SOCIO-ECONOMIC DETERMINANTS OF SPRAWL: CAUSES AND CONSEQUENCES OF URBAN GROWTH IN SWISS MUNICIPALITIES

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Abstract

In Switzerland, as elsewhere, over the past decades, urban areas have spread outwards – consuming the surrounding countryside in the process. The result has been an urban growth associated with negative effects such as the loss of cultivated land.

Sprawl is the term often used to describe this process, accentuating the perceived inefficiencies of the undesirable development. A number of hypotheses have been forwarded to explain sprawl, but empirical evidence of factors that influence sprawl per se is limited. The main objective of this thesis it to develop a sound understanding of socio-economic drivers of urban growth and to gain insights into the determinants of spatial patterning of land consumption.

Chapter 2 presents a comprehensive overview on socio-economic factors that shaped urban development processes in Swiss municipalities over three decades. In order to grasp urban sprawl, four different measurements of particular forms of urban growth are considered. The study shows that accessibility, increasing wealth or an aging population have all been important determinants in fostering the extension of urbanised area, altering its densification but also stimulating the dispersion of settlements. Population growth, however, seems to have a less straight forward effect on urban growth than received opinion would suggest.

Chapter 3 focuses on the relationship between tax and urban growth. Following the theory of Tiebout, the analysis engages in how differences in local tax, impact land consumption. The findings show that a municipality's low tax scheme either leads to a reduction of per capita land uptake and growth of the settlement area – densification – or to a growth of the per capita land uptake – urban sprawl. The different outcomes – mitigated by the respective accessibility of the municipality – supports that planning policies should be coordinated with other sector policies such as tax or transport infrastructure policies.

Chapter 4 focuses on three subjects: land scarcity, low density settlement structure, and the influence of the inhabitants' affluence. The results underline that a limited supply of land for construction reduces the per capita land consumption and the extension of the area, and thus fosters densification. However, in those municipalities accommodating wealthier households, land scarcity has only limited impact on the reduction of land uptake. This might be due to affluent households having an interest in securing a relatively low density structure in their neighbourhoods. This, in turn, raises concerns over equity, and efficiency of policies that limit land for construction. Accordingly, when applying such policies, suitable accompanying measures should be taken.

Why is the question of socio-economic determinants of urban growth important? Managing land development in a sustainable way is a challenging task which requires a certain understanding of causes and consequences of urban

growth. As shown in this thesis, socioeconomic factors affect land development in expected ways but might also have unexpected effects, depending on circumstances, geographical scale or spillover effects. With such insights, this thesis hopes to further the understanding of those variations, in order to contribute to a sustainable use of land.

Keywords: Switzerland, urban sprawl, densification, spatial spillovers, land scarcity, land planning

Résumé

En Suisse, comme ailleurs, le milieu urbain s'est étendu en périphérie ces dernières décennies. Cela a entraîné une croissance urbaine associée à des effets négatifs tels que la perte de terres cultivées.

L'étalement urbain est le terme souvent utilisé pour décrire ce processus. Bien qu'il y ait un nombre d'hypothèses, les données empiriques sur les facteurs qui influent sur l'étalement urbain en tant que tel sont limitées. Le principal objectif de cette thèse consiste à développer une solide compréhension des moteurs socio-économiques de la croissance urbaine en Suisse, et à passer en revue les déterminants de la configuration spatiale de la consommation des terres.

Chapitre 2 présente un aperçu des facteurs socio-économiques qui ont façonné les processus de développement urbain en Suisse sur trois décennies. Afin de saisir l'étalement urbain, quatre mesures différentes sont prises en considération. L'étude démontre que l'accessibilité, l'augmentation de la richesse ou le vieillissement de la population ont été des déterminants importants. Ils ont encouragé l'extension de la zone urbanisée, la dispersion du bâti, mais aussi modifié sa densification. Contrairement aux idées reçues, la croissance démographique semble avoir un effet moins direct sur la croissance urbaine.

Chapitre 3 se concentre sur la relation entre la charge fiscale et la croissance urbaine. Suivant la théorie de Tiebout, l'article démontre quel est, sur la consommation des terres, l'impact des différences entre les régimes fiscaux locaux. Il en ressort que la faiblesse du régime fiscal d'une municipalité soit entraîné une réduction de l'utilisation des terres par habitant – densification –, soit occasionne une croissance de l'utilisation des terres par habitant – étalement urbain. Ces résultats différents – atténués par l'accessibilité des municipalités– confortent l'idée selon laquelle les politiques d'aménagement du territoire devraient être effectuées en coordination avec d'autres politiques sectorielles (par ex. politiques fiscales, infrastructures de transport).

Chapitre 4 se concentre sur la pénurie de terres, la structure résidentielle à faible densité et l'influence de la richesse des habitants. Les résultats indiquent qu'une offre limitée de terrains à bâtir réduit la consommation de terres par habitant et l'extension de la zone, et encourage par là même la densification. Néanmoins, dans les municipalités qui accueillent des habitants au revenu moyen élevé, la pénurie de terres a seulement un impact limité sur la réduction de la consommation de celles-ci. Cela pose problème quant à l'équité et l'efficacité des politiques qui limitent les terrains à bâtir. Par conséquent, lors de la mise en œuvre de telles politiques, des mesures d'accompagnement adaptées devraient être prises.

Pourquoi la question des déterminants socio-économiques de la croissance urbaine importe-t-elle? La gestion durable de l'aménagement du territoire est une tâche exigeante qui requiert une compréhension de la croissance urbaine. Comme cette thèse l'a démontré, les facteurs socio-économiques ont des effets prévisibles sur

l'aménagement du territoire, mais certains d'entre eux peuvent aussi être imprévisibles. Grâce à de telles réflexions, cette thèse espère approfondir la compréhension de ces variations, afin de contribuer à une utilisation durable des terres.

Mots-clés: Suisse, étalement urbain, densification, répercussions dans l'espace, pénurie de terres, aménagement du territoire

Zusammenfassung

Wie anderswo hat sich das Siedlungsgebiet auch in der Schweiz in den letzten Jahrzehnten ausgebreitet - und dabei immer mehr Umland versiegelt. Das Ergebnis ist ein Siedlungswachstum, das mit negativen Auswirkungen wie dem Verlust von Anbauflächen verbunden ist.

