CRIME CONCENTRATION IN SWEDEN

AN EXPLORATIVE TEST OF A CRIMINOLOGICAL LAW

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According to the law of crime concentration, a certain percentage of crime is predicted to be concentrated at a certain percentage of microgeographic units, and relatively large amounts of crime are predicted to be accounted for by a small percentage of places. Given the lack of research testing the law in a Swedish context and for a whole country, this study set out to examine the concentration of crime at all densely populated areas in Sweden. Analyzing national grid net data, where all densely built-up areas of Sweden were divided into 250 x 250 meter pixels with added police recorded crime data, the study aimed to examine how many percent of the pixels are required to account for 25, 50 and 80% of the crimes in all densely populated areas; how the concentrations differ between small, medium-sized and big cities; how the concentrations differ between violent and property crimes in all of the country; and how an observed crime concentration compares to a counterfactual, randomized concentration. The results indicated a crime concentration that is stronger than the ones observed in most previous studies, with just 0.4, 2.3 and 10.2% of the pixels accounting for 25, 50 and 80% of all crimes in all densely populated areas, respectively. In line with previous research, the results also showed that crime is more strongly concentrated in smaller cities compared to the big ones, that violent crime is more strongly concentrated than property crime, and that the observed concentration of violent crime is considerably stronger than a counterfactual, randomized concentration in the form of a Poisson distribution. Further research on crime concentration in Sweden is requested to build on these findings.

Keywords: Crime concentration, criminology of place, hot spots, micro geography, micro places

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INTRODUCTION

In 2014, Weisburd (2015) held his Sutherland address to the American Society of Criminology, where he proposed a “law of crime concentration” based on empirical findings. According to this law, a certain amount of crime will be concentrated at a certain (small) percentage of microgeographic units, meaning that a narrow range in percentage of microgeographic units associated with, for example, 25 or 50% of crime in a city is predicted, with variations depending on the size of the city (ibid.). Concretely, the law predicts that 25% of crime will be concentrated at less than 1.5% of places and 50% of crime at around 4% of places, with greater concentrations in smaller compared to bigger cities (ibid.).

Previous research has shown that crime tends to be concentrated at a small number of places. A systematic review and meta-analysis (Lee et al. 2017) concluded that, regardless of type of crime, measure of crime and geographic unit of analysis, this is the case. However, crime tends to be more concentrated when the geographic unit of analysis is smaller and when calls for services to police are used as a measure of crime, compared to crime incident data. Violent crime also tends to be more concentrated than property crime (ibid.). The average crime concentration found in this systematic review and meta-analysis (63% of crime accounted for by 10% of places) is somewhat lower than the one suggested by Weisburd's (2015) law of crime concentration. Empirical findings of crime concentration at micro places also have given an impetus to hot spot policing, where police activity and resources are targeted at small high-crime places to prevent crime (Braga et al. 2012).

The importance of small geographic units of analysis was confirmed in a study by Steenbeek and Weisburd (2016). Here it was found that microgeographic units (street segments) account for the majority of the variability of crime, with the macrogeographic unit (district) accounting for most of the remaining variability. When these two levels of analysis are accounted for, the meso (neighborhood) level does not contribute with much knowledge (ibid.). Similar results were also obtained by Schnell et al. (2017). The present study will analyze microgeographic units, which is advantageous in the light of these research findings.

Although the concentration of crime at a small number of places is a robust research finding (e.g., Lee et al. 2017), the majority of research in this field originates from the United States, with no studies having been conducted in Sweden. Since countries can differ tremendously from one another in areas like immigration, housing segregation, legal systems and level of welfare, it is problematic to generalize research findings on crime concentration from one country to another (Šimon & Jíchová 2020). In addition, studies on crime concentration have previously focused on cities of varying sizes, but do the results hold for a whole country? The present study will contribute significantly to the field by, for the first time, testing the law of crime concentration for a whole country: Sweden. However, it is the densely populated areas of the country, which contain the vast majority of the Swedish population, that are referred to as ”the whole country” and will be examined in the present study (see more on this under ”Data” below). Due to the lack of research on crime concentration in Sweden and whole countries, this study will mainly take an explorative approach and examine to what extent the law applies in this context, which also could have implications for crime prevention. More specifically, the present thesis will set out to answer the following research questions:

1) How many percent of the places are required to account for 25, 50 and 80 percent of the crimes in the whole country of Sweden?
2) How does the concentration differ between big, medium-sized and small cities?
3) How does the concentration differ for violent and property crimes in the whole country?
4) How does an observed crime concentration compare to a counterfactual, randomized concentration?

LITERATURE REVIEW

This review of the literature begins with a summary of the extent to which crime has been found to be concentrated at places in empirical studies, followed by findings and theoretical perspectives on why crime clusters at certain places, and concludes with a brief overview of other findings from research in this area.

Crime concentration at places

The clustering of a significant amount of the total crime of a city at a small share of microgeographic units is a remarkably consistent finding in the research that has been conducted in this area. A pioneering study that, in a sense, laid the groundwork for subsequent explorations of crime concentration at places was conducted by Sherman et al. (1989), who found that 50% of calls to police in Minneapolis in a year came from just 3.3% of the addresses and intersections. When specific crime types were analyzed, the concentrations were found to be even greater: all calls related to auto theft were associated with 2.7% of the places, all robberies were associated with 2.2% of the places, and all rapes were associated with 1.2% of the places (ibid.).

