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ADDING VALUE TO THE URBAN REALM:
A STUDY ON PEDESTRIANIZATION AND PROPERTY PRICES

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Abstract. Understanding the value of public space is central to local authorities and stakeholders as cities develop their physical environment. The purpose of this thesis is to elicit preferences for a car-free urban environment. We employ a difference-in-differences research design with hedonic price modelling to estimate the effect of targeted street pedestrianization on apartment prices in Stockholm's inner town. Treating the implementation of the municipal program Levande Stockholm between 2015 and 2019 as a quasi-experiment, we exploit spatial discontinuities in housing prices caused by the intervention. We seek to identify a causal relationship and deal with methodological challenges common to revealed preference studies on environmental and non-market goods. The results indicate no effect from pedestrianization on apartment prices in the studied setting, in spite of its increasing popularity as a neighborhood revitalization strategy. In contrast to previous studies on street qualities and housing markets, the link between the physical environment and property prices is found to be weak in the studied setting. We suggest future research to investigate how pedestrianization interacts with the local context, and address associated values not incorporated in housing markets.

Keywords: difference-in-differences, hedonic price model, public space, housing market, Stockholm

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1. Introduction

Providing a high-quality urban environment is central to cities as they strive towards attractiveness and improved livability. Recently, many urban authorities are introducing car restrictions to enhance qualities of the urban realm as they may bring social (Gehl, 2011), environmental (Nieuwenhuijsen, 2016) and economic benefits (Hass-Klau, 1993) to neighborhoods. The purpose of this thesis is to gain a better understanding of whether citizens are willing to pay for a car-free urban environment. It adds to the current literature by investigating the value of a change in urban land use that has, to our knowledge, not previously been studied. Filling this research gap is of importance to urban authorities as they seek to develop land use policy in line with the interest of the local population. It is also of interest to local stakeholders participating in urban planning processes.

By exploiting spatial discontinuities in housing prices, we employ a quasi-experimental research design and hedonic price modelling to estimate the effect of targeted pedestrianization on housing prices in Stockholm between 2015 and 2019. Stockholm is the setting of this study as its pedestrianization scheme *Levande Stockholm* is easy to implement and has served as a source of inspiration for local policy-makers beyond a Swedish context (Landeshaupstadt München, 2018). This makes it an interesting case for policy evaluation. Despite the suggested benefits, our results indicate no effect on property prices and, consequently, that citizens revealed no marginal willingness to pay for the car-free environments in the studied setting.

This paper begins with a background on pedestrianization as a form of urban revitalization strategy in section 2. In section 3 we describe methods used in valuation of the urban realm, and previous findings with regards to urban environmental qualities and property prices. In section 4 and 5, the research question and hypotheses are presented. The setting and design of the studied policy are presented in section 6, followed by our method and a description of the data in section 7 and 8 respectively. Section 9 provides the results and robustness checks, which are thereafter discussed in section 10. Lastly, the conclusion in section 11 completes this thesis.

2. Background

2.1. Attractive cities and neighborhood revitalization

Creating attractive cities is at the core of today's urban policy. A central idea within urban planning is that the public space can be designed as a human-friendly place that provides economic, environmental and social benefits to residents, visitors and businesses (see e.g. Gehl, 2011; Wheeler and Beatley, 2004; Whyte, 2001). In the 1960's, influential writers such as Gehl, Jacobs and Whyte started to advocate design of the urban space based on human behavior and psychological insights. Their stance marked a clear shift from mid-twentieth century's modernist, car-centered and often abstract architectural principles (Wheeler and Beatley, 2004). The increased focus on social design in urban planning is reflected in a number of recent urban revitalization projects, such as New York High Line (NYC, 2012) and Oslo's move towards a car-free city center (Oslo kommune, 2019).

Neighborhood revitalization projects may be influenced by other interests than serving the local population. Harvey (1989) suggested that urban governance in the late twentieth century was characterized by the rise of entrepreneurial urban strategies intended to attract economic development and employment growth. Such strategies are often linked to inter-urban competition for resources rather than provision of services and facilities to the local population. He suggested that the physical and social imagery of cities has also been suited for the competitive purpose. Similarly, Peck (2005) described much of urban policy in the early twentieth century as constrained by a hypercompetitive environment where attracting the 'creative class' has become an imperative. These contributions raise the questions *for whom* the physical environment is designed, and *how* the competition on becoming the most attractive city affects the local neighborhoods.

2.2. Streetscape renewal

In many cities, the streetscape, i.e. the design and use of streets, has become the main target for new revitalization projects. Known as the project *Grünes Netz,* Hamburg is introducing an extensive network of pedestrian streets, bike lanes, and parks, as an effort to improve the recreational features of the city's physical environment (Hamburg, n.d.). In Oslo, 1.3 square kilometer of the city was closed for motorized traffic between 2015 and 2019 (Oslo kommune, 2019). Madrid has banned motorized traffic from an increasing number of main streets since 2004. In November 2018, all non-residential motor traffic was banned from almost 5 square kilometers of the city's center (Ayuntamiento de Madrid, n.d.).

The urban planning literature suggests that pedestrianization provides social, economic, and environmental benefits to neighborhoods. According to Gehl (2011), there is a close relationship between street quality and the outdoor activities performed by visitors and residents. Pedestrian streets increase time spent outdoors and encourage social interaction and children's play. As new visitors are attracted, retail sales and business activity may also increase (Hass-Klau, 1993). Further, pedestrianization may abate local air and noise pollution (Nieuwenhuijsen, 2016). Hence, pedestrianization is described as an urban revitalization strategy with various implications for the quality of life of residents and visitors.

3. Previous literature

3.1. Valuation of urban externalities

The urban realm may be described as a public good. The market is therefore unlikely to manage the space optimally in the absence of public intervention. Without understanding the value of public space, local governments may also fail in this quest. Eliciting preferences for urban environmental features has therefore become an extensive field of economic research (Xiao, 2017).

The value of non-market goods, such as features of the urban realm, is commonly analyzed using stated preference or revealed preference methods. Stated preference methods use contingent valuation, conjoint analysis or choice experiments to measure externalities from certain land-uses or environmental features (Baranzini, Ramirez, Schaerer, and Thalmann, 2008). The hedonic price model, as developed by Rosen (1974), is one of the most common revealed preference methods for valuation of urban externalities. The hedonic model uses housing market information to elicit preferences for locational, environmental and neighborhood characteristics. In an equilibrium market, the implicit price of each characteristic is reflected in property prices and corresponds to people's marginal willingness to pay (MWTP) for the feature of interest (Xiao, 2017).

Previous research has shown that revealed preference valuation of urban externalities through housing market information is a complex task. First and foremost, an uncountable number of locational, environmental and neighborhood characteristics may affect housing prices. There is no consensus in the literature on which characteristics to include in the hedonic price model (Ceccato and Wilhelmsson, 2011). Since environmental characteristics are difficult to select and quantify, studies employing hedonic modelling tend to use similar sets of physical property attributes but a wider and diverse range of external factors (Orford, 2002). Omitted and misspecified variables are therefore a ubiquitous concern.

To mitigate the challenges in modelling environmental features, hedonic price models can be complemented with other methods. Some scholars have combined hedonic modelling with repeated-sales methods to elicit preferences from sudden changes in the urban environment (Baranzini et al., 2008; Wilhelmsson, 2000). Others have employed a difference-in-differences approach to compare the price development between treated and non-treated properties in the housing market. Examples include installation of wind turbines (Dröes and Koster, 2016) and traffic calming devices (Polloni, 2019). The approach has also been used for evaluation of targeted neighborhood renewal projects (Aarland, Osland, and Gjestland, 2017). Although such quasi-experimental research designs may be less sensitive to misspecification of time-invariant factors, the main challenge is to find comparable treatment and control properties.

Another challenge is that valuation of the urban realm is highly contextual. Firstly, features of the urban environment can interact with other neighborhood characteristics. In a study on public parks in Stockholm, Iqbal and Ceccato (2015) found that parks located in low-crime areas can be regarded as urban amenities, while parks located in neighborhoods with high crime rates can instead subtract value from surrounding properties. Similarly, railway stations generally have a positive impact on property prices but may have the opposite effect if they work as crime magnets (Bowes and Ihlanfeldt, 2001). Secondly, since properties are immobile and supply inelastic in the short term, the MWTP is also likely to fluctuate over space due to differences in consumer tastes (Xiao, 2017). In other words, the inferred value of the feature of interest may depend both on how it is used, and where it is located.