Zersiedelung ist der Begriff, der häufig verwendet wird, um die unerwünschte Entwicklung zu umschreiben. Zwar gibt es eine Anzahl Hypothesen, um Zersiedelung zu erklären, aber der empirische Nachweis von Faktoren, die Zersiedelung fördern, ist begrenzt. Das Hauptziel dieser Arbeit ist es, ein fundiertes Verständnis der sozioökonomischen Treiber des Flächenwachstums in der Schweiz zu entwickeln, auch um Erkenntnisse über die Gründe der räumlichen Strukturierung des Flächenverbrauchs zu gewinnen.

Kapitel 2 gibt einen Überblick über die sozioökonomischen Faktoren, die den Flächenverbrauch in den Schweizer Gemeinden über drei Jahrzehnte beeinflusst haben. Um Zersiedelung zu erfassen, werden vier verschiedene Messungen bestimmter Formen von Siedlungswachstum betrachtet. Die Analyse zeigt, dass zunehmende Erreichbarkeit, zunehmender Wohlstand oder eine alternde Bevölkerung sowohl die Ausdehnung des Siedlungsgebiets, die Streuung von Gebäuden, aber auch eine Verdichtung von Siedlungen begünstigten. Das Bevölkerungswachstum hingegen, scheint sich weniger direkt auf das hier gemessene Siedlungswachstum auszuwirken als landläufig vermutet.

Kapitel 3 erläutert den Zusammenhang zwischen der Steuerbelastung und Siedlungswachstum in den einzelnen Gemeinden. In Anlehnung an die Theorie von Tiebout beschäftigt sich die Analyse mit der Frage, wie sich Unterschiede in der Gemeindesteuer auf den Flächenverbrauch auswirkt. Die Ergebnisse zeigen, dass niedrige Steuern entweder zu einer Verringerung der Pro-Kopf-Flächenkonsums und einer Verringerung des Wachstums der Siedlungsfläche – Verdichtung – oder zu einer Zunahme der Pro-Kopf-Flächenkonsums und damit zu einer Entwicklung, die als Zersiedelung bezeichnet werden kann führen. Unterschiedliche Ergebnisse für ländliche und städtische Gemeinden – abhängig von ihrer jeweiligen Erreichbarkeit – unterstützen die Forderung, dass die Raumplanungspolitik mit anderen Sektoren (z.B. Steuer- und der Verkehrsinfrastrukturpolitik) koordiniert werden muss.

Kapitel 4 konzentriert sich auf Landknappheit, Wohnstruktur mit geringer Dichte und den Einfluss von Wohlstand. Die Ergebnisse der Studie unterstreichen, dass ein begrenztes Angebot an Bauland den Pro-Kopf-Flächenverbrauch und die Flächenausdehnung reduziert und damit die Verdichtung fördert. In den Gemeinden, deren Einwohner ein hohes Durchschnittseinkommen haben, hat die Baulandknappheit jedoch nur begrenzte Auswirkungen auf die Verringerung des Flächenkonsums pro Kopf. Dies könnte darauf zurückzuführen sein, dass wohlhabende Haushalte ein Interesse daran haben in ihrer Nachbarschaft eine relativ geringe Baudichte zu erhalten und eine weitere

Verdichtung zu vermeiden. Dies kann zu Problemen hinsichtlich Gerechtigkeit und Wirksamkeit von Massnahmen zur Begrenzung von Bauland führen. Daher sollten bei der Umsetzung solcher Politiken flankierende Massnahmen ergriffen werden.

Warum ist es wichtig, sich mit den sozioökonomischen Treibern des Flächenwachstums auseinander zu setzen? Nachhaltiges Landnutzungsmanagement ist eine anspruchsvolle Aufgabe, die ein Verständnis für Siedlungswachstum erfordert. Wie in dieser Arbeit gezeigt wird, beeinflussen sozioökonomische Faktoren die Flächenentwicklung in zu erwartender Weise, können aber auch unerwartete Auswirkungen haben. Dies in Abhängigkeit von Kontext und Umständen wie dem Zusammenspiel von verschiedenen Faktoren, der geografischen Ausdehnung oder gemeindeübergreifenden Effekten. Die Ergebnisse dieser Arbeit sollten ein Verständnis dieser Variationen fördern und zu einer nachhaltigen Landnutzung beizutragen.

STICHWÖRTER: Schweiz, Zersiedelung, Verdichtung, räumliche Zusammenhänge, Bodenknappheit, Raumplanung

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Chapter 1: Introduction

1.1. General Context: Urban Growth and Urban Sprawl

Various growth processes take place in Switzerland: not only is the population increasing, but so are settlement areas for housing, workspace and infrastructure. The consequences are palpable wherever new buildings spread further, penetrating into the rural landscape, blurring boundaries between cities and villages and merging the latter into agglomerations. Land is a limited resource, and whereas between 1985 and 2009 the population grew by 17%, the residential area grew by 44% (SFSO Swiss Federal Statistical Office, 2015). The overall built-up area increased 23%, respectively 0.9% annually, most frequently at the expense of farmland (Price et al., 2015). Currently, about 40 km2 of area is being built up each day (Bächtold, 2015).

The average population density for Switzerland is only around 188 inhabitants/km2 (SFSO Swiss Federal Statistical Office, 2013), but the spatial distribution of the population is very heterogenic. Most of the population has settled on the Swiss Plateau, and the very southern part of Ticino, where almost four-fifths of the 8 million inhabitants of the country (as in 2015) live – in the metropolitan regions of Zurich, Basel, Bern, Lausanne, Geneva, and Ticino. 77% of Swiss (2010) live in urban areas according to the census (SFSO Swiss Federal Statistical Office, 2010). Accordingly, in the metropolitan regions, the average population density is over 400 inhabitants/km2. Settlement growth is not confined to urban areas though. On the contrary, the settlement area is growing at a constant pace in almost all Swiss regions, even in the remote valleys of the Alps (Schwick et al., 2010). In fact, in some of the remote areas, both the land consumption and the growth of settlement area per person is slightly above the Swiss average (FOSD Federal Office for Spatial Development, 2004; Müller-Jentsch, 2010).

The high land consumption in Switzerland is in contradiction to the national principles of the strategy for sustainable development established in 2002, when the Federal Government set the objective to limit the settlement area at 400 m2/head. Despite the limit, the latest statistics, for the period of 1992/97 to 2004/09, indicate that land consumption per capita has grown from 400.9 m2/head to 406.9 m2/head (SFSO Swiss Federal Statistical Office, 2014c). However, as the preliminary results from the current survey of the land use statistics 2013/18 show, the pace of growth in land use consumption per capita might have slowed down (SFSO Swiss Federal Statistical Office, 2016b). In 2005, the Federal Office for Spatial Planning published a report (FOSD Federal Office for Spatial Development, 2005), in which it was very critical of the state of spatial development in Switzerland, describing it as unsustainable. There have been no further developments in the meantime which would revoke this description.