In the more recent decades, an influential study was conducted in Seattle, where Weisburd et al. (2004), using official crime data, found that all of the crimes in the city over a 14-year period were associated with approximately half of the street segments. In this study, 50% of the crimes were clustered at just 4-5% of the street segments (ibid.). Later, other studies have, by and large, replicated the findings of the two aforementioned studies, with results showing 50% of crime associated with 3-5% of places, or close to that bandwidth (Andresen & Linning 2012; Andresen & Malleson 2011; Andresen et al. 2017; Boivin & de Melo 2019; Curman et al. 2015; de Melo et al. 2015; Favarin 2018; Hardyns et al. 2019; Jaitman & Ajzenman 2016; Schnell et al. 2017; Stanković 2021; Weisburd 2015; Weisburd & Amram 2014). Regarding 25% of crime, several studies have concluded that around 1% of places account for this percentage (Chainey et al. 2019; Haberman et al. 2017; Hardyns et al. 2019; Jaitman & Ajzenman 2016; Perry 2020; Weisburd 2015; Weisburd & Amram 2014).

However, some studies have found crime to be less concentrated than the percentages reported in the previous paragraph, while still finding evidence of crime concentration (Breetzke & Edelstein 2019; Chalfin et al. 2021; Šimon & Jíchová 2020; Steenbeek & Weisburd 2016; Umar et al. 2020), while others actually have found crime to be concentrated at place to an even greater extent (Braga et al. 2011; Chainey et al. 2019; Gill et al. 2017; Hibdon et al. 2017; Vandeviver & Steenbeek 2019; Weisburd et al. 2009). Still other scholars have taken a different approach, examining the street segments that are in the top 5% of crime, also generating support for concentration, with bandwithds around 50-80%

of crime in these street segments and over 90% for some crime types (Braga et al. 2010; Hipp & Kim 2017; Levin et al. 2017).

Why some places have more crime than others

Research has also shown that observed crime concentrations tend to be fairly stable over time (Andresen & Malleson 2011; Andresen et al. 2017; Braga et al. 2011; Breetzke & Edelstein 2019; Curman et al. 2015; Gill et al. 2017; Hardyns et al. 2019; Hibdon et al. 2017; Jaitman & Ajzenman 2016; Levin et al. 2017; Perry 2020; Stanković 2021; Vandeviver & Steenbeek 2019; Weisburd 2015; Weisburd et al. 2004; Weisburd et al. 2009). The temporal stability of high crime street segments was studied in Seattle by Weisburd et al. (2012), who found that variables related to both social disorganization and opportunity theories of crime could distinguish persistent high crime street segments from others. The strongest correlates of such hot spot segments included social disorganization measures like measures of housing assistance, values of property, collective efficacy, and physical disorder, including the presence of truant juveniles on street segments, as well as opportunity measures such as the presence of bus stops and arterial roads, public facilities, employees and residents, and ”high risk” juveniles (ibid.).

The measures of high risk juveniles (likely offenders) and residents, employees and public facilities (suitable targets) are drawn from the highly influential routine activity theory. According to this theory, the risk of a crime taking place is elevated when a likely offender, a suitable target and the absence of a capable guardian converge in time and space (Cohen & Felson 1979). From this perspective, crime would cluster at places where these three elements continuously come together. Regarding social disorganization theory, different versions of the theory exist, all stressing the importance of factors related to neighborhoods in facilitating crime. Originally the theory postulated that neighborhoods characterized by poverty, residential mobility and ethnic heterogeneity have a limited ability to exercise social control, which in turn makes crime more likely (Bursik & Grasmick 1993). The concept of collective efficacy has evolved out of social disorganization theory and is hypothesized to be rooted in the social disorganization variables. Collective efficacy, which is defined as a combination of social cohesion among residents and their willingness to intervene for the common good, has been found to be negatively related to violence in neighborhoods, and also to mediate the association between social disorganization variables and violence (Sampson et al. 1997). However, it is problematic to transfer the neighborhood-level mechanism of collective efficacy to the street segment level and draw conclusions about its link to persistent crime concentrations at this level (Braga & Clarke 2014), which puts into question the operationalization made and conclusions drawn by Weisburd et al. (2012) in this regard.

Nonetheless, a study has found that the social disorganization variable of concentrated disadvantage at the neighborhood level is positively related to crime concentration at the street segment level, and also found support for interaction effects between social disorganization and routine activity theory variables (Jones & Pridemore 2019). Similarly, interaction effects between variables derived from social disorganization theory and routine activity theory have been found to contribute to the spatial concentration of street robberies at face blocks (street segments) in another study (Smith et al. 2000). Additionally, a Swedish study found that low collective efficacy at the neighborhood level was associated with higher levels of violence around bus stops (Gerell 2018a). Moreover, the studies cited in this paragraph also concluded that the presence of certain facilities, such

as retail stores (Jones & Pridemore 2019; Smith et al. 2000), bars (Gerell 2018a; Jones & Pridemore 2019; Smith et al. 2000), gas stations (Jones & Pridemore 2019; Smith et al. 2000), restaurants (Gerell 2018a; Jones & Pridemore 2019; Smith et al. 2000), motels and hotels (Jones & Pridemore 2019; Smith et al. 2000), and ATMs (Gerell 2018a) was related to crime at places.