3.2. Streetscape and property prices

Previous studies indicate that street design may be incorporated in housing markets. For instance, a report by the British Commission for Architecture and Built Environment (CABE) investigated a set of ten neighborhoods in London using a score index ranging from -3 to +3 as a measure of street quality. The findings suggested that a one-score improvement was associated with an apartment price premium of approximately 5% (CABE, 2007). Similarly, Tu and Eppli (1999; 2001) compared housing prices in areas characterized by new urbanism*,* i.e. pedestrian-friendly neighborhoods with more public space, to conventional neighborhoods in the US. By using hedonic price modelling, it was found that consumers are willing to pay a premium of between 4% and 15% for living in areas with new urbanism features. A later study by Song and Knaap (2003) used more disaggregate hedonic price modelling and found the walkability component of new urbanism to be particularly associated with higher housing prices.

Although no studies, to our knowledge, have elicited preferences for pedestrian streets, many have investigated their associated externalities in relation to housing prices. As to air quality and noise reduction, Wilhelmsson (2000) found in a study on single-family homes in Stockholm that properties exposed to intense traffic noise pollution sell at a considerable discount in the housing market, corresponding to 30% compared to non-polluted properties. Further, greenery and plantations, an often-central element of pedestrianized areas, may affect property values positively. Several studies indicate that the value of urban community parks is incorporated in housing prices up to approximately 200 meters distance (Crompton, 2005). Proximity to green open space may have a particularly strong impact on property values in densely built-up environments (Dehring and Dunse, 2006). Also, small-scale investments in greenery, in terms of street trees, may affect housing prices positively (Donovan and Butry, 2010).

The character of a street's economic activity may also be of importance to housing prices. An extensive study of value drivers on Stockholm's housing market found developed urban business activity to be one of the neighborhood features valued most by homebuyers (Spacescape, 2011). Li and Brown's (1980) early work on micro-neighborhood externalities suggested a two-edged relationship between proximity to businesses and housing prices. While proximity to developed business activity affects property values positively through accessibility, it may also affect housing prices negatively through locally increased congestion, pollution, noise and trash (Li and Brown, 1980). Thus, if neighborhood revitalization projects cause increased economic activity and larger human flows, they may also result in new disamenities.

4. Contribution and research focus

While previous studies in urban planning have mainly focused on the environmental and social benefits from pedestrianization, no previous research has, to our knowledge, tried to elicit preferences for it from housing market information. The purpose of this thesis is to investigate whether providing a car-free urban environment is valued in local neighborhoods. Through investigating homebuyers' MWTP for changes in neighborhood externalities, this paper intends to answer the following research question:

Does pedestrianization of urban streets affect property prices?

Several previous studies on street qualities and housing prices have employed non-experimental hedonic modeling methods (e.g. CABE, 2007; Song and Knaap, 2003; Tu and Eppli, 1999; 2001). These have suggested that human-oriented street design is highly valued by homebuyers. However, studies valuing urban externalities are sensitive to how they incorporate the environmental features of interest (Orford, 2002). By employing quasi-experimental research design and in a new setting, we hope to contribute to the current literature and provide further insights into what extent urban environmental qualities affect property prices.

5. Hypothesis development

With regards to the current literature, we present the following hypotheses:

> H1: Proximity to pedestrian streets is incorporated in housing prices.
> H2: Proximity to pedestrian streets affects housing prices differently in different parts of a city
> H3: Proximity to pedestrian streets affects housing prices differently depending on project-specific characteristics and/or use by the public.

If hypotheses 1 to 3 are confirmed, it indicates that targeted pedestrianization encompasses a transformation of the urban realm that is of importance to residents. If hypothesis 2 is confirmed, it suggests that the value of a car-free environment depends on local context due to local preferences and inelastic supply. If hypothesis 3 is confirmed, it indicates that the MWTP depend on specific design and use by the public. For instance, the nature of the business located at the streets and the changes in human flows may differ across pedestrianized areas.

If none of the hypotheses are confirmed, pedestrianization is likely to be of lesser importance to homebuyers and their perceived quality of life. Another explanation is that the new amenities and disamenities stemming from pedestrianization cancel each other out.

In this paper, we will test these hypotheses by using Stockholm as a case study. Before presenting the method used for this purpose, we will provide a description of the setting and studied policy's design in detail.

6. Setting of the study

May to September each year, several streets in Stockholm's inner town are closed off for motorized traffic and turned into decorated car-free zones. The stated purpose of the municipal program, known as *Levande Stockholm*, is to revitalize the public space, create attractive outdoor environments and an attractive urban life. The program started with two locations in 2015 and has been expanded stepwise to include nine areas and

Figure 6.1: Map of Stockholm's inner town

Note: The administrative city-district borders for Kungsholmen (KH), Norrmalm-Vasastan (NV), Östermalm (OM) and Södermalm (SM) are in black. The pedestrianized streets in 2018 are labeled accordingly and presented with buffers of 200 meters. Source: Lantmäteriet (2019)

more than two kilometers of road in 2018 (Stockholms Stad, 2019). The full extension of the program as of 2018 is illustrated in Figure 6.1.

Levande Stockholm has provided an opportunity for local business owners to expand their activities and install parklets for outdoor customer seating. Further, furniture and decoration has been installed to make the street aesthetically pleasing and attractive for social interaction (Stockholms Stad, 2018b).

Stockholm's traffic authority, Trafikkontoret, have selected candidate streets by using a set of criteria. The closure of motorized traffic should not delay public transport and emergency response vehicles, nor affect any arterial roads for cyclists and car traffic. The streets should have business activity on both sides that is not dependent on heavy delivery traffic. After potential candidates are identified by Trafikkontoret, the close-off decisions are made in consultation with local businesses and property owners (Stockholms Stad, 2016c). For each new street included in the program, the decision has been made in between one and five months in advance of pedestrianization (dates are provided in Appendix A).

According to surveys conducted by the municipality in 2018, 75% of the city's inhabitants were aware of the seasonal car-free zones. Further, a majority of the respondents agreed that the program had recreational features, provided space for social interaction, and contributed to the local neighborhood's attractiveness (Stockholms Stad, 2018a). Several real estate agencies have marketed proximity to the car-free zones in apartment listings. Recent examples include: "The street is nowadays a summertime pedestrian street with a lively street life" (Södermäklarna, 2019, our translation) and "the neighborhood is extra idyllic as Rörstrandsgatan is a pedestrian street from May to September" (Diplomat Fastighetsmäkleri, 2019, our translation).

The performance and public perception of Levande Stockholm has varied depending on local context. Some citizens have raised concerns regarding traffic safety, and media has reported on related noise and drunkenness (Kämpe, 2019). Half of the complaints received by the municipality and most of the negative media attention is related to one single car-free zone, Skånegatan in the city district of Södermalm (personal communication, H. Blom, April 3, 2019).

7. Method

To see whether property prices respond to targeted pedestrianization, we will treat the implementation of Levande Stockholm as a quasi-experiment in an urban setting. In section 7.1 and 7.2, the hedonic price model and the difference-in-differences research design are presented in detail. We proceed to discuss methodological issues in section 7.3.

7.1. Hedonic price model

According to Xiao (2017), determinants of property prices can be divided into structural, neighborhood, locational and environmental characteristics. Structural attributes relate to the physical characteristics of properties, such as living area, floor and number of rooms. Neighborhood characteristics relate to demographic and socioeconomic conditions, and locational characteristics to proximity to public facilities such as business activity or public transportation. Environmental characteristics relate to the physical environment surrounding properties, such as air quality or green areas. The relationship between a property's price and characteristics can be expressed as follows,

$$\log(P_i) = \beta X_i + \varepsilon_i \tag{1}$$

Where $\log(P_i)$ is the logarithmic market value of a property, X is a vector of the above mentioned structural, locational, environmental and neighborhood characteristics, and β a vector of associated coefficients. According to Kuminoff et al. (2010) the choice of functional form of the hedonic model is an empirical, rather than theoretical, issue. In this thesis, we follow the literature and transform the continuous variables to logarithmic form.

7.2. Generalized difference-in-differences research design

In this thesis we employ a difference-in-differences research design to exploit spatial discontinuities in housing prices caused by the introduction of Levande Stockholm. This approach is commonly used for policy evaluation and has earlier been used to elicit preferences from changes in a property's environment (Dröes and Koster, 2016) or targeted neighborhood renewal projects (Aarland et al., 2017). As Levande Stockholm has been communicated and implemented stepwise in nine areas, we employ a generalized difference-in-differences approach to assess the average effect on property prices. In contrast to the standard difference-in-differences approach, the generalized form allows for multiple groups and multiple treatment periods (Cook, 2015) which is suitable in this setting.