In recent years, the general public has expressed strong views against the current process of urban growth (Müller et al. 2010, Wissen 2010, Jaeger 2014). The issue of extensive urban growth and high land consumption was placed definitively on the national agenda in a public vote with unexpectedly high turnout. 63 percent of the Swiss population endorsed a revision thus strengthening the national law on spatial development in spring 2013. The

revision includes, among other things, measures to promote compact urban development through infill redevelopment and densification, the introduction of a nationwide tax on planning gains ("Mehrwertabgabe"), and the obligation to reduce the size of undeveloped building zones for which there is no predicted demand in the next 15 years (cf.2.2.3). Presently, several popular federal initiatives further respond to the public concern, e.g. the 'Zersiedelungsinitiative' ("sprawl initiative") which aims to allow future creation of new building zones only if similar land is withdrawn from the zoning area, or 'Für Ernährungssicherheit' ("initiative for food security") which calls for effective measures to address the loss of productive land. The 'Zersiedlungsinitiative' is currently submitted at federal level. An amendment of the constitution integrating some of the propositions of the 'Für Ernährungssicherheit' was subject to a popular vote in the fall of 2017 and was highly endorsed by the voters.

However, not only the general public, planners and political actors in Switzerland but also the scientific community lean towards the assessment that the pace and extent of urban growth and land consumption as described above – and typically referred to as urban sprawl – bring more negative than positive environmental and societal impacts. One important aspect is that soil is a finite resource, and its loss or destruction irreversible within a human lifespan. Various researchers point out that settlement encroaching on green areas causes ecological impacts by destroying or harming ecosystems, causing habitat fragmentation and increasing transportation and thus energy consumption and pollution. Moreover, it raises commuting and commuting times, infrastructure costs, noise, and contributes to the decline in social capital (Brown et al., 2005; Brueckner, 2000b; Gagné and Fahrig, 2010; Hammer et al., 2004; Theobald, 2005). A recent report from the European Environment Agency and the Swiss Federal Office for the Environment provides a comprehensive overview of the negative impacts of urbanisation (EEA European Environment Agency and FOEN Federal Office for the Environment, 2016).

Against that, proponents of the current urban development consider it an efficient outcome process as it fulfils resident's preferences for matters such as cheaper housing (Downs, 1999). Holden and Norland (2005), in a study carried out in the greater Oslo region, point out that living in suburbs with access to a private garden may actually limit the extent of leisure travel and thus reduces energy consumption in connection with transport (see also Gordon and Richardson, 2000). In this regard, it is particularly difficult to separate negative impacts of sprawl from its positive implications, since sprawl means different things to different people (Ulfarsson and Carruthers, 2006).

However, as Antrop (2004) puts it, settlement development changes the view of a landscape significantly. Eigenbrod et al. (2011) suspect that urbanisation will be the main cause of land-use changes in Europe. Thus, while it is important to keep in mind that urban sprawl is not an unambiguous subject, urban growth that encroaches on hitherto unsettled areas is largely considered to be a serious and harmful process and a grave threat to sustainability (Haber, 2007), especially when it conflicts with conservation targets, agriculture and social development.

In the light of the negative repercussions of the current urban growth (as discussed in this introduction), and particularly also in Switzerland, the Swiss Government initiated a CHF 13 million national research program on the topic of 'soil as a resource'. The present thesis is part of one research project entitled 'Controlling urban sprawl to limit soil consumption (SPROIL)'. The main focus of SPROIL is to better understand the planning and economic drivers of sprawl so as to develop tools to identify and mitigate uncontrolled urban growth, and also to focus on the knowledge gaps on urban growth. SPROIL aims at (1) assessing current spatial planning policies; (2) identifying socio-economic determinants of urban sprawl; and (3) developing a predictive tool to identify fertile soils particularly at risk of getting built up. The present thesis addresses the second of these three aspects. The two other

aspects of the SPROIL were addressed in two further PhD theses. Since the results derived from the analysis are part of the complete SPROIL project, the data used and the scale of the analysis in this thesis is compatible with aspect (1) and (3). The presented analysis of this thesis is both application-oriented and fact and data-driven, and aims at decreasing the gap between conceptual understanding and day-to-day management of spatial development in Switzerland. The main concern of the thesis is to gain knowledge on the socio-economic determinants of urban sprawl. To address the main concern, the thesis takes an empirical approach and resorts mainly to quantitative methods, such as regression modelling.

1.2. Research Challenges

As an answer to the above described threat to land use caused by sprawling urban development, Haber (2007) urges reliance on ecological science, monitoring and planning. Also other authors call for valid and reliable operationalisations for urban sprawl measurements to improve the (quantitative) knowledge-base, strengthen empirical results (Duranton and Puga, 2013), and thus contribute to a less normative discourse about urban growth (Burchfield et al., 2006a; Gómez-Antonio et al., 2016; Oueslati et al., 2014; Siedentop, 2005). Gaining knowledge on determinants of urban growth, e.g. on socio-economic factors that drive or hinder sprawl, is of academic interest but is also highly relevant to support land use planning and policy, and anticipating future urban growth processes (Antrop, 2004; Gómez-Antonio et al., 2016; Hersperger and Bürgi, 2010; Verburg et al., 2004). As Hersperger et al. (2010) remark, models relating determining forces directly to land changes (i.e. soil consumption) are especially suitable for modelling spatially predictive future scenarios. Placing urban land development in a wider context, and providing knowledge about urban growth is also of use in fields as diverse as climate change, landscape ecology or transportation. Urban growth can, for example, change precipitation patterns (Kaufmann et al., 2007) or reduce the supply of ecosystem services such as agricutural production (Alcamo et al., 2005).

However, and as Wissen and colleagues (2011) point out, future settlement development is difficult to predict; there are many factors that may lead to completely different alternatives regarding where and how people decide to live and work. Furthermore, these factors interconnect spatial, economic and political dimensions (Ulfarsson and Carruthers, 2006). In addition, and partly as a consequence of a narrow sprawl definition (cf. Chapter 2), relatively little is known about what determines the settlement pattern of land consumption, i.e. the density and spatial distribution of settlement development (Burchfield et al., 2006a). In consequence, it is often not clear which degree of urban growth should be assessed as being so harmful that further negative development should be strongly avoided.