The importance of such facilities and different land uses for the concentration of crime at places can be related to crime pattern theory. In the framework of this theory, facilities such as these can be understood as crime generators, which are locations that attract many people and thus provide opportunities to commit crimes, or crime attractors, to which offenders are attracted because of their known opportunities to commit crimes (Brantingham & Brantingham 1995). Another important type of place in the theory is edges, which are barriers or boundaries between areas with different characteristics or land uses, and also have been linked to high crime rates (ibid.). Crime pattern theory posits that crime is likely to occur at such places, and generally at places where the activity spaces of many potential victims and offenders intersect, such as central places like work or school (nodes) and the paths leading to and from them (ibid.). This has found partial support in research showing that flows of large amounts of people (bus passengers) are related to crime hot spots in Sweden, particularly for theft and violence (Gerell 2021). A somewhat related suggested explanation of why crime tends to concentrate at places is that human activity in general is concentrated, and crime concentration thus should be understood as a reflection of this concentrated activity (Weisburd 2015).

Other findings from research on crime concentration

Other findings from the literature on crime concentration include: more serious, violent crime tends to be more highly concentrated than less serious, non-violent crime (Andresen & Linning 2012; Andresen & Malleson 2011; Andresen et al. 2017; Chainey et al. 2019; Favarin 2018; Hardyns et al. 2019; Hipp & Kim 2017; Jaitman & Ajzenman 2016; Levin et al. 2017; Sherman et al. 1989; Stanković 2021); crime tends to be more highly concentrated in smaller compared to bigger cities (Gill et al. 2017; Weisburd 2015 – but see Chainey et al. 2019 for another result); and observed crime concentrations tend to be higher than randomized, counterfactual concentrations (Chalfin et al. 2021; Levin et al. 2017; Sherman et al. 1989; Weisburd et al. 2009). The law of crime concentration has also been tested for specific types and categories of crime, such as burglary (Vandeviver & Steenbeek 2019), robbery (Braga et al. 2011; Haberman et al. 2017), gun violence (Braga et al. 2010), drug activity (Hibdon et al. 2017), juvenile crime (Weisburd et al. 2009), and terrorism (Perry 2020), generating support for the law across all these types and categories.

The majority of studies on crime concentration has been conducted in North America, but in recent years tests have also been carried out in countries in Africa (Breetzke & Edelstein 2019; Umar et al. 2020), Israel (Perry 2020; Weisburd & Amram 2014), and countries in Latin America (Chainey et al. 2019; de Melo et al. 2015; Jaitman & Ajzenman 2016), with support for the law established in all these contexts, especially in Latin America where crime seems to be even more concentrated than in Western developed countries. European studies include research from the Czech Republic (Šimon & Jíchová 2020), Serbia (Stanković 2021), Italy (Favarin 2018), Belgium (Hardyns et al. 2019; Vandeviver & Steenbeek 2019), the Netherlands (Steenbeek & Weisburd 2016), and Norway (Allvin 2019). So far, the law of crime concentration seems to hold in a European context, with variation from country to country, but no study in this field has come

out of Sweden. Likewise, the law has not been tested in a whole country, with the most large-scale studies to date, to the best of the author's knowledge, being those conducted by Hipp and Kim (2017) and Chainey et al. (2019), which included 42 cities each in California and Latin America, respectively. The law held in these large-scale studies, too. The present study aims to begin to close some of the gaps in the knowledge base by testing the law of crime concentration in all densely populated parts of the whole country of Sweden.

METHODS

The present study employed a quantitative approach to answer the research questions. Below the data, the analytical strategy and ethical considerations are described and discussed.

Data

The data used for this thesis are drawn from a research project on vulnerable neighborhoods in Sweden (Gerell et al. 2021). National grid net data, where all densely populated areas of Sweden are divided into 250 x 250 meter squares/pixels (N = 116 660), were provided by Statistics Sweden, and data from other sources were joined to the grid cells. In the analysis, ”one place” is operationalized as one of the 250 x 250 meter pixels. It is important to point out that only the densely populated parts of the country, in the form of densely built-up areas (tätorter in Swedish), are included in the data set. Densely built-up areas are interconnected settlements with at least 200 inhabitants, and in 2018 around 87% of the Swedish population lived in such areas (Statistiska centralbyrån [SCB] 2020), that are included in this data. In essence, this means that around 2000 densely built-up areas are included in the data (ibid.). However, while the vast majority of the population lives in places included in the data, well below 1% of the area of Sweden is covered by the pixels, since the majority of the country consists of forests and other sparsely populated areas. It is important to keep in mind that it is the densely populated areas that are referred to as ”the whole country” in this study.

