.** Neighbourhood cluster summaries: summaries of the 4 neighbourhood categories identified through K-means clustering, Affluent native Dutch families, Native Dutch, Diverse young professionals and Non-native Dutch.
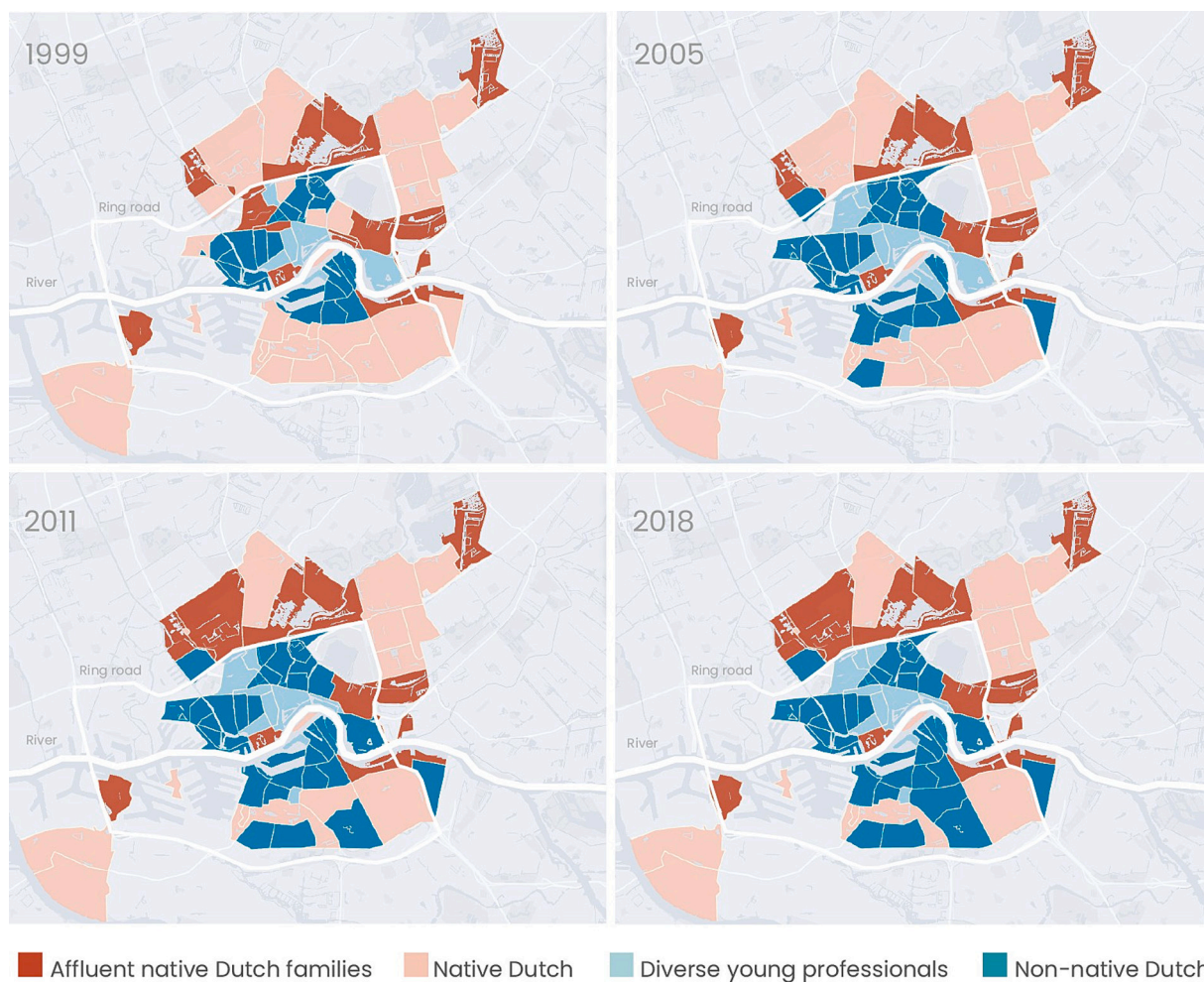
**Fig. 5.** Visualisation of neighbourhood categories: Rotterdam's neighbourhoods classified in their different categories in 1999, 2005, 2011 and 2018.

neighbourhood trajectories over time. This allows insights to be gained into whether a neighbourhood has remained stable within a particular category or transitioned between different categories over time. Subsequently, the sequence trajectories are clustered, as shown in Fig. 6, to identify categories of similar sequences. For example, *Stable native Dutch to Non-native Dutch* contains neighbourhoods which transformed from being originally *Native Dutch* in categorisation to pre- dominantly *Non-native Dutch* over this period of time.