We define the nine targeted areas as individual treatment groups (KH1, KH2, … SM2 in Figure 6.1), and the rest of Stockholm's inner town as the control group. The key identifying assumption is that the latter represents the counterfactual. In other words, we assume that housing prices in the treatment groups would have evolved equally to housing prices in the rest of the inner town, had the car-free zones not been introduced. By comparing relative changes in price levels in control and treatment groups over the studied period, unobservable factors with a common effect on housing prices are taken into account. If the choice of counterfactual group is valid, the average policy effect can be identified (Cook, 2015).

The main challenge when applying the difference-in-differences approach is to find a suitable control group. Homogenous control and treatment groups are desirable to reduce the need for control variables. One alternative is to match treatment groups to individual control groups defined by proximity. However, as some pedestrianized streets are located near each other, control groups would be overlapping. A second alternative is to compare the price development in targeted areas to the general price development in Stockholm's inner town. An advantage with this alternative is that results will be less sensitive to our identification of appropriate control groups. Further, Stockholm's inner town is a small area and homogenous in terms of street layout and socioeconomic composition (Stockholms Stad, 2017a; Stockholms Stad, 2017b). All non-targeted areas in the inner town are therefore used as the counterfactual.

Since we study Levande Stockholm as a neighborhood revitalization strategy, we need to take proximity to the pedestrianized streets into consideration. Applying buffers to incorporate proximity to geographical features of interest is common in spatial econometrics (e.g. Bauer, Braun, and Kvasnicka, 2017; Dröes and Koster, 2016; Iqbal and Ceccato, 2015). Properties are assigned to a treatment group if they are located within a buffer of b meters from a targeted street. Properties located in Stockholm's inner town but beyond b meters from any of the targeted streets form the control group. We initially set b = 200 meters, and test for alternative buffer distances as part of the robustness checks to investigate less or more local effects.

The starting point for the difference-in-differences model specification follows,

$$\log(P_i) = \alpha Treatment_{ijt} + \gamma_j + \theta_t + \varepsilon_i \qquad (2)$$

where $Treatment_{ijt}$ is an indicator variable taking on value 1 if observation i located in treatment group j was exposed to active treatment in year t and 0 otherwise, α is the average treatment effect, γ_j are nine treatment-group specific intercepts for j = KH1, KH2, … SM2, and θ_t are year fixed effects. Active treatment means that streets in area j to which observation i pertains had been included in Levande Stockholm in the year of transaction. As all streets were pedestrianized for the first time in early summer, we use the periodicity May to April for the year fixed effects.

To test hypothesis 1, that proximity to pedestrian streets is incorporated in property prices, we follow previous studies and include the hedonic price model in our difference-in-differences specification. The new model specification follows,

$$\log(P_i) = \alpha Treatment_{ijt} + \beta X_i + \gamma_j + \theta_t + \mu_t + \eta_g + \varepsilon_i \quad (3)$$

where, X_i is a vector of property characteristics, and β the associated coefficients. To take into account unobservable locational characteristics and seasonality in the housing market, spatial fixed effects and month-of-year fixed effects are included, labeled η_g and μ_t. We include two sets of spatial fixed effects: city districts and five-digit zip codes, that will be used separately. The coefficient of interest is still α. If significantly different from zero, it indicates that the average price gap between treatment and control areas is affected by pedestrianization.

To test hypothesis 2, that the treatment effect depends on local context, we proceed by applying model specification 3 to each of the four city districts separately. The district-specific estimates are valid under the assumption that the four city-districts operate as submarkets with distinct buyer preferences. We thus compare the price development of the treated areas with only their surrounding city district as control group. The coefficient of interest is still α.

To test hypothesis 3, that the effect on housing prices depends on project design and use by the public, two interaction effects are added. Firstly, $Treatment_{ijt}$ is interacted with a variable taking on value 1 if the size of the car-free zone j is above median, and 0 otherwise. As the size of a car-free zone can serve as a proxy for services and traffic calming provided, we expected surrounding properties to be affected differently. Hypothetically, larger pedestrian streets will have stronger effect on property prices. Secondly, $Treatment_{ijt}$ is interacted with a variable taking on value 1 if the car-free zone j is associated with above-median number of complaints to public authorities, and 0 otherwise. Complaints encompass citizens' concerns about how the car-free zones are used by the public in terms of noise and disturbance (Stockholms Stad, 2018b).

Hypothetically, high levels of noise and disturbance due to pedestrianization are associated with lower apartment prices.

7.3. Methodological considerations

7.3.1. Housing market conditions

The common criticism of the hedonic price model suggests several ways it can fail. Firstly, to estimate the MWTP, the model requires that housing markets are in equilibrium, no external shocks, and zero transaction costs in the housing market (Xiao, 2017). Incomplete information could exist if sellers have better knowledge of negative externalities stemming from local streets, which they choose not to disclose. Estimates may then be biased upwards (Wilhelmsson, 2000). Further, treating cities as single markets implies making strong assumptions. If property characteristics are priced differently across city districts, due to taste differences or inelasticity in demand and supply, it is more accurate to treat cities as groups of submarkets (Xiao, 2017). This is partially dealt with as we test hypothesis 2 and apply model specification 3 to each city district separately.

7.3.2. Random policy assignment

The quasi-experimental research design hinges on the assumption that the car-free zones are imposed exogenously. Since the targeted streets must fulfill certain requirements, the policy assignment is not fully random. However, many areas in Stockholm's inner town serve as potential candidates as the requirements are general. Further, the requirements are based on mainly time-invariant factors such as street layout. According to Meyer (1995), selection based on time-invariant characteristics with importance to the outcome can be differenced away to identify the policy effect in quasi-experimental research designs. Despite this, it cannot be ruled out that existing street layout is important to the perceived benefits from pedestrianization. Unrepresentative responsiveness to treatment may be a threat to external validity (Meyer, 1995). Hence, the average treatment effect is most likely representative for other streets in Stockholm's inner town with similar characteristics, rather than any street.

7.3.3. Anticipation effects

In addition, the temporal dimension of the difference-in-differences research design requires a clear point in time at which the treatment starts. If homebuyers are rational and have access to full information, the car-free zones would be fully incorporated in property prices at the announcement date of the new policy. However, if information is incomplete between announcement and implementation, defining transactions from this period as treated will underestimate the policy effect. This can easily be dealt with by excluding observations in the treatment groups sold between decision and implementation.

Another issue is that two areas, NV1 and SM2, were locally expanded in 2018. For instance, SM2 increased in length from three to five blocks in 2018 (Stockholms Stad, 2017c). Compared to when Trafikkontoret targets and communicates new areas for pedestrianization, local expansions are more likely to be anticipated by the public. As any studied policy should ideally be implemented with as little anticipation as possible, these locally expanded areas are not suitable to include in a quasi-experimental research design. We therefore choose to use only the originally targeted areas as treatment groups, and fully exclude areas that were in 2018 introduced as local expansions of Levande Stockholm from the analysis.

7.3.4. Contamination

The difference-in-differences approach requires a clear distinction between treatment and control observations, which is challenging in spatial econometrics. The effect of any urban amenity or disamenity on housing prices over space is highly contextual and dependent on the city structure (Orford, 2002). As other studies within urban planning, we therefore lack a clear-cut spatial limit to separate the treatment group from the control group. Any choice of b meters treatment buffer implies making strong assumptions on the data. If the effect is not confined to properties within b meters, there will be a contamination between control and treatment groups. Previous research gives some guidance that green open space, such as community parks, are incorporated in housing prices up to approximately 200 meters (Crompton, 2005), and others have used 150 meters as a buffer to assess the value of urban parks (Iqbal and Ceccato, 2015). For this reason, 200 meters is chosen as the starting point for the analysis. To address the risk of contamination and see how the potential effect levels off with distance, we include alternative cut-offs at 100 and 300 meters in the robustness checks.