For the purposes of this thesis, variables covering nine different crime categories, the name of the municipality to which each pixel belongs, and the population size of the municipalities to which the pixels belong were taken from the original data set. The data on population size are taken from Statistics Sweden and are from the year 2018 (Gerell et al. 2021), and the crime data are based on police reports, which can be generated by police themselves but most often are created after a crime is reported to the police. The data cover illegal firearm discharges November 2016-2019 and outdoor crime 2016-2019 (ibid.). Since November 2016, the Swedish police tracks all gun violence in the illegal firearm discharge registry. The offences registered in this registry include homicide, attempted homicide, vandalism, aggravated assault, and crimes against the weapons act (ibid.). Police reported outside crime includes the offences assault, robbery, assaulting a public official, public endangerment through bombing, bicycle theft, theft from a motor vehicle, vandalism, and narcotics crime (ibid.). Some of the illegal firearm discharges may also be included in the data on the violent crime types, but since the illegal firearm discharges are few this is not likely to matter in regard to the results (ibid.). Since the data set was originally created for a research project on vulnerable neighborhoods in Sweden, these specific crime types were included because they represent crimes that occur outdoors and for this reason can have an impact on inhabitants in neighborhoods.

Although Swedish statistics do not distinguish between reported crimes based on how and by whom they were reported, most of the crime data in this data set are comparable to what is often called ”calls for services” in international research (e.g., Hibdon et al. 2017; Sherman et al. 1989), since the majority of the reported crimes are generated from citizen reporting (Gerell et al. 2021). For crimes like narcotics crime and weapons crime on the other hand, the source is often the police themselves, which means that data on these crimes also are measures of police activity (Brottsförebyggande rådet [Brå] 2006; Gerell et al. 2021). All crime data were registered at an address, then automatically geocoded to a coordinate in the SWEREF coordinate system by the police, and finally aggregated to 250 x 250 meter pixels (Gerell et al. 2021).

Analytical strategy

The present study examined the spatial concentration of crime among all places in the data set, which has been labeled ”prevalence” by some scholars and can be contrasted with ”frequency”, where only places where at least one crime has been registered are studied (Lee et al. 2017). The percentage of places accounting for 25 and 50% of the crimes has been studied frequently in previous research (see ”Literature review” above). The figure of 80% is derived from the so called Pareto principle, also known as the rule of 80/20. According to this principle, around 20% of the causes are responsible for around 80% of the outcome, which can be applied to various aspects of nature and society (Sanders 1987), including crime distribution, where 80% of the crimes would be thought to be accounted for by 20% of the places, which was tested by Allvin (2019) in Oslo.

To examine how many percent of the places (pixels) are required to account for 25, 50 and 80% of the total crimes in Sweden, first all the crime types were summed into an additive index using SPSS (IBM SPSS Statistics 27, IBM, New York, US). Cronbach’s alpha for the total crime index was .54. Then descriptive statistics (frequencies) were obtained for this index in SPSS, and the table generated in the SPSS output was copied and pasted into Excel (Microsoft Excel 365, Microsoft, Redmond, US).

In Excel, the number of crimes was multiplied with the number of pixels at which this number of crimes had occured for every row, and the values for all rows were added to obtain the total number of crimes for the whole country (1 074 736 crimes). Then the number of crimes for a chosen row was added to the number of crimes for all rows below it in the table, and the sum was divided with the total number of crimes, until numbers of crime representing 25, 50 and 80% of the total were identified. It can be noted that not exactly 25.0, 50.0 and 80.0% of crimes were calculated using this method, but the closest alternative was chosen, usually no more than one percentage point away from these figures. At the same row, the number of pixels was added to the number of pixels for all rows below it in the table, and the sum was divided with the total number of pixels (116 660), thus obtaining what percentage of pixels corresponds to a certain percentage of crimes.

When analyzing the concentration of violent and property crime, indices were also created. Assault, robbery and assaulting a public official were combined into an additive index for violent crime, while bicycle theft, theft from a motor vehicle and vandalism were added into a property crime index, both in SPSS. Thereafter, the procedure was identical to the one described for total crime above, with the concentrations for violent and property crime being examined separately. Bombings and illegal firearm discharges were not included in the violent crime

index because these crimes are rare (a total of 383 and 936 registered crimes, respectively) and would not impact the results. Cronbach's alpha was .63 for the violence index and .26 for the property index, in the latter case due to inconsistency for vandalism in relation to the other two crime types. Nevertheless, this index was used to include all property crimes in the analysis. However, because of the low Cronbach's alpha for this scale, an additional property crime index was created without vandalism, but including the other two crime types, with a Cronbach's alpha of .58. This index was also included in the analysis.

To examine differences in crime concentration for all crimes between small, medium-sized and big cities, "Select Cases" was chosen in SPSS, and for small cities the cut-off point was set at 39 999 or fewer inhabitants. For medium-sized cities, a range between 40 000 and 199 999 inhabitants was chosen, and those cities with 200 000 inhabitants or more were deemed big. These cut-off points were adapted from the recommended way to divide Swedish municipalities into categories provided by Sweden's Municipalities and Regions (Sveriges Kommuner och Regioner [SKR] 2021). Then descriptive statistics (frequencies) were run for the total crime index with these filters from "Select Cases", and the procedure was identital to the one described above, with the concentrations for the three categories of cities being examined separately in Excel.