Besides a lack of quantitative knowledge on urban growth, and the related difficulties of its predictions, a further challenge is the scope of analysis. The recent research on urban growth and sprawl has largely focused on assessing urban sprawl on the scale within confined areas, without considering the impact of this phenomenon beyond certain boundaries. In the north American context, Hamidi and Ewing (2014), for example, examined urban sprawl at the level of the 162 largest so-called urbanised areas in the U.S. (ESA, 2011) while Spivey (2008) considers all of the 452 urbanised areas. Burchfield et al. (2006b) in their often cited study on causes of urban sprawl used rasterised data across the conterminous United States with a very fine 30 m resolution to estimate the characteristics of urban growth (e.g. continuous vs. non-continuous) and assessed the causes of sprawl at the level of 275 individual metropolitan areas. Also in European studies, the focus is mostly on particular regions, cities or countries often involving a comparison between the study areas. Kasanko et al. (2006), provide an overview of the urban sprawl in 15 European cities since the 1950s, Oueslati et al. (2014), compare 282 European cities in their extent of urban

sprawl, Siedentop and Fina (2012) look at patterns of urban growth of 26 European countries and Pirotte and Madre (2011) study urban sprawl in the four largest metropolitan areas in France (see also Hennig et al., 2015; Salvati and Carlucci, 2015; Schwarz, 2010). Studies that consider the urban development of a whole country on a finer scale are missing. At the scale of municipalities, Fernandez Milan and Creutzig (2016) look at local tax policies and patterns of sprawl in 265 out of 8'188 Spanish municipalities, also for Spain, Hortas-Rico (Hortas-Rico, 2014) investigate the fiscal impact of sprawl in 4'000 municipalities, and Gomez-Antonio et al. (2014) investigate the causes of urban sprawl in 3'890 Spanish municipalities. Broitman and Koomen (2015), in contrast, look at the development of residential areas over time and considered the territory of the entire Netherlands employing rasterised data with a 100 m resolution. The approach of Broitman and Koomen is very detailed but does not take into account the political delineations, such as municipalities.

However, explaining urban growth in a delimited area and on too coarse a scale ignores the fact that the boundaries of cities and urban areas in general are permeable and stretched, both geographically and socially for them to be theorised as a whole (Amin and Thrift, 2002). Metropolises may have significant spillover effects into adjacent municipalities, for example because of commuting (Brown et al., 2005) or concentration of skilled workers in a specialised city (Duranton and Puga, 2013). In other words, urban extension is a cumulative result of many decisions and factors that aggregate over space and it is not an independent, isolated process (see also Carrion-Flores and Irwin, 2004). Hammer et al. (2004) argue that urban growth should be analysed at a grain fine enough to capture location-specific impacts, but also coarse enough to put patterns and changes into regional contexts. A report of the U.S. transportation research board (Transit Research Board, 2009), for example, calls explicitly for studies that track urban land use patterns at fine levels so as to better adjust their own predictions. Up to now, and despite the ever growing importance of land change beyond the cities, urban growth developments outside the cities and their agglomerations have long time been ignored or dismissed by the research, mainly because of data limitations (Irwin et al., 2007).

1.3. Scope and overview of the thesis

Some of the challenges and difficulties faced by previous research that are highlighted in the previous paragraph are addressed via three research emphases that focus on socio-economic drivers of different patterns of settlement growth, on spatial interrelations, and on spatial variation of the urban growth processes. Prior to detailing them, the present section outlines the general context of the doctoral thesis. The overview is completed by a clarification of the research boundaries.

Please note: in this PhD dissertation, the concept of urban areas and urban growth refers to any built-up area – ranging from large areas with urban character such as the central cities, to villages, hamlets and single isolated buildings in the open landscape. This is because the causes and consequences of urban growth are an issue present across various spatial scales.

1.3.1. Scope

This thesis is based on a thorough review of international and Swiss-specific literature on the basis of which statistical analysis of urban development in Switzerland are proposed. The sound, valid and comprehensive analyses help to better grasp how socio-economic factors influence settlement growth. The results are summarised as

recommendations and thereby contribute to the public and expert debates, but also transferred within the NFP 68 project SPROIL in order to develop a predictive model on soil consumption in Switzerland.

The thesis addresses the research gaps as follows: in providing a more detailed description of the temporal and spatial processes of urban development, this thesis focuses on understanding the causes of the current unsatisfactory situation of urbanisation processes in Switzerland. Drawing on data available in 10-years intervals since 1970 allows the examination not only of snapshots but the concept of urban growth as a process. The database established in the course of this thesis includes data on all of the Swiss municipalities (as of 2012). The quality and comprehensiveness of the database enables an investigation into some of the research questions for the entire country. The thesis also accounts for the fact that urban growth manifests in multiple ways, for example either through expansion or densification of built-up areas. The modelling approaches applied in the thesis take into account that urban growth cannot be measured as a confined phenomenon of a singular region, for example a municipality's network of transportation infrastructure is commonly dependent upon the region's network.

The thesis aims at accounting for the need to better understand the mechanisms of urban growth at the local scale, namely the Swiss municipalities. This is especially of interest for highly federalist countries like Switzerland where planning policies and fiscal autonomy are partly on a regional or local level and where municipalities enjoy a large measure of autonomy. The underlying hypothesis of the thesis is that urban growth is strongly driven by region-specific economic conditions, infrastructures and incentives. Based on this hypothesis, the following research questions are derived:

1) What are the major socio-economic determinants of urban growth in Switzerland at the municipal level?
2) Is there temporal and spatial variation in the strength of the impact of particular determinants on urban growth?
    a. Spatially explicit since urban growth is not a confined process but one of interdependence of regions and spillover effects.
3) What approaches control the influence of the considerable heterogeneity of Swiss municipalities?
    a. Considering the fact, that urbanisation is not a linear process
    b. Focusing on spatial variation of the strength of the impact of particular determinants on urban growth
    c. Differentiating the particular spatial patterns that result from a multitude of decisions and processes in a context of intense competition for space
    d. Integrating the fact that humans have preferences for certain urban structures, and that the means to pursue these preferences influence spatial structure

1.3.2. Limitations

In this thesis, urban growth is mainly related to an increasing demand for urban space, e.g. housing space (Bassett and Zaninovich, 2008; Eigenbrod et al., 2011; Evans, 1988; Pozdena, 2002). However, urban growth, in particular changes in urban growth related to low utilisation density, can also occur because of population loss (Kabisch and Haase, 2011). This debate is mainly summarised under the term of urban shrinkage and includes literature analysing the social and economic issues that have led to population flight, resulting e.g. in the eventual abandonment of blocks of housing, neighbourhoods or regions (Martinez-Fernandez et al., 2012).