7.3.5. Local shocks

Local shocks can violate the assumption of conditional parallel trends. For instance, opening of new businesses, public transportation connections or other public investments can lead to an uneven price development across neighborhoods. This could lead to biased estimates due to price changes not attributable to the studied policy. This issue is of lesser concern with regards to the control group, as local shocks are likely to be netted out against each other in Stockholm's inner town. As to the treatment groups, shocks must coincide both in space and time to bias the estimates. Furthermore, the shocks must be large enough and of equal direction across treatment groups to have any impact on the average treatment effect. If this is the case, the assumption of parallel trends is violated.

The plausibility of the common trends assumption can be assessed by investigating the historical price development, prior to the policy implementation (Aarland et al., 2017). We will do this as part of the robustness checks. Even if such analyses indicate parallel trends among neighborhoods, biased estimates due to local shocks during the actual treatment period cannot be ruled out.

7.3.6. Spatial dependency

Spatial autocorrelation arises when nearby observations are correlated to each other. For instance, apartments in proximity to each other are likely to have similar characteristics. Spatial dependency can also arise from the market valuation process, as individuals may use nearby transactions for benchmarking (Xiao, 2017). If this is the case, inference from the results will be affected (Baranzini et al., 2008).

Spatial dependency can be mitigated by employing spatial fixed effects or spatial autoregressive (SAR) models. According to Kuminoff et. al. (2010), the former alternative is often preferable, as SAR models are too rigid for the complexity of metropolitan areas. In spatial fixed effect models, only intra-group spatial autocorrelation is a potential problem (Baranzini et al., 2008). When we employ city-district fixed effects, spatial autocorrelation is still likely to be a problem due to the large groups. As the more finely distributed five-digit zip code fixed effects are included, encompassing 237 unique areas, we further mitigate inter-zip code spatial correlation, but intra-zip code correlation is still likely to exist.

8. Data

8.1. Data sources and descriptive statistics

Data on apartment transactions were downloaded from Booli's API (2019). Booli retrieves publicly available information from various real estate web sources. The full dataset consists of 50,275 apartment transactions in central Stockholm, from May 2013 through April 2019. The data include living area, year of construction, monthly fee paid to tenant-owner association, rooms, final price, date of transaction, and geographical position in terms of address and coordinates. As to the data quality, Booli states that the reported coordinates may be approximate. After visual inspection, we deemed the coordinates sufficiently accurate for the purpose of this thesis (Appendix B). We cannot exclude other potential reporting errors given Booli's data collection method. For instance, some websites report only the second-last bid as the final price. As Booli's data collection method is similar to the one used by NASDAQ Valueguard index (Toll, 2010), we deem potential errors small enough to proceed with the data.

Geographical information was obtained from the database of Lantmäteriet (2019), the Swedish mapping and land registration authority. The geodata provide information on environmental and neighborhood features such as proximity to water, metro stations, green areas, and administrative city district borders. We obtained five-digit zip code geodata from the open database ArcGIS Hub (2017). The maps were matched with data on apartment transactions, and each observation was assigned categorical information relating to its location (see Appendix B for further details on the method).

Information on the program Levande Stockholm was collected from the City of Stockholm's public documents and through personal communication with

Trafikkontoret (H. Blom, March 27, 2019). The information includes decision dates, locations, duration of the program, and complaints. In total, nine car-free zones of varying length and year of introduction were reported. The complaints were available only from 2018, and statistics per area are presented in Appendix A. Ideally, we would include information on increases in human flows and noise levels as a measure of how each area is used by the public. As this information is not available, we use the number of complaints as a proxy. It is important to note that reported complaints are sensitive to the residents' behavior and could possibly be distorted by, for instance, single citizens reporting repeatedly. This should be kept in mind when interpreting the results.

The full set of structural, locational, environmental and neighborhood characteristics obtained from the data processing is presented in Table 7.1. Properties were categorized in six age groups from the reported year of construction. This is to take into account property characteristics on which data is missing, such as balcony, elevator, parking lot and overall quality of the building, but that may be associated with historical construction norms. Following Iqbal and Ceccato (2015), proximity to the geographical features of interest were included as indicator variables by using buffering. Maps of sold apartments in relation to the waterbodies, parks and metro stations are provided in Appendix B.

In total 10,187 observations outside of Kungsholmen, Östermalm, Norrmalm-Vasastan and Södermalm were excluded. Further, 75 observations missing living area, 44 observations missing rooms, 208 observations missing rent, and 3,156 observations missing construction year were excluded from the sample. Ten observations of less than 15 square meters were removed due to potential reporting errors, such as parking lots being listed as apartments. Two observations with misreported coordinates were excluded. As we will perform a logarithmic OLS estimation, 129 zero-rent transactions were removed from the sample.

Table 8.1: Variable description

Type of variable	Name	Description	Unit
Dependent variable	Price	Transaction price	SEK
Structural characteristics	Area	Living area	Square meters
	Rooms	Number of rooms	Number
	Rent	Monthly fee	SEK
	Age5	Before 1891	Binary
	Age4	1891-1920	Binary
	Age3	1921-1950	Binary
	Age2	1951-1980	Binary
	Age1	1981-2010	Binary
	Age0	After 2010	Binary
Environmental characteristics	Water100	0-100 meters from waterfront	Binary
	Water200	100-200 meters from waterfront	Binary
	Water300	200-300 meters from waterfront	Binary
	Park100	0-100 meters from major park	Binary
	Park200	100-200 meters from major park	Binary
	Park300	200-300 meters from major park	Binary
Locational characteristics	Metro100	0-100 meters from metro station	Binary
	Metro200	100-200 meters from metro station	Binary
	Metro300	200-300 meters from metro station	Binary
Neighborhood characteristics	NV	Norrmalm-Vasastan	Binary
	OS	Östermalm	Binary
	SM	Södermalm	Binary
	KH	Kungsholmen	Binary
	ZIP	Five-digit zip codes	Categorical

Table 8.2: Descriptive statistics for Stockholm's inner town

	Mean	Standard deviation	Minimum	Maximum
Price	4,921,093.69	2,622,095.60	1,028,000.00	57,000,000.00
Rent	2,665.80	1,217.92	1.00	14,123.00
Area	58.63	29.05	15.00	333.00
Rooms	2.23	1.01	1.00	9.00
Construction year	1932	33	1645	2019
N	36,464			

Note: Descriptive statistics of structural housing characteristics for all observations in the cleaned data set over the full period May 2013-April 2019. Construction year is presented in its continuous form.

Table 8.3: Descriptive statistics for the targeted areas

	Mean	Standard deviation	Minimum	Maximum
Price	5,420,294.49	2,486,964.20	1,028,000.00	34,000,000.00
Rent	2,705.92	1,225.54	1.00	9,875.00
Area	63.34	28.51	17.00	308.00
Rooms	2.38	1.02	1.00	9.00
Construction year	1929	38	1827	2018
N	4,968			

Note: *Descriptive statistics of structural housing characteristics for observations in any of the targeted areas KH1, KH2, KH3, NV1, NV2, OM1, OM2, SM1 and SM2 over the full period May 2013-April 2019. The used buffer distance is b = 200 meters. Construction year is here presented in its continuous form.*

The remaining sample consists of 36,464 observations. In total, 4,968 transactions were assigned to any of the nine treatment groups. Of these, 2,231 apartments were sold after the introduction of their closest car-free zone. The typical transaction had a living area of 58.63 square meters, 2.23 rooms, a monthly fee of SEK 2,666 and was sold for SEK 4,921,093 million (Table 7.2). Descriptive statistics per city district are presented in Appendix C. Transactions in the treatment groups had a larger living area and were more expensive than the average inner town apartment (Table 7.3). Most likely, the price difference is explained by the policy being implemented in above-average attractive neighborhoods. The introduction of car-free zones may also have contributed to the difference.

8.2. Data limitations

To make inference from the data, assumptions must be made about representativeness. We define the population as the full stock of apartments in Stockholm's inner town. In this regard, our sample may be unrepresentative in several ways. For instance, observed apartments may differ systematically from the population in terms of price as the most expensive apartments are not likely to be listed online. Further, apartments with high exposure to noise from street activity may be overrepresented in the sample, if these have higher turnover rates due to information bias. Data is also missing on whether apartments face the street or not, which is likely to be of importance as neighborhoods undergo change. Lastly, we only observe a limited time period which is not necessarily representative for Stockholm's housing market.

9. Results

This section starts with a presentation of the results from our hedonic price model in section 9.1, which is the starting point of the analysis. We proceed by presenting the results from our main model specification in section 9.2. Next, we test for heterogenous effects across city districts and project areas in section 9.3, and finally present the robustness checks in section 9.4.