To answer the fourth research question, initially a randomized Poisson distribution with the same mean as the variable for total crime for the whole country (9.2) was generated in SPSS. Poisson distributions have previously been constructed by researchers to generate randomized distributions to compare with observed crime concentrations (Levin et al. 2017; Sherman et al. 1989; Weisburd et al. 2009). However, since Poisson distributions increasingly resemble normal distributions as the means get higher, to the point of completely resembling normal distrubutions when the means are as high as 12 (The Analysis Factor n.d.), the obtained distribution was deemed to be too similar to a normal distribution and to have too few zeros to be comparable to the highly skewed total crime variable. For this reason, a randomized Poisson distribution with the same mean as the violent crime index, which has the lowest mean among the crime indices (1.1), was generated to be distributed across the 116 660 pixels in SPSS. The output covering the descriptive statistics (frequencies) for this variable was exported to Excel, but since the values for this variable only range from 0 to 8 it was not possible to calculate 25, 50 and 80% of the "crimes" using the method described above. Therefore, the concentrations of 10, 30 and 67% of the "crimes", which were possible to obtain, were calculated and compared to the concentrations of 10, 30 and 67% of the violent crimes, which were calculated for this purpose.

Descriptive statistics for all the crime indices used in the analysis and crime in different categories of cities are displayed in Table 1. Illegal firearm discharges, bombings and narcotics crime were included in the total crime index, but not the violent and property/non-violent crime indices, and thus are presented separately in Table 1 to give an overview of all crime variables in the data set. Also included are the second property crime index, vandalism, which was exluded from this index, and the Poisson distribution. As can be seen, the crime variables are highly skewed, as a result of a plurality of the pixels having no recorded crime at all.

Table 1. Descriptive statistics for crime at the pixels and the Poisson distribution.

Variable	Total	Min	Max	Mean	SD
Total crime, the whole country	1 074 736	0	6222	9.2	53.9
Violent crime, the whole country	124 865	0	731	1.1	7.2
Property crime, the whole country	665 293	0	4249	5.7	38
Property crime without vandalism, the whole country	330 185	0	891	2.8	11
Illegal firearm dis., the whole country	936	0	11	.01	.11
Bombings, the whole country	383	0	6	.00	.07
Narcotics crime, the whole country	283 259	0	2296	2.4	17
Vandalism, the whole country	335 108	0	4237	2.9	33.2
Total crime, small cities	211 323	0	470	3.6	11.8
Total crime, mid-sized cities	458 248	0	1939	9.1	37.3
Total crime, big cities	405 165	0	6222	51	175.9
Poisson distribution	129 247	0	8	1.1	1

Ethical considerations

It is important that no participants are harmed in any way as a result of their participation in research, and that societal interests related to research are not valued more than the security of individuals (Vetenskapsrådet 2017). The integrity of the individual should always be protected (ibid.) and the four main principles of research in the social sciences – the principle of informing participants about the purpose of the research, the principle of informed consent, the principle of confidentiality, and the principle of only utilizing obtained information for purposes of the research project (Vetenskapsrådet 2002) – should be respected when conducting research on participants. However, sensitive data or data related to individuals were not studied in the present thesis. Although the geographic units studied are small, no information can be tied to individuals, and pixels with few inhabitants were registered as missing on some variables to ensure that no individual could be identified. The author's supervisor has made an application to the Ethical Review Agency in Sweden and received the verdict that ethical review is not necessary for this data set (decision: Etikprövningsmyndigheten 2020-01125).

RESULTS

Results pertaining to the first and third research questions are available in Table 2 below. It can be concluded that crime concentration exists to a remarkable extent for the whole country of Sweden, with just 0.4% of the places accounting for 25% of the total crimes, 2.3% of the places accounting for 50% of the total crimes, and 10.2% of the places accounting for 80% of the total crimes. The results for property crime studied separately are similar to the results for total crime, while violent crime is concentrated to a greater extent: 25% of violent crimes are concentrated at just 0.25% of the pixels, 50% at just 1.4%, and 80% at 6.2% of the pixels. It can also be seen that property crime excluding vandalism is not as strongly concentrated as the property index with this crime included. χ^2 (chi square) tests were conducted and all differences between the concentrations of violent crime, property crime and property crime excluding vandalism, for 25, 50 and 80% of the crimes, were significant at the .001 level, which was to be expected given the size of the data set.

Table 2. Crime concentrations for the whole country of Sweden.

	Percentage of pixels accounting for 25% of crime	**Percentage of pixels accounting for 50% of crime**	**Percentage of pixels accounting for 80% of crime**
Total crime, the whole country	0.4%	2.3%	10.2%
Violent crime, the whole country	0.25%	1.4%	6.2%
Property crime, the whole country	0.3%	2.3%	9.8%
Property crime without vandalism, the whole country	0.75%	3%	11.2%

Regarding the difference between crime concentrations in small, medium-sized and big cities, results are displayed in Table 3. Here it is shown that crime is less concentrated in all three categories of cities compared to the whole country. Among the categories, crime is most highly concentrated in the medium-sized cities, with 0.7, 3.2 and 11.9% of the places accounting for 25, 50 and 80% of the total crimes, respectively. However, these concentrations are quite similar to those obtained for the small cities, whereas crime is concentrated at places to a lesser extent in the big cities, where 25% of the crimes occured at 0.9% of the pixels, 50% at 4.5% of the pixels, and 80% at 19.5% of the pixels. The differences between medium-sized and big cities at 25% concentration and between small and

Table 3. Crime concentrations for different categories of cities.