In examining the transition rates between the categories, two significant findings become clear. Firstly, they indicate polarisation between *Affluent Native Dutch* and *Non-native Dutch* neighbourhoods. Once a neighbourhood is classified as predominantly *Non-native Dutch* or predominantly *Affluent Native Dutch*, the neighbourhood is unlikely to transition from that category and usually remains stable within the category. The neighbourhoods which have been subject to the *Rotterdam Law* have remained within the *Non-native Dutch* category, which is relatively the poorest neighbourhood type, therefore indicating that the policy appears to have had little to no effect in uplifting the socio-economic statuses of these neighbourhoods. Secondly, according to the analysis, either *Diverse Young Professional* Neighbourhoods or *Native Dutch* neighbourhoods may have transitioned to *Non-native Dutch* Neighbourhoods, with only *Native Dutch* neighbourhoods transitioning to the *Affluent Native Dutch* category. Thus, the category which has been transitioned to the most is the *Non-native Dutch* categorisation which possess the lowest income levels, indicating that trends of downward neighbourhood social mobility were more likely than upward neighbourhood social mobility.

### 4.3. Relating the spatial-temporal trends to the housing policy phases

To relate the neighbourhood trajectories to the housing policy phases, we focus on how the variables, which are specifically centred on housing, have changed over time within each of the sequence trajectories. The specific variables that are examined are: percentage of homeowners, percentage of social housing units, house prices and ratio of mean income to house prices. Refer to Fig. 7, for a visual representation of the distribution of these variables across the sequence trajectory categories.

Whilst the percentage of homeowners across all the neighbourhood trajectories has increased, the trajectory of neighbourhoods that has increased home ownership rates to the largest extent is the *Native Dutch to Affluent Native Dutch* trajectory category. Furthermore, the *Stable affluent native Dutch* neighbourhoods have consistently significantly higher percentages of home ownership rates than the other trajectories. These results suggest an imbalance, and that home ownership levels have not risen to the extent to which one would expect considering the significant emphasis on home ownership through national policy.

Whilst levels of social housing are not included directly in the analysis, as this variable was unavailable for earlier years, data exists from 2009 to 2018. When linking the categories of trajectories to levels of social housing across this period, we observe that social housing has reduced across the entire city, in line with the goals of National Housing Policy trends. However, the neighbourhoods with higher levels of non-native Dutch and poorer residents have consistently the highest levels of social housing, suggesting that the location of social housing probably

**Fig. 6.** Neighbourhood Sequence Trajectories: The nine categories of sequence trajectories highlighting changes in socio-spatial aspects of neighbourhoods. The 70 neighbourhoods of Rotterdam have been classified among 4 categories of affluent native Dutch families, native Dutch, diverse young professionals and non-native Dutch. The sequences of trajectories of these neighbourhoods are then clustered according to trajectories of change, resulting in 9 variations.
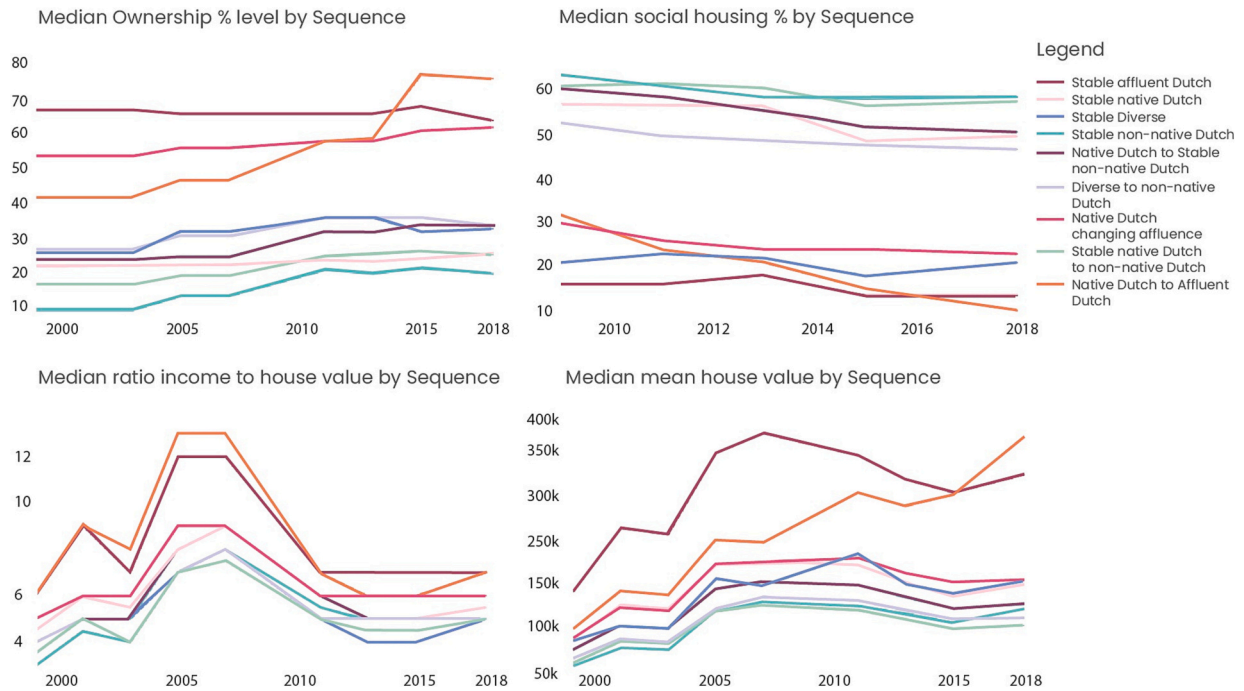