9.1. Hedonic price model

In Table 9.1, the estimation of the hedonic price model is presented without policy variables. In column 1, only structural attributes are included. All coefficients follow the expected pattern and are significant on a 1% level. In column 2, we add environmental and locational attributes. This only marginally improves the model, most likely due to the abundance of water, parks and metro stations in the studied area as illustrated in Appendix B. In column 3, city district fixed effects are included to reduce spatial dependency and take into account neighborhood characteristics. The difference in price level between the least and most expensive city districts Kungsholmen and Östermalm is 19%, ceteris paribus. In column 4, city-district fixed effects are replaced by five-digit zip code fixed effects. Both versions of spatial fixed effects incur similar changes to the coefficients of the locational and environmental attributes. All independent variables except for proximity to park and metro follow their expected pattern. The high adjusted R-squared is likely explained by the homogenous group of properties and is discussed in more detail section 10.

9.2. Difference-in-differences approach

Results from model specification 3 are presented in Table 9.2. Before estimating our difference-in-differences model, 174 properties sold with more than one month between decision and implementation of the car free zones are excluded, due to possible anticipation effects. We also exclude 716 observations from areas that were introduced as local expansions of Levande Stockholm.

Before including property characteristics, the average treatment effect is insignificant and estimated to -1.8%. This suggests that the car-free zones reduced the attractivity of targeted areas. When controlling for structural attributes, the treatment effect becomes less negative and is estimated on a 5% significance level. Including locational and environmental characteristics does not significantly affect the estimated treatment effect.

In columns 4 and 5, spatial fixed effects are included. When employing city-districts fixed effects, the treatment effect is not significantly different from zero. The change reflects an uneven distribution of treated properties across city districts, that in turn are of importance to the final price. As we use zip-code fixed effects to control for more local neighborhood characteristic, the treatment effect is still insignificant. There is a risk that the zip-code areas are too finely distributed and that we therefore lack sufficient variation to identify any effect. However, the nine treatment-group intercepts are all positive, with an average of 2.6% corresponding to approximately SEK 130 000 for the average apartment in the sample. This indicates that the model successfully takes into account the time-invariant relative attractiveness of the targeted areas. The insignificant average treatment effect indicates that the same neighborhood premiums are not attributable to the introduction of the car-free zones. In contrast to our first hypothesis, pedestrianization seems to have no general effect on apartment prices.

Table 9.1: Hedonic price model

	(1) Structural	(2) Environmental/ Locational	(3) Spatial FE (1)	(4) Spatial FE (2)
Area	0.76^{***}	0.76^{***}	0.73^{***}	0.71^{***}
	(0.0051)	(0.0051)	(0.0045)	(0.0041)
Rooms	0.08^{***}	0.08^{***}	0.077^{***}	0.077^{***}
	(0.0017)	(0.0017)	(0.0016)	(0.0015)
Rent	-0.087^{***}	-0.086^{***}	-0.062^{***}	-0.042^{***}
	(0.0045)	(0.0046)	(0.0039)	(0.0029)
Age5	0.14^{***}	0.15^{***}	0.085^{***}	0.019^{**}
	(0.0057)	(0.0059)	(0.0054)	(0.0075)
Age4	0.1^{***}	0.11^{***}	0.061^{***}	0.021^{***}
	(0.0053)	(0.0055)	(0.0051)	(0.0072)
Age3	0.022^{***}	0.032^{***}	0.0017	-0.027^{***}
	(0.0052)	(0.0053)	(0.0049)	(0.007)
Age2	-0.038^{***}	-0.027^{***}	-0.061^{***}	-0.086^{***}
	(0.0059)	(0.006)	(0.0055)	(0.0073)
Age1	-0.071^{***}	-0.067^{***}	-0.076^{***}	-0.071^{***}
	(0.0055)	(0.0056)	(0.0052)	(0.0066)
Water100		0.0015	0.043^{***}	0.047^{***}
		(0.0025)	(0.0025)	(0.0042)
Water200		-0.015^{***}	0.017^{***}	0.022^{***}
		(0.0022)	(0.0021)	(0.0036)
Water300		-0.02^{***}	0.011^{***}	0.0061^{**}
		(0.0021)	(0.002)	(0.0028)
Park100		-0.026^{***}	-0.0089^{***}	-0.0015
		(0.0021)	(0.002)	(0.0035)
Park200		-0.017^{***}	-0.0065^{***}	-0.0056^{**}
		(0.0019)	(0.0018)	(0.0029)
Park300		-0.02^{***}	-0.015^{***}	-0.0075^{***}
		(0.002)	(0.0019)	(0.0026)
Metro100		0.0046^{*}	0.016^{***}	-0.0056^{*}
		(0.0025)	(0.0024)	(0.0033)
Metro200		0.013^{***}	0.019^{***}	-0.00043
		(0.0019)	(0.0017)	(0.0024)
Metro300		0.014^{***}	0.021^{***}	0.0063^{***}
		(0.0017)	(0.0016)	(0.0021)
NV			0.084^{***}	
			(0.0019)	
OM			0.19^{***}	
			(0.0029)	
SM			0.02^{***}	
			(0.0017)	
Constant	13^{***}	13^{***}	12^{***}	12^{***}
	(0.027)	(0.027)	(0.023)	(0.049)
Year FE	Yes	Yes	Yes	Yes
Month of year FE	Yes	Yes	Yes	Yes
Zip-code FE	No	No	No	Yes
Observations	36464	36464	36464	36464
Adjusted R^2	0.908	0.909	0.922	0.935

Note: The dependent variable is the natural logarithm of the transaction price. In column 1, structural housing characteristics are the dependent variables. In column 2, environmental and locational housing characteristics are included. In column 3 and 4, city district and five-digit zip code fixed effects are included respectively. All continuous variables are transformed to logarithmic form. KH is the reference city district, and Age0 the reference age group. Heteroscedasticity-robust standard errors in parentheses. * *$p < 0.10$,* ** *$p < 0.05$,* *** *$p < 0.01$*

Table 9.2: Difference-in-differences

	(1) DiD	(2) Structural	(3) Environmental /Locational	(4) Spatial FE (1)	(5) Spatial FE (2)
Treatment	-0.018	-0.0096**	-0.0091**	-0.0038	-0.0012
b = 200 m	(0.013)	(0.0038)	(0.0038)	(0.0036)	(0.0035)
KH1	0.26***	0.011	0.016**	0.017**	0.099***
	(0.015)	(0.0074)	(0.0075)	(0.0071)	(0.018)
KH2	0.14***	0.0071	0.0096*	0.071***	0.042***
	(0.019)	(0.0055)	(0.0057)	(0.0053)	(0.0083)
KH3	0.13***	0.027***	0.025***	0.092***	0.05***
	(0.023)	(0.006)	(0.0062)	(0.0059)	(0.0099)
NV1	0.11***	0.057***	0.058***	0.013***	0.022***
	(0.013)	(0.0039)	(0.004)	(0.0041)	(0.0074)
NV2	0.26***	0.039***	0.038***	0.028***	0.0065
	(0.014)	(0.0045)	(0.0046)	(0.0045)	(0.0062)
OM1	0.18***	0.19***	0.19***	0.057***	0.0028
	(0.046)	(0.017)	(0.017)	(0.017)	(0.018)
OM2	0.27***	0.14***	0.13***	0.022*	0.000047
	(0.047)	(0.012)	(0.012)	(0.012)	(0.015)
SM1	0.12***	-0.0094*	-0.027***	0.028***	0.015**
	(0.016)	(0.0048)	(0.0049)	(0.0049)	(0.0074)
SM2	-0.023	0.0056	-0.0044	0.053***	0.027***
	(0.017)	(0.0053)	(0.0054)	(0.0053)	(0.0066)
Constant	15***	13***	13***	12***	12***
	(0.0098)	(0.027)	(0.027)	(0.023)	(0.049)
Year FE	Yes	Yes	Yes	Yes	Yes
Month of year FE	Yes	Yes	Yes	Yes	Yes
Structural	No	Yes	Yes	Yes	Yes
Locational	No	No	Yes	Yes	Yes
Environmental	No	No	Yes	Yes	Yes
City-district FE	No	No	No	Yes	No
Zip-code FE	No	No	No	No	Yes
Observations	35574	35574	35574	35574	35574
Adjusted R^2	0.088	0.909	0.910	0.923	0.936

Note: The dependent variable is the natural logarithm of the transaction price. In column 1, the average treatment effect is estimated without control variables. In column 2, structural housing characteristics are included. In column 3, environmental and locational characteristics are included. In column 4 and 5, city-district fixed effects and five-digit zip code fixed effects are included respectively. All continuous variables are transformed to logarithmic form. The average of the treatment group intercepts is 0.0263. Heteroscedasticity-robust standard errors in parentheses * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

9.3. Heterogenous effects

In Table 9.3, we investigate heterogeneous treatment effects across districts and targeted areas. Possibly, heterogeneity could explain the zero average treatment effect on property prices. In columns 1a to 1d, model specification 3 is applied to each city district individually to test if the car-free zones are valued differently across submarkets. In Kungsholmen, the estimated effect is -1.7% and statistically significant on a 1% level. In the remaining three districts, the effect is insignificant and close to zero. In accordance with our second hypothesis, this indicates that the effect depends on local context, although differences are small.