	Percentage of pixels accounting for 25% of crime	**Percentage of pixels accounting for 50% of crime**	**Percentage of pixels accounting for 80% of crime**
Small cities	1.0%	3.8%	12.9%
Medium-sized cities	0.7%	3.2%	11.9%
Big cities	0.9%	4.5%	19.5%

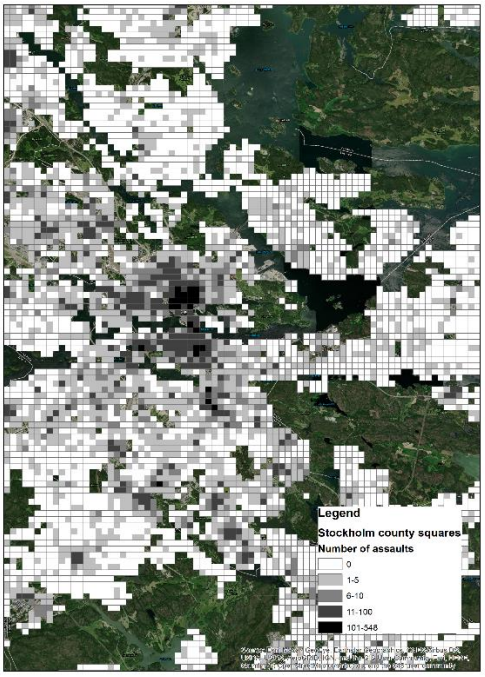
big cities at 50% concentration were statistically significant at the .05 level, while the difference between small and big cities at 25% concentration was not significant, since it is only a difference between 1.0% and 0.9% of the pixels. The remaining differences were significant at the .001 level.

Table 4 displays the results from the comparison between the observed concentration of violent crime in the whole country and a randomized, counterfactual Poisson distribution. The actual crime concentration is considerably stronger than the counterfactual one. The percentage of pixels accounting for 10% of the ”crimes” in the Poisson distribution (2.6%) most closely resembles the percentage of pixels accounting for 67% of the violent crimes (3.3%). At 10% of ”crimes”, the concentration of violent crimes is 52 times stronger than the one for the random numbers (0.05% of pixels compared to 2.6%), and at 30 and 67%, the violence concentration is 25 times (0.4% compared to 10%) and 9.2 times (3.3% compared to 30.4%) stronger, respectively. The χ^2 tests showed that all these differences were significant at the .001 level.

Table 4. Violent crime concentration compared to a random Poisson distribution.

	Percentage of pixels accounting for 10% of ”crime”	**Percentage of pixels accounting for 30% of ”crime”**	**Percentage of pixels accounting for 67% of ”crime”**
Violent crime, the whole country	0.05%	0.4%	3.3%
Poisson distribution	2.6%	10%	30.4%

Figures 1 and 2 provide a visualization of the strong concentration of violent crime, as exemplified by assault, in Stockholm and Malmö respectively, in maps created by the author’s supervisor Manne Gerell. As can be seen, the darker pixels with many recorded assaults are few and concentrated in the central parts of both cities.



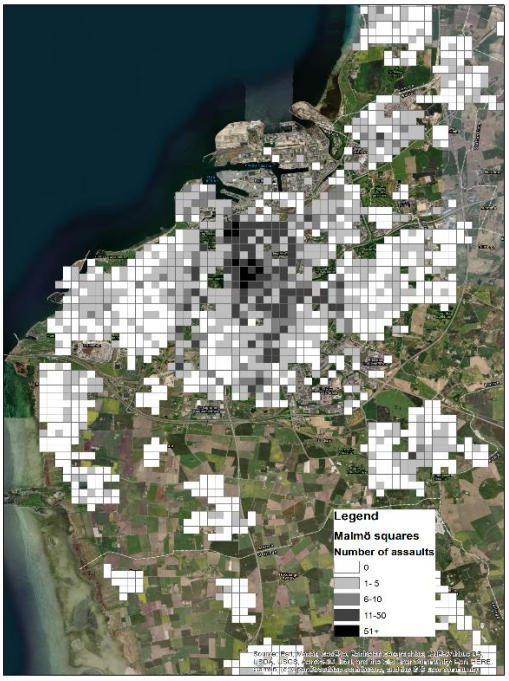


Figure 1. Assault concentration in Stockholm. *Figure 2*. Assault concentration in Malmö.

DISCUSSION

For the first time, to the best of the author's knowledge, the law of crime concentration was tested for a whole country (all densely populated parts) in this thesis. The results for all crimes in the whole country of Sweden show that crime is concentrated at places to a greater extent than what has been found in most previous studies, where a smaller amount of cities was examined. Indeed, the results showing that 25% of all crimes are clustered at 0.4% of the places and 50% of crimes at 2.3% of places reveal stronger concentrations than the ones predicted by Weisburd (2015) when he presented the law of crime concentration. However, since the data solely cover Sweden's densely built-up areas, of which there are around 2000, it can be noted that the crime concentrations would have been even stronger had the whole territory of the country, including forests and other sparsely populated areas where very few crimes occur, been analyzed. Moreover, not all crimes in Sweden from the years 2016-2019 for the included crime types were analyzed in this study, since not all crimes are reported to or recorded by police.