**Fig. 7.** Variable comparisons: Visualisation of changing distributions of variables, namely Median ownership %, Median social housing %, Median ratio income to house value and Median house value, across the neighbourhood sequence trajectories over time.

has a role in determining where poorer and non-native Dutch families reside in Rotterdam. Whilst it is difficult to know for certain, due to constraints on the data, it suggests that inter-generational, low income families rely on social housing, probably reinforced by the growing divide between the regulated prices of social housing and renting in the free market (van Gent & Hochstenbach, 2020).

In examining the real value of homes, we observe that the value of housing peaked across the trajectories between 2006 and 2010 and subsequently dropped, revealing the local implications of the global financial crisis. Despite the 2008 financial crisis, the real value of housing has effectively doubled across all neighbourhood trajectories from 1999 to 2018. This is indicative of vast capital gains for homeowners - especially in wealthier neighbourhoods, which have had relatively the largest increases. This also confirms the incredible gains in wealth of the Housing Associations (Aalbers et al., 2017). The neighbourhood trajectory which has relatively the greatest capital gains, is the *Native Dutch to Affluent Native Dutch* category. Aligning with the work of others (Coulter et al., 2016; Hochstenbach, 2018), these results firstly emphasise the increased real cost for new homeowners to enter the market and secondly the incredible gains in wealth that homeowners have experienced over time. Motivations for deregulating the housing market in the Netherlands were embedded in increasing access to home ownership in the 1990s, but the real price of housing has soared and inadvertently it has become more expensive to enter the housing market than before in Rotterdam.

When examining the ratio of income-to-house prices, (house price divided by income), the effect of the global financial crisis can also be observed, with these ratios peaking around 2008 and dropping after across the trajectories. Despite these vast changes in global structural processes, the largest ratios are consistently in the wealthier neighbourhoods. This suggests that the wealthy not only have the highest incomes but have been able to invest much more and thus have been in a position to benefit the most or have benefited the most from rising housing prices. The 1989 document government memorandum, 'Housing in the 1990s', (Klandermans, 1989), emphasises the rediscovery of the market and these results suggest that the wealthy have benefited the most from the "commodification" (Ronald & Dol, 2011) or "hyper-commodification" (Madden & Marcuse, 2016) of real estate both in increasing home ownership levels and capital gains.

## 5. Discussion

In this paper we develop as approach to relate institutional changes in housing policy with the spatial- temporal analysis of neighbourhood change, utilising Rotterdam in the Netherlands as a case study. This discussion is centred on how the results may enhance our understanding of the structural nature of housing inequalities.