In Switzerland, this phenomenon of shrinking (due to population decline) affects, above all, some of the peripheral regions in the Alps and Jura where the loss of population is mainly due to emigration and ageing of the population (Stokar et al., 2009; see also Diener et al., 2007 for a debate and typology of urban Switzerland). However, in this thesis, the phenomenon of shrinking regions is not addressed. In the empirical model, several controls are applied in order to distinguish different contexts of the regions. For example the categorisation of the municipalities (Schuler et al., 2005) which may differ between rural and urban municipalities, recognises certain regional influence. However, a more specific approach and a qualitative evaluation of the results in this respect is outside the scope of this thesis.

Some of the limitations of the thesis are linked to the metrics used to assess urban growth, and the availability of explanatory variables. This limitation is mostly due to a lack of appropriate data covering all of the Swiss municipalities and for more than a single time period. For example, data on second homes is missing. In the year 2000, about 12% of all residential homes were second homes (SFSO, 2000), with some of the cantons exhibiting an exceptionally high amount of second homes, e.g. Grisons (37%), Valais (36%), Ticino (24%) or Obwalden (22%). While the models can control for affiliation to cantons, the exact data on the amount of second homes per municipality is missing. A second example is the differentiation between residential land and commercial land, with respect to infrastructure. While the focus of this thesis is on urban growth and sprawl in general, it would have been of interest to compare the distribution different types of land-use. Fulton et al. (2001) in a study of US metropolitan areas, find that commercial construction leads to more land consumption compared to residential construction (see also Burchfield et al., 2006a).

1.3.3. Overview over the thesis

This PhD thesis consists of 6 chapters and one appendix. The second chapter comprises a state-of-the-art summary on urban growth theories, and land management in Switzerland. Furthermore, it presents the metrics that are used to measure urban growth in the course of the NFP 68 project and, accordingly, also in this thesis. The three main chapters (Chapter 3, 4 and 5) address each of the main research foci and consist of scientific publications submitted to international peer-reviewed journals. The first paper (Chapter 3) was published in Landscape and Urban Planning in 2017. The second paper (Chapter 4) was submitted to the Journal of Regional Science in August 2018, while the third paper (Chapter 5) was submitted to Urban Policy in November 2017. Chapter 6 presents the synthesis and conclusion. Finally, the Appendix A entails a paper about the socio-economic drivers of urban sprawl in Switzerland 1980-2010 written in German and published in the Swiss Real Estate Journal in 2016.

In detail, the chapters of this thesis are organised as follows:

Chapter 2: Provides an overview of current knowledge regarding key aspects and concepts of this dissertation, including urban growth theories, a description of spatial planning in Switzerland, and a clarification on the term urban sprawl. Also included is a visualisation of the data used to depict urban growth in the course of this thesis.

Chapter 3: Presents an analysis which identifies the main socio-economic factors that influence the level of urban growth patterns in Switzerland. The extended literature research includes a definition, elaboration and clarification of the use of the term sprawl. The analysis presents a short overview over modelling approaches (state of the art) as well as some reflection about choosing the right

spatial scale to identify determinants of urban growth. Considerable effort was invested in gathering, checking and cleaning the data from various sources (e.g. land-use statistics, census, financial statistics). Whenever possible, the data was collected as time series to identify time-lag effects in order to avoid endogeneity.

In the models, four different urban sprawl metrics (Jaeger and Schwick, 2014) at the level of all Swiss municipalities are related to a range of control variables over a long timeframe (1980–2010). With that, the intention of the study was to derive insights into determinants of urban growth – and particularly urban sprawl – by employing multidimensional dependent variables depicting settlement area development. Furthermore, the models are specified as spatial regression models (Anselin et al., 2006) which control for spatial autocorrelation, and accounts for possible spatial effects between neighbouring municipalities.

Chapter 4: Aims at understanding more precisely the articulation between land consumption – measured as per capita uptake of settlement areas and as growth of settlement area – and income tax. Following Tiebout (1956) theoretical concept of household sorting, the paper engages in how municipal autonomy, in particular differences in local tax, impacts land consumption. The sample is divided in two subgroups of rural versus urban municipalities to account for some of the present heterogeneity in the data sample. Furthermore, to model also middle-range types of municipalities that are neither clearly rural nor clearly urban, an interaction between tax and accessibility is introduced. The analysis is carried out for the decade 2000-2010 and includes all Swiss municipalities.

Methodologically, the analysis mitigates the concern of possible reverse causation between population growth and land consumption where construction activity is assigned on the basis of expected population growth, by using an instrumental variable approach (2sls). For those models with significant test statistics, the models are specified as 2sls. To better understand the connection between accessibility and tax burden, the analysis comprises an additional analysis of marginal effect plots.

Chapter 5: Explores the impact of scarcity of building zones on the growth of settlement developments. Due to data availability, this analysis is confined to the municipalities of the canton of Zurich and to the two decades between 1990 and 2010. Focusing especially on the growth of land consumption per capita, the outward growth of settlement areas, and the growth of building density in residential areas, this analysis also refers to the debates and practices on densification in current urban growth management. Furthermore, and in order to test whether affluence of inhabitants effects urban growth patterns, an interaction term is introduced between land availability and affluence. The insights gained by this interaction contribute to the debate on social segregation along an urban densification pattern.

The spatial models employed are expanded so that they differentiate between direct and indirect effects – that is spillover – of adjacent municipalities. Furthermore, effort was put in specifying relevant W-matrixes (used to assess spatial dependencies between the municipalities) for the

different dependent variables that depict urban growth. Similarly to the second paper (Chapter 4), marginal effect plots help to reveal more information, particularly so on the relationship between urban growth patterns, land scarcity and affluence.

Chapter 6: Presents a synthesis of the thesis' main findings, and concludes with an outlook on future research needs and implications for planning practices.

Appendix A: Entails the article 'Gründe für die Zersiedelung der Schweiz: Die sozioökonomischen Treiber der Siedlungsentwicklung 1980-2010. This document presents an overview over socio-economic determinants of urban sprawl in Switzerland.