To test if the value of the car-free zones depends on how they are designed or used, we interact the treatment effect with the complaints and length indicator variables. The results presented in column 2 and 3 respectively. The results suggest no differential effect in areas associated with above median number of complaints nor above median length. Thus, we find no support for the third hypothesis.

Table 9.3: Difference-in-differences with heterogeneous effects

	(1a) Kungs-holmen	(1b) Norrmalm-Vasasan	(1c) Östermalm	(1d) Södermalm	(2) Complaints	(3) Length
Treatment	-0.017^{***}	0.0048	-0.008	0.0021	-0.0051	0.0031
b = 200 m	(0.0067)	(0.0056)	(0.02)	(0.0066)	(0.0059)	(0.005)
Treatment x complaints					0.0059 (0.0071)	
Treatment x length						-0.0081 (0.0067)
Full set of control variables	Yes	Yes	Yes	Yes	Yes	Yes
Observations	10154	9679	3926	11815	35574	35574
Adjusted R^2	0.930	0.935	0.950	0.918	0.936	0.936

Note: The dependent variable is the natural logarithm of the transaction price. In column 1a-1d, the treatment effect is estimated for each city-district separately. In column 2 and 3, the treatment variable is interacted with a binary variable indicating above-median complaints and above-median length respectively. The full set of control variables includes treatment-group intercepts, year fixed effects, structural, locational, and environmental characteristics, month-of-year fixed effects and five-digit zip code fixed effects. All continuous variables are transformed to logarithmic form. Heteroscedasticity-robust standard errors in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

9.4. Robustness checks

The aim of the robustness checks is to verify the results from the previous subsections. The foremost concerns are the choice of appropriate control and treatment groups, and whether the key identifying assumption of conditional parallel trends holds.

9.4.1. Alternative control groups

To address potential contamination between control and treatment groups, we define new cut-off distances $b = 100$ and $b = 300$ meters. We assess the average treatment effect using both city-district and zip-code fixed effects. Following our earlier method, we exclude properties sold between decision and implementation, and areas introduced to Levande Stockholm as local expansions in 2018. This corresponds to 61 plus 482 transactions using $b = 100$, and 352 plus 662 transactions using $b = 300$.

The results, presented in Table 9.4, are similar to the previous findings. The average treatment effect is approximately zero and insignificant across all columns, which supports our previous findings with regards to hypothesis 1. There is no indication that the effect would level off with distance.

Table 9.4: Difference-in-differences with alternative buffers

	(1) DiD 0-100 m, city-district FE	(2) DiD 0-100 m, zip-code FE	(3) DiD 0-300 m, city-district FE	(4) DiD 0-300 m, zip-code FE
Treatment b = 100 m	-0.0046 (0.0057)	-0.00084 (0.0056)		
Treatment b = 300 m			-0.0021 (0.0029)	0.00013 (0.0027)
Full set of control variables	Yes	Yes	Yes	Yes
Observations	35921	35921	35450	35450
Adjusted R^2	0.923	0.936	0.924	0.936

Note: The dependent variable is the natural logarithm of the transaction price. In column 1-2, treatment groups are defined by b = 100 meters. In columns 3-4, treatment groups are defined by b = 300 meters. The form of spatial fixed effects is specified in the column title. The full set of control variables includes treatment-group intercepts (for b = 100 in column 1-2, and b = 300 in column 3-4), year fixed effects, structural, locational, and environmental characteristics, month-of-year fixed effects and five-digit zip code fixed effects. All continuous variables are transformed to logarithmic form. Heteroscedasticity-robust standard errors in parentheses $^{*} p < 0.10$, $^{**} p < 0.05$, $^{***} p < 0.01$.

9.4.2. Pre-policy price trends

When applying the difference-in-differences approach, we estimated the treatment effect as an average shift in the price gap between the treatment and control groups. This price gap is assumed to be constant, had Levande Stockholm not been introduced. If apartment prices in any of the targeted areas and the rest of the inner town were already on diverging or converging paths prior to the intervention, results are likely to be biased (Aarland et al., 2017). To analyze price trends prior to the implementation of Levande Stockholm, we estimate,

$$\log(P_i) = \lambda_{jt} + \beta X_i + \eta_g + \varepsilon_i$$

Where λ_{jt} are time-group fixed effects for the control and the treatment groups respectively, β the standard set of housing characteristics, and η_g five-digit zip code fixed effect. As in the main model specification, treatment groups are defined by b = 200 meters while remaining properties in the inner town form the control group. Since we only have pre-policy data from May 2013 through April 2015, years are broken down into four periods of six months each.

The time trends are plotted in Figure 9.1. In Kungsholmen, the three treatment groups display parallel trends to the control group prior to the policy implementation. For instance, the group KH1 had a stably higher price level compared to the rest of the inner town of about 15% in the studied period. In Norrmalm-Vasastan and Södermalm, trends are parallel, although a small dip can be seen in the treatment groups NV1, NV2 and SM2 in 2014. In Östermalm, the price indices do not to follow parallel trends to the inner town. However, the city district's two treatment areas contain only 25 and 38 observations from presented period, compared to between 100 and 376 observations in each of the other treatment areas. It is therefore difficult to draw any conclusions from the OM1 and OM2 price indices.

In summary, we cannot corroborate any clearly diverging or converging price trends in any of the targeted areas relative to the rest of the inner town in the pre-policy period. Although differential price development attributable to other factors than Levande