### 5.1. Housing inequalities are multi-scalar

All housing possesses a local context, but processes of globalisation and shifts in macro-economic policy in the 1980s, have led to policies that emphasise the free market, privatisation and deregulation which in turn makes it difficult to separate real estate from global financial markets (Forrest, 2021; Modai-Snir & van Ham, 2020). The analysis of historical housing policy phases illustrates significant institutional changes, from the housing market largely driven by a high-level of State intervention to the primary responsibility shifting to the private sector. Policies such as the Promotion of Home Ownership Act implemented in 2000 (see Section 4.1) specifically target low-income families and signify the State's intention to stimulate home ownership, even for those of the least means. National statistics reflect increases in home ownership levels and decreases in the number of social housing units, conveying that these policies have had an impact. However, the spatial and temporal analysis of local neighbourhoods in Rotterdam reveals that persistent housing inequalities exist in relation to levels of home

ownership and capital gains, especially when comparing *Non-native Dutch* and *Affluent native Dutch neighbourhoods* from 1999 to 2018. In this way, the analysis emphasises that uptakes in home ownership have not been uniform or equally distributed.

### 5.2. Spatial polarisation and concentrations of disadvantage

The analysis of housing policy shows that housing marketisation has been central to housing policy in the Netherlands since the 1990s. The spatial-temporal analysis reveals that the real house prices in Rotterdam have more than doubled across all neighbourhoods over the twenty-year period and the greatest capital gains are in the wealthiest areas, which are predominantly *Affluent Native Dutch* or have become predominantly *Affluent Native Dutch* over time. Other studies have shown that there is a tendency for market driven housing economies to result in increased spatial polarisation (van Gent & Hochstenbach, 2020; van Gent & Musterd, 2016) and this study provides further evidence of this trend.

Large increases in housing prices, make it challenging for first time buyers, whether of a younger generation or recent immigrants, to enter the market. The persistence of low ownership levels in *Non- native Dutch* neighbourhoods speaks to the work of Hochstenbach et al. (2020) who emphasises that inter-generational wealth plays a role in owning a home in the Netherlands. Over time, the number of predominantly *Non-native Dutch* neighbourhoods has increased in the South of Rotterdam below the Nieuwe Maas River, contrasted against a persistent agglomeration of *Affluent native Dutch* neighbourhoods in the far North above the main ring road, refer to Fig. 5. This suggests that the river and ring road serve as spatial boundaries, which are being reinforced by vastly different housing prices and tenure options, highlighting the concentration of housing wealth and inequalities in space. Furthermore, the neighbourhoods which are subject to the *Rotterdam Law* have persistently remained in the *Non-native Dutch* category, which are relatively the most deprived neighbourhoods in Rotterdam, with many of the adjacent neighbourhoods also transitioning to *Non-native Dutch* dominated over time, bringing into question the efficacy of the continued implementation of this regulation. The *Diverse young professional* category is the most socially inclusive category based on demographic mixing, possessing almost equal numbers of native Dutch and non-native Dutch populations. In examining other characteristics associated with this category, these neighbourhoods possess the highest access to tram, metro and non-residential amenities. This suggests that the availability of a wide range of transport options and non-residential amenities has a relationship with demographically socially inclusive neighbourhoods in Rotterdam and may be able to counteract some of the negative effects of spatial polarisation through market differentiation.

### 5.3. Spatial-temporal analysis and policy making

The analysis of historical housing policy provides insights into changing institutional relationships and Fig. 3 illustrates how international banking has become increasingly integral to the financing of housing over time. It also emphasises how regulation has increased emphasis on the private housing sector, through restricting social housing to lower income tenants and deregulating the market to allow for international investment. This induces more demand as middle-income tenants shift towards private rentals, squeezing the private rental sector (Ronald & Kadi, 2018; Wind et al., 2020). It is important to reflect on more recent policy changes that were not included in the historical analysis. The landlord levy which was placed on HA in 2014 has subsequently been abolished, releasing them of 1,7 Billion Euros which they can use to reinvest in more housing stock. Commitments have also been made to ensure that across municipalities there is 30 % social housing stock available. This indicates a recognition of the importance of availability of housing for low-income tenants, although middle income tenants still rely fully on the free market and will continue to experience rising rents, which remain largely unregulated.

In contrast to the analysis of historical housing policy phases, the spatial-temporal analysis provides empirical insights into neighbourhood social mobility in Rotterdam and distributions of home ownership and capital gains. The analysis suggests that if a neighbourhood had transitioned to a different category, it would have most likely transitioned to a neighbourhood category dominated by low income and non-native Dutch residents. Comparatively these are the poorest neighbourhoods with the highest levels of rental units and possess homes of the least value, which highlights the persistent lack of social mobility for non-native Dutch population groups.