Chapter 2: State of the Art

2.1. Urban Growth Theories

To investigate the socio-economic determinants of urban growth, economic theory can provide guidance. Urban economists and regional scientists have generated a plethora of theoretical and empirical work on the subject, which, according to Mieszkowski and Mills (1993), can be grouped into two basic categories, namely the monocentric city models (MCM), and the public finance/spatial amenity models. Both approaches offer an explanation for urban sprawl.

Classical urban economic theory tells us that the spatial growth of cities is a result of three fundamental forces, namely population growth, rising incomes and lower transportation costs derived from important investments in transportation infrastructures. The so-called monocentric city model (MCM), which combines these aspects, was originally developed by Muth (1969) and Mills and Edwin (1972) and more completely elaborated by Wheaton (1974). According to the monocentric city model, there is strong competition for access to cities' central business districts, including an increase in land prices and in development densities towards the city centre (Paulsen 2013). In contrast, land prices tend to decline with distance from the centres, lowering the incentive to use land efficiently and inducing a decrease of building density. In recent times, these models have become more realistic and complicated by incorporating polycentric cities, or different expectations concerning the future, etc. (for a more complete review of this literature, see Anas et al., (1998)). In 2000, Brueckner (2000b) famously argued that urban sprawl is a resource problem to the extent that it results from so-called market failures which the monocentric city model does not take into account. Brueckner identifies three of these market failures (see also Wiewel et al. 1999, Bruckner 2000, Nechyba & Walsh 2004, Byun & Esparza 2005, Hersperger & Bürgi 2009): the failure of land markets to internalise the social values associated with open space, the failure of households to internalise the congestion costs generated in urban transportation, and the failure of municipal governments to accurately estimate the fiscal burden of the development and maintenance of infrastructure. For instance, landscape is a public good and its value is not considered an economic loss in the conversion of agricultural land for real estate purposes (Guastella et al., 2017).

US-based evidence suggests that the variables of the classical monocentric city model (MCM), namely population, income, transport costs and agriculture rents, explain about 80% of the variation in the urban city size (Paulsen, 2012). However, as Nechyba and Walsh (2004) state, the monocentric city model might be a useful starting point for studying urban growth patterns, but empirical evidence suggests strongly that location choices are made on the basis of many other factors than those offered by the MCM. Local inhabitants may choose residential locations situated far away from the city centres to avoid the perceived disadvantages of central urban locations, such as noise, crime or taxes. A recent study that assessed preferences for residential choice in Switzerland confirmed the people's liking for green and quiet surroundings (Tobias et al., 2016) – which is a hint that further factors determine residential decisions.

The public finance/spatial amenity models, deriving from the Tiebout (1956) model, include such preferences by describing a situation where people sort themselves into different local locations based on their likings for location-specific public goods and amenities (see e.g. Fujita, 1989; Glaeser and Kahn, 2003; Roback, 1982). Burchfield et al. (2006), following Tiebout's (1956) model, predict that if local public services are more costly when development is scattered, then aversion to scattered development should be less strong, and sprawl more prevalent where local taxpayers pay a smaller share of local government expenses. Indeed, in their study, Burchfield et al. (2006) find evidence for their prediction. Further empirical studies that focus on the relationship between urban growth and personal residential preferences often relate to the relationship between sprawl and racial segregation (Glaeser and Kahn, 2003; Pirotte and Madre, 2011), or flight from blight mechanisms (R Wassmer, 2008), especially in the U.S. However, other studies that focus on location-specific political conditions, come to the conclusion that sprawl is the result of land-use policies and financing decisions by local government which heavily distort the use of land (Gómez-Antonio et al., 2016). Slack (2002), for example, looks critically at the revenue-raising tools of local governments, such as local development tax, and finds they sometimes encourage low-density development.

It is clear that urban sprawl is a multidimensional issue, with multiple causes and effects (Nechyba and Walsh, 2004). Thus, the two approaches, the monocentric city model and public finance/spatial amenity models, are complementary rather than exclusionary. As Geoghegan (2002) emphasises, the applied literature on urban growth modelling has incorporated aspects of both strands of theoretical models, as it is the case in almost all studies cited above. Geoghegan, for example, combines in her models assumptions that individuals have a preference for their locations related to commuting distances as well as the spatial amenities surrounding their locations.

The first paper of the present thesis (Chapter 3) is specifically dedicated to a review of empirically assessed determinants of urban sprawl in the literature and contributes an empirical analysis on determinants of urban growth for Switzerland.

2.2. Planning in Switzerland

2.2.1. Functioning of the planning system

Switzerland profits from a relatively long tradition of implementing regulation policies (Jaeger and Schwick, 2014). The Swiss Federal Law on Spatial Planning, which was introduced in 1980, stipulated that land has to be used economically, and that settlements' extensions should be limited. Since the 1980s, the organization of the Swiss spatial planning system has been shaped by the country's federalist structure, with its important division of power between the federal state, the 26 cantons and the 2495 municipalities as at 2012 (Mueller and Hersperger, 2015). The federal government enforces the Federal Law on Spatial Planning and coordinates cantonal planning activities (Muggli, 2012). The cantons are in charge of the implementation of Federal spatial planning law and enforce cantonal laws on spatial planning and regulations about the construction of buildings and roads (Gennaio et al., 2009). They also develop a comprehensive plan (Richtplan) that specifies the general organisation of land-use in the cantons, and the future direction of spatial development. These plans are binding for cantonal authorities and have to be approved by the Federal Council (Muggli, 2012). Almost all of the cantons (except for Geneva) delegate the responsibility of specifying how land should be used in practice to the municipalities. The municipalities develop land-use plans (Nutzungspläne), which are binding for landowners and stipulate e.g. which land can be used for building and which for agriculture at the level of individual lots (Hersperger et al., 2014). Thus, while responsibility for framework

legislation and co-ordination on spatial planning lies within the Confederation, the practical planning implementation remains essentially a matter for the Cantons and the municipalities.

2.2.2. Current challenges in spatial planning

Based on the system of federalism described above, in Switzerland the negotiation between promoting spatial growth on the one hand and promoting sustainability and the efficient use of land on the other hand takes place not so much on the national but rather on the regional level. Although the spatial planning law obliges cantons to regulate housing development and promote sustainability, there has been an implementation problem under existing law, with the consequence that municipalities and cantons have relatively free rein in the area of spatial planning (Hersperger and Bürgi, 2010; Müller-Jentsch and Rühli, 2010; Wissen Hayek et al., 2011). Since the cantons and municipalities vary for example in size, culture and landscape so do the demands for settlement development that face each jurisdiction. The result is a highly localised variety of spatial planning concepts and instruments (Scholl, 2015; VLP-ASPAN, 2012).