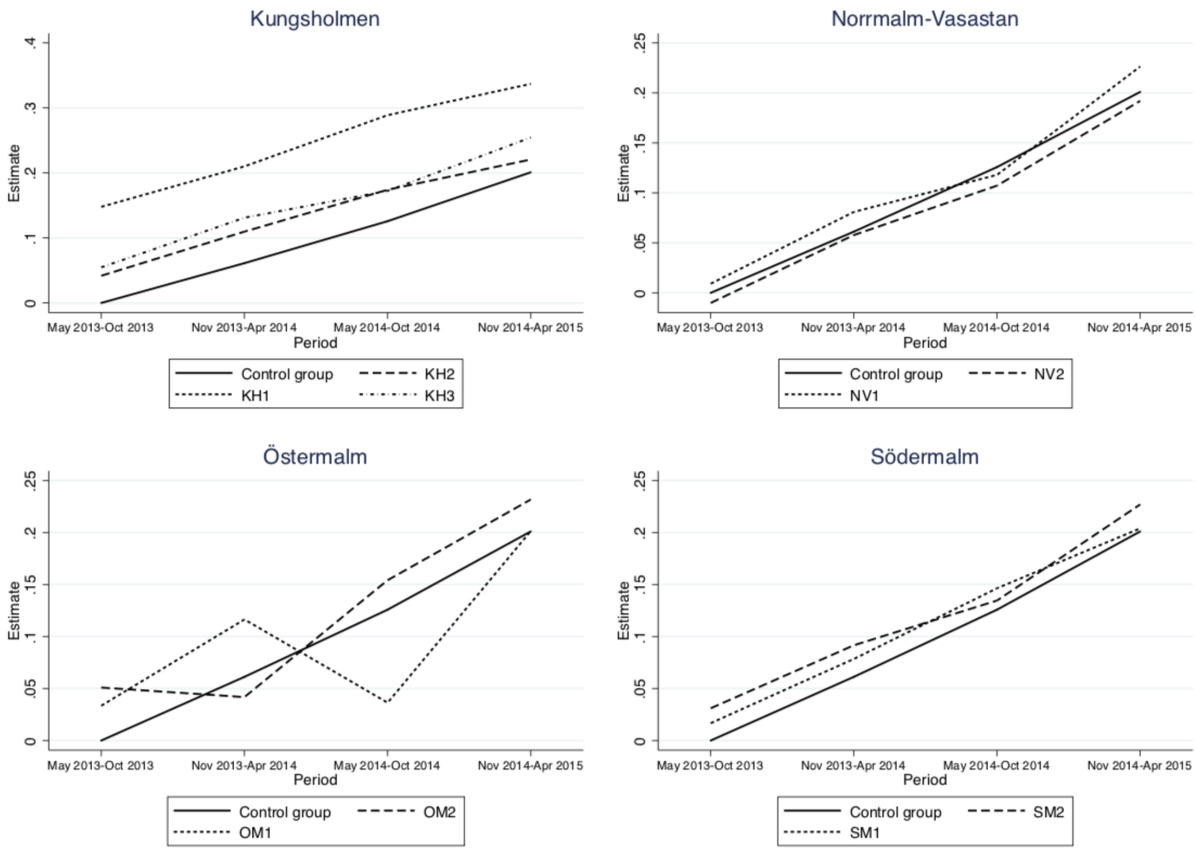

Figure 9.1: Pre-policy price trends

Stockholm during the actual treatment period cannot be excluded, the results reduce the concern for bias due to already existing non-parallel trends. The results from the two treatment areas in Östermalm cast some doubt on the data quality. However, as the average treatment effect is weighted per observation and not area, these are likely to minor importance for our estimated city-level effects.

10. Discussion

10.1. Analyzing the results

The results presented in the previous section suggest that the introduction of Levande Stockholm had no effect on property prices. Thus, we find no support for the first hypothesis. As suggested by hypothesis 2, the effect on property prices varies across city-districts, indicating that the MWTP for a car-free urban environment is mediated by local context and depend on submarket-specific preferences. With regards to hypothesis

3, the magnitude of the intervention and number of complaints were not associated with any differential effect. Over all, the inferred MWTP is small, if not zero, in the studied setting.

The interpretation of hypothesis 2 and 3 can benefit from a more thorough discussion. The varying results across city districts can indeed be interpreted as evidence of local preferences and inelastic supply, as hypothesized. However, as the variation is small, it is possible that local unobservable characteristics of the car-free zones or coinciding shocks contribute. Furthermore, we hypothesized that size and complaints would be associated with differential effects. The insignificant results in this regard indicate that pedestrian streets are of minor importance to the housing market, independent of design and use by the public. However, the complaints may also be an inaccurate proxy for human flows, as discussed earlier.

The high adjusted R-squared in Table 9.1-9.4 could indicate that too many dependent variables are included in the model, which in turn capture noise from the sample. However, the figure is likely explained by the homogenous group of properties whose variation in structural characteristics determines the transaction price in a high degree. Possibly, this indicates that the market is competitive, as apartments are priced precisely by their structural characteristics. If this is the case, remaining variation could be explained by data that is missing such as balcony, elevator or floor.

The insignificant average treatment effect was supported also when alternative treatment buffers were used. In general, the findings can be explained by the design of the project and the specific setting, as well as the previously presented challenges in valuation of neighborhood externalities.

As to the specific design of Levande Stockholm, it is possible that pedestrianization needs to encompass larger areas to be reflected in housing markets. Tu and Eppli (1999; 2001) found the design of the urban realm to be of great importance to property prices, but in contrast to this study they compared entire neighborhoods designed by different principles. Further, the introduced car-free zones can also be considered abundant in Stockholm's inner town given its limited size. If fewer car-free zones were introduced, the relative attractiveness of targeted areas could possibly be affected differently, due to scarcer supply.

As to the complexity of valuing neighborhood externalities, our study confirms that the perceived benefits from an improved street environment may be highly contextual. While CABE (2007) found a strong relationship between improved street quality and housing prices in London, our results indicate that the relationship is not that evident in the studied Swedish setting. As our findings suggested some heterogeneous effects across different city districts of Stockholm's inner town, it also confirms that not only inter-urban but also intra-urban variation is of importance in valuation of features in the urban realm. Just like parks (Iqbal and Ceccato, 2015) or railway stations (Bowes and Ihlanfeldt, 2001) may be valued differently within cities, finding any average city level-effect of pedestrianization on property prices is challenging.

Our study also confirms that that results from revealed preference valuation of the urban realm are highly dependent on how features of interest are quantified and incorporated in econometric models (Orford, 2002). Studies employing non-experimental hedonic modelling (CABE 2007; Tu and Eppli, 1999; 2001) have generally found a stronger link between the urban realm and housing prices. Since our quasi-experimental research design exploits spatial discontinuities in housing prices, time-invariant factors not directly linked to changes in street quality are differenced away. While our results suggested that properties in targeted areas were valued higher due to time-invariant unobservable factors, the difference-in-differences model confirmed that the price discrepancy was not attributable to the introduction of Levande Stockholm.

As most research in this field and as earlier mentioned, there are limitations to the inference from our results. The main problems are that the method may be sensitive to unobservable shocks, and that the sample is not necessarily representative to the full stock of properties in the studied area. Further, unrepresentative responsiveness, as earlier stated, can be a threat to external validity (Meyer, 1995). If streets are targeted for pedestrianization due to characteristics that are intended to attract people, such as areas with already low traffic volumes and business activity on both sides of the street, the treatment response may be unrepresentative. In a setting where pedestrianization merely entails cuts in motorized traffic, but no increases in human flows or business activity, the effect is possibly different.

Lastly, although we excluded observations between decision and implementation, potential anticipation by the public may have biased the results. Local governments do not seek to shock the market with new interventions. Further, politics are subject to change which may raise questions on how permanent interventions like Levande Stockholm are considered by the market. These are challenges most quasi-experimental policy studies need to deal with, this thesis being no exception.

10.2. Further implications

The findings are of interest for *urban authorities* as new pedestrianization schemes should be implemented with regards to their overall benefits, including economic consequences. Among these, increased property prices appear to be of minor importance. Urban authorities should be aware of this when considering similar changes in land use policy to not overestimate the economic benefits from targeted pedestrianization. The findings are also of interest to *property owners* participating in local decision-making processes or consultations with urban authorities. They should be critical to accept any 'housing value argument' when similar pedestrianization schemes are proposed. Similarly, *individual citizens* in search for a new home should not expect to pay premiums for properties located in car-free zones, despite being used as a sales argument from real estate agencies.

Although we found no MWTP for car-free environment in our studied setting, the suggested social and environmental benefits from pedestrianization may still affect the quality of life for residents and visitors. Revealed-preference studies should therefore be complemented with qualitative evaluations of pedestrianization taking into account, among others, health-related and psychosocial aspects.

Future studies can assess the impact of a car-free urban environment on housing prices in other cities and neighborhoods, to gain a better understanding on how they interact with the local context. With better data availability, it would also be possible to distinguish more local effects, such as comparing apartments with street view to those facing backyards. Lastly, the local population is only one of many stakeholders when urban authorities are undertaking new revitalization projects. Thus, it could also be of interest to conduct more extensive cost-benefit analyses to see into what extent similar revitalization strategies are still economically justifiable and beneficial to the public from a wider urban policy perspective.

11. Conclusion

This thesis has investigated whether citizens are willing to pay for a car-free urban environment. It adds to the current literature on urban externalities by investigating the value of a change in urban land use that is today used as a neighborhood revitalization strategy by many urban authorities. We hypothesized that pedestrianization of urban streets affects housing prices, as it changes the social and environmental qualities of the physical environment and gives rise to new neighborhood externalities. Treating the implementation of the municipal program Levande Stockholm between 2015 and 2019 as a quasi-experiment, we sought to exploit spatial discontinuities in housing prices caused by local interventions in the urban environment.

Our findings suggested that the program had no general effect on housing prices, although small and varying effects were found across city-districts. In accordance with previous studies, this indicated that valuation of urban environmental features may be contextual, pedestrian streets being no exception. However, we could not exclude that the variation stemmed from other factors such as unobservable shocks in the housing market, not attributable to the policy. Further, the estimated results may have been affected by unrepresentative responsiveness due to the character of the targeted streets. The findings are difficult to generalize due to limited data, and the methodological challenges associated with valuation of environmental and non-market goods. We suggest future research to further investigate how pedestrianization interacts with the local context, and address associated values not incorporated in housing markets.