## 6. Conclusion

Empirical research through spatial-temporal analysis and the analysis of policy are often seen as different worlds. For the purpose of studying and addressing complex problems, such as housing inequalities, there is value in increasing engagement between the two. In line with thinking proposed by Kandt and Batty (2021:7) urban analytics rarely provides direct answers to urban policy problems; however it can be used as exploratory material for the development of new hypotheses and could be a powerful resource in developing evidence which can support the policy making process. To understand housing inequalities at the urban scale requires engaging with the relationship between policy and spatial-temporal conditions. The analysis of housing policy phases offers insights into the dynamics of high-level institutional relationships and changing institutional goals, whereas the spatial-temporal analysis allows opportunity to critically reflect on the *who* and *where* may have benefited the most in accessing home ownership and increasing capital gains. In summary, this analysis has led to these new findings, which speculate on the relative contribution of each of the factors on housing inequalities from both the macro and micro:

1. The role of path dependency

The spatial-temporal analysis reveals that despite large, structural shifts in policy, such as those that came about from the Global Financial crisis of 2008, the relative hierarchies of neighbourhood development patterns tended to persist, refer to Fig. 6. This emphasises the role of path dependency, which implies that a sequence of events or decisions matter, and once a particular path is chosen, it becomes increasingly difficult to deviate from it. These results suggest that neighbourhood path dependency plays an important role in the perpetuation of housing inequalities.

2. Demographic composition of a neighbourhood

In Rotterdam there are clear differences between neighbourhoods characterised by non-native Dutch and native Dutch residents, with much higher levels of housing wealth associated with *Affluent native Dutch* neighbourhoods. This reflects historical patterns of wealth, as it is well known that many of the non-native Dutch population arrived in Rotterdam as low wage workers as a result of the bi-lateral trade agreements with foreign countries in the 1960s (Dekker and van Breugal, 2019). However, polarisation between non-native Dutch and native Dutch neighbourhoods has increased over time and this is correlated with both widening housing inequalities and increased emphasis on the marketisation of housing.

3. Weaknesses of a national approach to housing policies

Housing policies in the Netherlands are currently enacted predominantly at a national level, and in their current form, do not take path-dependent effects or the varying socio-spatial characteristics of neighbourhoods into account. Understanding path-dependent effects and local socio-spatial conditions should be key for policymakers, planners, and community stakeholders when making decisions about housing, as they need to consider the constraints and opportunities shaped by the past to create more sustainable and equitable neighbourhoods in the future.

This empirical study is limited by data constraints, predominantly due to the data's aggregation at the neighbourhood level. Access to disaggregated data would enable the tracking of the movement of individuals over time between different kinds of neighbourhoods. This could enable an increased quantification of the specific effects of different kinds of neighbourhoods on intergenerational housing economic prospects and increased insights into social mobility for individuals. Furthermore, whilst the scope of this analysis is limited to Rotterdam, expanding the analysis to include other cities in the Netherlands would shed more light on how specific housing inequalities are more impacted by certain policies or particular socio-spatial neighbourhood conditions. Future research might focus on agent-based modelling, to simulate the interactions between individuals, their environment, and policies. An advantage of this approach is that the global behaviour of the system is not explicitly programmed but arises from the interactions of individual agents, making it suitable for modelling complex and dynamic systems. Simulating these interactions could lead to an increased understanding of strength and nature of relationships between different factors which contribute to housing inequalities.

Housing inequalities are complex, and this study has shown that they are reproduced by many interconnected, multi-scalar factors. The results have important implications for policy formation, suggesting that national, blanket policies in their current form, do not consider the needs of different neighbourhoods, which are a result of their varying socio-spatial characteristics. The continuation of the development of methods to relate the analysis of past, current, and future policy with spatial-temporal analysis has the potential to enhance our understanding of both the "bottom-up" effects and "top-down" structures which reproduce complex urban problems, such as housing inequalities.

**CRediT authorship contribution statement**

**Ruth Nelson:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Visualization, Writing – original draft, Writing – review & editing. **Martijn Warnier:** Supervision, Writing – review & editing, Conceptualization. **Trivik Verma:** Supervision, Writing – review & editing, Conceptualization.

**Data availability**

Data will be made available on request.

**Appendix A. Supplementary data**

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cities.2023.104727.

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