Nevertheless, the finding that crime is more highly concentrated in the smaller compared to the bigger cities is consistent with previous research (Gill et al. 2017; Weisburd 2015), as is the result showing stronger concentrations for violent crime than for property/non-violent crime (Andresen & Linning 2012; Andresen & Malleson 2011; Andresen et al. 2017; Chainey et al. 2019; Favarin 2018; Hardyns et al. 2019; Hipp & Kim 2017; Jaitman & Ajzenman 2016; Levin et al. 2017; Sherman et al. 1989; Stanković 2021). The Pareto principle, according to which 80% of the outcome is thought to be associated with 20% of the causes (Sanders 1987), came closest to hold true for 80% of the crimes in the big cities, which were accounted for by 19.5% of the pixels. Otherwise, the results regarding 80% of crime were somewhat similar to those obtained by Allvin (2019), who found that 80% of commercial burglaries were accounted for by 11.7% of the cells. The result showing that the violent crime concentration was considerably stronger than the counterfactual, randomized concentration is also in line with findings in previous studies (Chalfin et al. 2021; Levin et al. 2017; Sherman et al. 1989; Weisburd et al. 2009). The robustness of the results can be inferred from the fact that the χ^2 tests showed that almost all the observed differences were highly statistically significant.

In Table 1 it can be observed that the mean number of crimes at pixels in the big cities is 51, compared to 9.1 and 3.6 in the medium-sized and small cities, respectively. When observing the whole country, crime becomes more concentrated than what is the case for either small, medium-sized or big cities, because the high-crime pixels in the big cities have a greater impact compared to the smaller cities when all pixels are considered. Similarly, the importance of the smaller amount of crimes in the small cities diminishes when the whole country is examined, when these crimes "disappear" among the greater concentration of crimes in the bigger cities. The findings regarding differences between big and small cities is in line with the literature, where it is well established that big cities have considerably more crime than small cities, for example due to demographic factors like the presence of more female-headed households (Glaeser & Sacerdote 1999).

Regarding the stronger concentration for violent compared to property crime, it is known that the violent crime rates are much higher in big cities compared to smaller ones (Glaeser & Sacerdote 1999). The concentrations of assault in

Stockholm and Malmö, two of Sweden's three biggest cities, are visualized in Figure 1 and 2. This exemplifies a strong clustering of violence in the central parts of the big cities. It is possible that these concentrations of violence in the big cities have a greater impact when compared to property crime, thus rendering stronger concentrations for violent crime. In these central areas of the big cities entertainment facilities are located and many people converge in time and space, which would give support to aspects of routine activity and crime pattern theory. Another possible explanation of why violent crime is more highly concentrated than property crime is that there are fewer violent crimes than property crimes, as can be seen in Table 1. Because of this, it is also more likely that these fewer violent crimes will concentrate in fewer of the pixels.

The Poisson distribution was not optimal. Initially, the plan was to compare the concentration of all crimes in the densely populated areas of Sweden to a Poisson distribution. However, the Poisson distribution created with the same mean as the total crime scale had too few zeros and was deemed too similar to a normal distribution to make it meaningful to compare it to the crime scale. Therefore, a Poisson distribution with the same mean as the violent crime index, which is lower, was created and the random distribution was compared to violent crime. Still the zeros in the counterfactual distribution can be regarded as too few (38 446 or 33% of the total, compared to 92 379 or 79.2% of the total for the violent crimes). Additionally, because the pixels in this distribution were distributed across 0-8 ”crimes”, concentrations at 25, 50 and 80% were not possible to calculate with the method used in this paper. For this reason, other percentage points were calculated and compared to the corresponding percentage points for the violent crime scale. These limitations notwithstanding, it has been recommended that studies on crime concentration should test if crime could have been highly concentrated by chance (Levin et al. 2017), and the results regarding the random distribution indicate that violent crime indeed is significantly more unequally distributed than what would be expected by chance alone. For example, the Poisson distribution suggests that no pixels should have more than 8 ”crimes”, whereas in the violent crime distribution many pixels have more than 8 crimes, with some pixels having several hundred crimes.

As mentioned in the introduction, research has shown that microgeographic units account for most of the variability of crime when compared to larger spatial units (Schnell et al. 2017; Steenbeek & Weisburd 2016). Similarly, in a Swedish context, a study found that the smallest geographical units explain most of the variance of arson (Gerell 2017). Likewise, Andresen and Malleson (2011) emphasize the importance of studying crime at micro places for a satisfactory understanding of crime. Some scholars have argued that smaller spatial units are superior to larger ones because they are more internally homogenous and more closely resemble behavior-settings, that is, environments that individuals can experience with their senses, which are the environments hypothesized to influence individuals' actions (Oberwittler & Wikström 2009). For these reasons, it is a strength of the present study that it examines crime at a small geographical scale, i.e., the 250 x 250 meter pixels, which could be considered behavior-settings (Hardyns et al. 2019).