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Appendices

Appendix A: Statistics per targeted area

Table A1

Treated area	Street name	Implementation month	Decision month	Number of complaints	Length	Observations within 200 m	Obs. within 200 m sold after implementation
KH1	Hornsbergs strand	May 2017	Apr 2017	20	450 m	449	188
KH2	Norra Agnegatan	May 2018	Dec 2017	2	50 m	412	85
KH3	Bergsgatan	May 2018	Dec 2017	0	70 m	413	86
NV1	Rörstrandsgatan	June 2016*	Feb 2016	12	105 m	1,223	652
NV2	Norrtullsgatan	May 2018	Dec 2017	16	380 m	845	150
OM1	Humlegårdsgatan	May 2016	Feb 2016	1	65 m	86	48
OM2	Nybrogatan	May 2018	Dec 2017	3	115 m	141	27
SM1	Swedenborgsgatan	June 2015	May 2015	7	340 m	761	545
SM2	Skånegatan	June 2015*	May 2015	49	180 m	638	450
Total				110	1,755	4,968	2,231

*Note: Month of first implementation and complaints were obtained from personal communication with H. Blom at Stockholms Stad (March 27, 2019). Decision dates were retrieved from Stockholms Stad (2015; 2016a; 2016b; 2017c) and Bernövall (2017). *These streets were locally expanded in 2018.*

Appendix B: Maps and GIS

We used the software QGIS for geocoding. Maps were downloaded as vector layers from Lantmäteriet (2019), and buffers surrounding waterfront, metro stations, parks and pedestrianized streets were created with the tool *Multi Distance Buffer*. The pedestrianized streets and major parks were mapped manually according to information from Trafikkontoret and Stadsbyggnadskontoret's open source geodata (Stockholm stad, 2019) respectively. The buffered areas were thereafter saved and imported as shapefiles to Stata using the spatial analysis tool *gpsbound* (Brophy, Daniels, and Musundwa, 2015).

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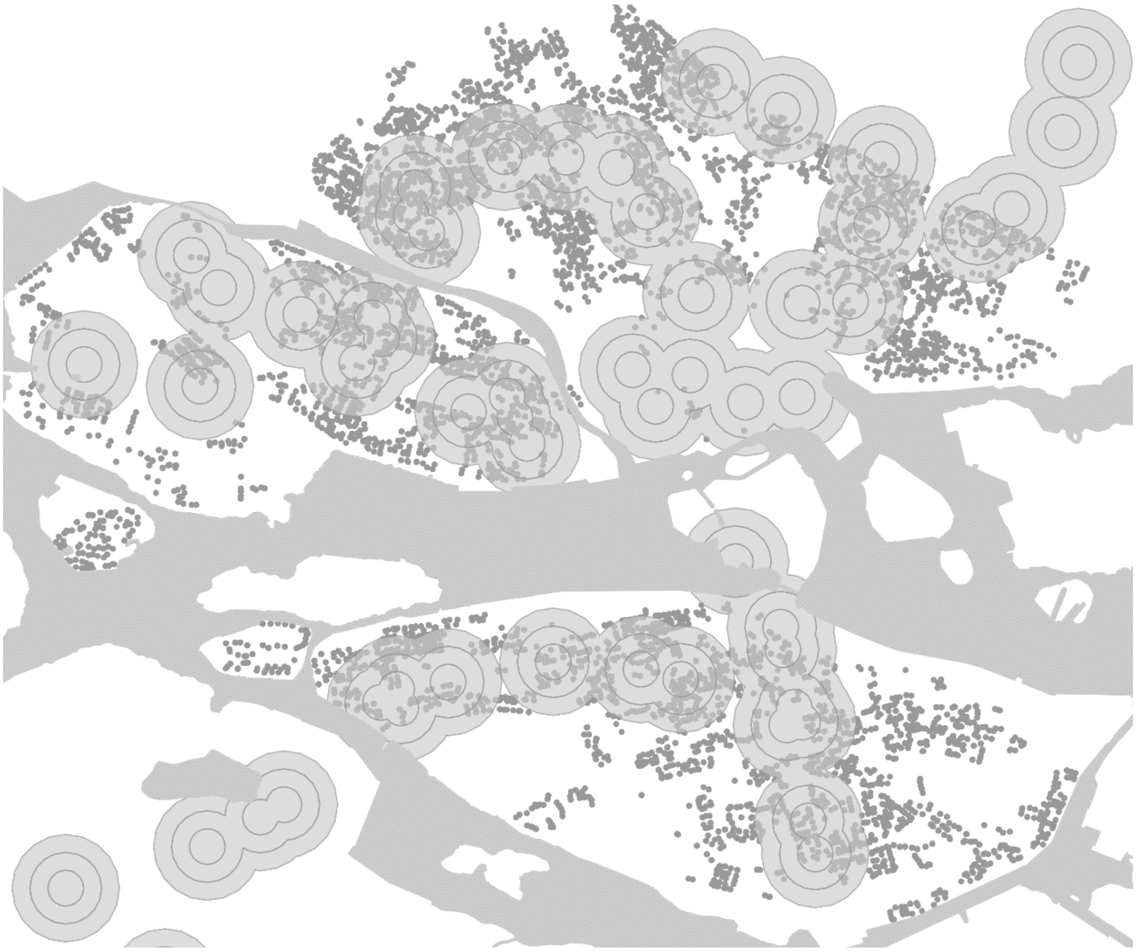

Figure B1: Map of Stockholm's inner town with observed transactions and metro stations with distance bands of 100, 200, and 300 meters.

Note: Source: Lantmäteriet (2019) and Booli (2019)

Figure B2: Map of Stockholm's inner town with observed transactions and parks with distance bands of 100, 200, and 300 meters.

Note: The parks were selected by size. Included parks are Humelgården, Vasaparken, Observatorielunden, Vanadislunden, Kronobergsparken, Fredhällsparken, Rålambshovsparken, Mariebergsparken, Tantolunden, Högalidparken, Stora and Lilla Blecktornsparken, as well as the the park between Ladugårdgärdet och Östermalm. Source: Lantmäteriet (2019) and Booli (2019)

Figure A3: Map of Stockholm's inner town with observed transactions and the waterfront with distance bands of 100, 200 and 300 meters.

Note: Source: Lantmäteriet (2019) and Booli (2019)

Appendix C: Descriptive statistics per city district

Table C1: Kungsholmen

	Mean	Standard deviation	Minimum	Maximum
Price	4,350,932.27	1,978,343.79	1,300,000.00	22,500,000.00
Rent	2,692.40	1,138.19	169.00	9,836.00
Area	54.57	24.92	15.00	223.00
Rooms	2.15	0.91	1.00	7.00
Construction year	1943	34	1860	2018
N	10,209			

Note: Descriptive statistics of structural housing characteristics for Kungsholmen in the cleaned data set over the full period May 2013-April 2019. Construction year is presented in its continuous form.

Table C2: Norrmalm-Vasastan

	Mean	Standard deviation	Minimum	Maximum
Price	5,328,061.85	2,473,773.70	1,028,000.00	23,250,000.00
Rent	2,558.23	1,166.39	1.00	11,137.00
Area	61.54	28.91	15.00	242.00
Rooms	2.28	1.00	1.00	7.00
Construction year	1920	28	1745	2019
N	10,045			

Note: Descriptive statistics of structural housing characteristics for Norrmalm-Vasastan in the cleaned data set over the full period May 2013-April 2019. Construction year is presented in its continuous form.

Table C3: Östermalm

	Mean	Standard deviation	Minimum	Maximum
Price	7,022,644.87	4,524,830.81	1,480,000.00	57,000,000.00
Rent	2,768.30	1,621.85	1.00	14,123.00
Area	71.48	42.91	15.00	333.00
Rooms	2.57	1.26	1.00	9.00
Construction year	1918	30	1840	2018
N	3,932			

Note: Descriptive statistics of structural housing characteristics for Östermalm in the cleaned data set over the full period May 2013-April 2019. Construction year is presented in its continuous form.

Table C4: Södermalm

	Mean	Standard deviation	Minimum	Maximum
Price	4,389,206.04	1,870,936.55	1,350,000.00	27000000.00
Rent	2,698.87	1,165.60	100.00	10,236.00
Area	55.51	25.18	15.00	308.00
Rooms	2.14	0.97	1.00	9.00
Construction year	1936	31	1645	2019
N	12,278			

Note: Descriptive statistics of structural housing characteristics for Södermalm in the cleaned data set over the full period May 2013-April 2019. Construction year is presented in its continuous form.