One of the main challenges that has been identified in Swiss planning policy, and which partly results from both high jurisdictional autonomy and their heterogeneity, is the oversized stock of building zones (Jaeger and Schwick, 2014; Müller-Jentsch, 2010). According to ARE (2012) between 12% and 18% of the building zone areas have not yet been developed. Assuming stable conditions in the amount of building zones per capita, the current supply of building zones could host an additional 1 to 1.7 million inhabitants. Menghini (2013) identifies the main shortcoming in the imbalanced supply and demand for undeveloped building zones; whereas in urban areas the expected demand for the next twenty years exceeds the supply of current reserves on building zones, in remote areas the supply outstrips the demand. Indeed, in 2012 only 6% of undeveloped building zones are located in regions classified as very accessible, whereas 63% are located in regions classified as marginal or non-accessible (FOSD Federal Office for Spatial Development, 2012). For Hersperger et al. (2014) the root of the problem lies in the excessive designation of building zones in the past, owing partly to unrealistic population projections but also in politically motivated decisions to encourage growth and land development. The latter can be attributed to the traditional perception of many localities, such as municipalities, that link growth to more tax revenues (see e.g. Razin and Rosentraub, 2000).

A further issue that challenges Swiss local planning is the strong property rights (Müller-Jentsch and Rühli, 2010). In Switzerland, any reduction of property value resulting from the rezoning of a building zone into a non-building zone must be compensated for (Article 5(1) Law on Spatial Planning). This represents a major financial burden for most municipalities and severely impedes the effective reduction of undeveloped building zones (Menghini, 2013). Furthermore, the strong right to private property limits the flexibility of public actors to influence decisions taken on private property. For example a report that assesses spatial development strategies within a program of regional development in the canton of Berne names the lack of a consensus between the stakeholders (canton, municipality, private owners) as a major challenge to the implementation of coherent spatial strategies (Jäggi and Gerber, 2014). As Gerber and Nahrath (2013) remark, a broader (public) discussion on the implication of private property rights on public planning policy only started when the subject gained attention through the approval of the so-called second home initiative ("Zweitwohnungsinitiative") in 2012. The initiative limits the right of private persons to acquire property as a second home in municipalities where the second home ratio is more than 20%.

Finally, Swiss local planning exhibits a high level of public participation due to the principles of direct democracy (Muggli, 2014). In many municipalities, any revision of the land-use plan has to be approved by the population in a

public vote (Hersperger et al., 2014). Specific stakeholder groups, such as local parties or house-owner associations may thus play an important role in local planning by forming coalitions to ensure their own interest prevails. In a comprehensive study on cantonal instruments to manage urban growth, Müller-Jentsch and Rühli (2010) find that the close proximity of municipal planning authorities to local landowners can be problematic.

2.2.3. Revised Law on Spatial Planning 2013: Reclassification and densification

The revision of the Law on Spatial Planning in 2013 promotes the reduction of the size of undeveloped building zones, compact urban development through infill redevelopment and densification, and encourages developers and authorities to use land more economically. Furthermore, the revised Law on Spatial Planning specifies that (1) added property values created through planning measures (e.g. the increase of the real estate value a plot experiences due to its assignment to a building zone) have to be levied through a tax amounting to at least 20% of the increase in property value, and (2) undeveloped building zones for which there is no predicted demand in the next 15 years have to be reclassified as non-building zones.

More recently, attention has been given to the practices of residential densification, that is the urban restructuring to accommodate the increase in the demand for housing within the existing urban space. The densification of existing built-up areas is likely to be more complicated to implement and may lead to more conflicts than the old practice consisting of designating new building zones at the fringe of settlement areas. In a meta-analysis, Haaland and van den Bosch (2015) reviewed 102 published studies on urban green space and densifications, and identified pitfalls and negative effects of densification, such as crowding or lower living quality. They find that also seemingly positive aspects of densification, such as less environmental impact, can be questioned if e.g. ecosystem services are threatened by a lack of green space. In the light of these challenges, the authors plead for careful planning. The same theme is found in a study by Schmid-Thomé et al. (2013) carried out in the metropolitan region of Helsinki, Finland, which shows the challenge that planners face when reconciling values of the existing built environment with new urban densification. Also in this study, the authors urge a general sensitivity and understanding of the area which is to be densified, but seem hopeful that densification is not necessarily a bad scenario. Hersperger and Cathomas (2015), who provide positive examples of local growth controls and densification in Switzerland also offer a promising approach.

2.3. Measuring Urban Growth and Urban Sprawl

The undesirable aspects of urban growth are very often referred to as urban sprawl. However, there is no common agreement either on the defining characteristics and impacts of urban sprawl nor on the ultimate desirability or undesirability of it. Urban sprawl is thus an elusive concept that describes a particular form of urban growth, often bearing a negative connotation, or in other words a pejorative term (Brueckner, 2001; Brueckner and Fansler, 1983). As Mumford (1961) observed already in the 1960s, suburbia was not problematical when it served a favoured minority, but only when it became a mass phenomenon. It thus is a matter of definition and values at which point of which scale the growth is considered undesirable and which dimension of urban development, e.g. urban continuity, is considered. An objective measurement of what is too much is not available and depends on norms and valuations that relate to the patterns, processes, and consequences of urban growth. On this note, Johnson (2001) and also Chin (2002) see sprawl as a direction on a continuum rather than a fixed category.

2.4. Data that depicts urban growth used throughout the thesis

Based on the broad review of the many definitions attributed to the term sprawl in the international literature, Jaeger et al. (Jaeger, Bertiller, Schwick and Kienast, 2010) concluded that the prevailing confusion mainly arises because of the ambiguous use of the term in most studies to describe different kinds of urban development patterns on the one hand, and characterise causes and consequences of the patterns on the other hand. In order to clarify the terminology and clearly distinguish the spatial phenomenon of urban sprawl from its causes and consequences, Jaeger, Bertiller, Schwick, Cavens et al. (2010) proposed a new definition of urban sprawl and enclosing metrics, as part of the NFP 54 project on sustainable development of the built environment in Switzerland. According to the definition, the degree of urban sprawl depends on three main parameters: (1) the amount of built-up area, (2) the dispersion of the built-up area in the open landscape, and (3) the land uptake per person or job. This definition allows the distinction between urban sprawl and other forms of urban growth which – under current planning norms – have positive repercussions, e.g. infill development. The latter is not considered to be urban sprawl, since urban densification increases the number of people living and working in a given settlement, thereby decreasing mean land uptake per capita and workplace.