The problem of scale/size of geographical units is one aspect of the modifiable areal unit problem (MAUP), according to which the definition and understanding of areas can impact the results (Gerell 2017; Oberwittler & Wikström 2009). Another aspect of the MAUP relates to zonation, i.e., the problem of drawing boundaries that are meaningful and not arbitrary within an area (ibid.). The

MAUP also operates at the scale of small geographical units (Gerell 2017), and where the boundaries are drawn between different units of analysis, i.e. the pixels, can have an impact on the results, which is important to consider regarding the present study. Another pitfall that can be regarded as related to the MAUP concerns the geographical reliability of police recorded crime data. The Swedish police records reported crimes at specific addresses, even in instances where a crime has occured at a place that does not have a specific address or when the exact address is unknown (Gerell 2018b). This can result in some places appearing to have more or less crime than what is actually the case when the addresses are geocoded to exact locations on a map (ibid.). The extent of this problem was probed for motor vehicle arson by Gerell (2018b), who compared data from the police and the rescue services, which could be deemed more reliable, and concluded that the median error for the police data for this crime was 83 meters. Since the coding of motor vehicle arson is more geographically reliable than many other crimes (ibid.), and since the present study is based on police recorded crime data, this is worth contemplating when interpreting the results. However, since the data were aggregated to 250 x 250 meter pixels these errors tend to even out, with some pixels having higher and some lower values than the actual ones, and the overall impact should be limited considering the size of this data set (Gerell et al. 2021).

The most utilized microgeographic unit of analysis in studies on crime concentration has been street segments, also called face blocks, which are defined as both sides of a street between two intersections (e.g., Weisburd et al. 2009). This could pose problems regarding comparability for the present study, where the microgeographic unit analyzed was 250 x 250 meter pixels. However, recently some studies analyzing pixels/squares/grid cells have been published, such as the ones conducted by Hardyns et al. (2019) in Belgium, where the unit of analysis was 200 x 200 meter grid cells, by Allvin (2019) in Norway, who analyzed 100 x 100 meter grid cells, and by Stanković (2021) in Serbia, where grid cells of 100 x 100, 500 x 500, and 1000 x 1000 meters were utilized. In a European context, street segments might be a less appropriate unit of analysis, since the length of street segments can vary considerably, unlike the major American cities with their gridiron plans (Hardyns et al. 2019). Another advantage of pixels/grid cells compared to street segments is that the former are standardized, meaning that all pixels have the same dimensions, which also might be advantageous in regard to the MAUP (ibid.). Furthermore, the present study examined the percentage of pixels accounting for 25, 50 and 80% of crime. Some researchers propose other approaches to measuring and presenting results for crime concentration, such as the Gini coefficient and the Lorenz curve (Bernasco & Steenbeek 2017). An advantage of the Gini coefficient is that crime concentrations can be studied without cut-offs like 25 or 50%, which can be considered arbitrary, but it is also difficult to interpret, especially when communicating results for crime concentration to a wider audience (Chalfin et al. 2021). Additionally, most studies examine percentages and thus comparisons between the results obtained in this study and other findings are facilitated in this regard (Chainey et al. 2019), and Weisburd's (2015, page 138) law of crime concentration was formulated in terms of a "bandwidth of percentages".

Although the major contributions to the criminological literature of the present study are in the theoretical and empirical domains, for the first time testing the law of crime concentration in Sweden and for all densely populated areas of a whole country, the results do have practical implications. The fact that crime is highly concentrated at a small proportion of micro places in Sweden suggests that

interventions and crime prevention measures should be adjusted accordingly. This entails place based interventions like situational crime prevention where, for example, certain features of high-crime places could be manipulated and opportunities and situations could be altered to prevent crime (Clarke 1980). Particularly relevant is hot spot policing, a police strategy where resources and interventions are targeted at the small places where crime is most strongly concentrated (Braga et al. 2012). Hot spot policing has proven to be effective in reducing crime (ibid.), and there are promising but inconclusive results regarding hot spot policing in Sweden (Brå 2014; Frogner et al. 2013). Given the strong crime concentrations found in this paper, this is something that should be considered to be implemented and evaluated more in a Swedish context.

CONCLUSIONS

In the largest-scale study on crime concentration to date, to the best of the author's knowledge, it was found that crime is strongly concentrated at places in Sweden. Given the lack of research on this topic in a Swedish context, this paper took an explorative approach to explore the extent to which crime is concentrated in the country, differences in concentration between cities of varying size, and differences in concentration between crime types. This study is not without its limitations, which have been mentioned above, and future research should build on the findings in this thesis and go further in exploring crime concentration in Sweden.

Since so much crime occurs at so few places, it is pivotal to understand these places in-depth (Andresen & Malleson 2011). Future research on crime concentration in Sweden should employ more sophisticated statistical methods, examine the temporal and spatial stability of crime concentrations, study crime types not included in the data set analyzed here, and explore the causes and correlates of crime concentrations at certain places, among other aspects. The present study, the author hopes, could spur interest and further investigations by taking the first steps.

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