Four years later, Jaeger and Schwick (2014) suggested an improved version and a database of the measurements, which is the basis for the analyses in this PhD. The data cover a time span of 125 years with seven points in time where Jaeger et al. provide the exact data of the variables, namely for 1885, 1935, 1960, 1980, 1990, 2000, and 2010. The exact same data are also used by the federal office for the environment (FOEN) as an indicator for landscape monitoring (FOEN Federal Office for the Environment, 2016). Furthermore, some of the data are comparable e.g. to those used in the European environment agency (EEA) report of 2016 on urban sprawl in Europe (EEA European Environment Agency and FOEN Federal Office for the Environment, 2016). However, the data for the European project are on a broader scale (NUTS II regions instead of municipalities) and have different categories of data sources, which represents a certain hindrance to direct comparison.

Because there is no complete overview - particularly mapping - of the data in the following chapters 3-5 of this thesis, the main dependent variables that depict urban growth in Switzerland are mapped at this point.

2.4.1. Description and Visualisation of data on urban growth

Short descriptions of the most important dependent variables used in this thesis

	Lowest value per year Year: **Value** (municipality)	Highest value per year Year: **Value** (municipality)
Percentage of Built-Up Area (PBA) (Figure 1), in %		
The percentage of built-up area (PBA) is the ratio of the size of the built-up areas to the size of the potentially developable area of the reporting unit and is given as a percentage. The built-up area is measured as the spatial extent of built-up areas independent of function, form, utilisation and spatial location of the buildings. Areas where construction is impossible, such as bodies of water, protected areas, unstable soil, forests or steep slopes, are excluded from the potentially developable area.	2010: **0.41**% (Bivio) 2000: **0.40**% (Casti-Wergenstein) 1990: **0.39**% (Avers) 1980: **0.39**% (Bivio) 1960: **0.35**% (Bivio) 1935: **0.24**% (Innerthal) 1885: **0.14**% (Chavannes-des-Bois)	2010: **100**% (several municipalities)* 2000: **100**% (several municipalities) 1990: **100**% (several municipalities) 1980: **100**% (Muralto) 1960: **96**% (Peseux) 1935: **86**% (Muralto) 1885: **59**% (Gottlieben)
Utilisation density (UD) (Figure 2), in $N_{population + workplaces}$		
The utilisation density (UD) measures the number of people working or living ($N_{population + workplaces}$) in a built-up area. Built-up areas with more workplaces and/or people are considered more intensively used, and hence less sprawled, than areas with a lower density of workplaces and/or people.	2010: **9** (Campo Vallemaggia) 2000: **27** (Campo Vallemaggia) 1990: **12** (Campo Vallemaggia) 1980: **16** (Campo Vallemaggia) 1960: **37** (Sobrio) 1935: **60** (Hüniken) 1885: **56** (Arosa)	2010: **2053** (Genève) 2000: **1952** (Genève) 1990: **2030** (Genève) 1980: **1809** (Genève) 1960: **2050** (Le Vaud) 1935: **3569** (Le Vaud) 1885: **7657** (Paradiso)
Per Capita Land Consumption (PLCU) (Figure 3) , in m^2		
The metric of per capita land consumption (PCLU) is the reciprocal of UD and measures the built-up area divided through the number of people working or living in the corresponding area. High PLCU values indicate that more space is used per inhabitant or workplace than in areas of low PCLU values.	2010: **44** (Genève) 2000: **46** (Genève) 1990: **44** (Genève) 1980: **50** (Genève) 1960: **44** (Le Vaud) 1935: **25** (Le Vaud) 1885: **12** (Paradiso)	2010: **9725** (Campo Vallemaggia) 2000: **3279** (Campo Vallemaggia) 1990: **7816** (Campo Vallemaggia) 1980: **5678**(Campo Vallemaggia) 1960: **2407** (Sobrio) 1935: **1508** (Hünikon) 1885: **1598** (Arosa)
Dispersion (DIS) (Figure 4), in DIS/m^2		
The dispersion (DIS) quantifies the spatial distribution of built-up areas. The further dispersed the built-up areas, the larger the value of DIS. Therefore, more compact built-up areas have lower values of DIS than less compact built-up areas.	2010: **23** (Bargen, SH) 2000: **22** (Bargen, SH) 1990: **22** (Bargen, SH) 1980: **22** (Bargen, SH) 1960: **20** (Bargen, SH) 1935: **19** (Bargen, SH) 1885: **19** (Sisseln)	2010: **56** (Meienried) 2000: **56** (Meienried) 1990: **56** (Meienried) 1980: **56** (Meienried) 1960: **56** (Meienried) 1935: **55** (Meienried) 1885: **55** (Clavaleyres)
Weighted urban proliferation (WUP) (Figure 5), in WUP/ m^2		
Weighted urban proliferation (WUP) is a metric used to quantify urban sprawl. It is the product of the dispersion (DIS), a weighting of DIS the percentage of built-up area (PBA) and a weighting of the land uptake per person (PCLU), that is land uptake per inhabitant or workplace. The higher the value, the more sprawled is the settlement structure of the municipality.	2010: **0.0032** (Genève) 2000: **0.0061** (Genève) 1990: **0.0036** (Genève) 1980: **0.0157** (Genève) 1960: **0.0001**(Kirchenthurnen) 1935: **0.0003** (Schelten) 1885: **0.0001** (several municipalities)	2010: **58** (Carabietta) 2000: **60** (Carabietta) 1990: **58** (Carabietta) 1980: **59** (Carabietta) 1960: **54** (Carabietta) 1935: **50** (Carabietta) 1885: **24** (Carabietta)

*100% PBA is possible due to the method of measurement of built-up areas.

For a more detailed description of how the data was calculated, e.g. information on the weighting that was applied, please refer to Jaeger, Bertiller, Schwick and Kienast (2010), Jaeger, Bertiller, Schwick, Cavens, et al. (2010), and Jaeger and Schwick (2014).

Figure 1: Value of built-up area [PBA] for Switzerland 1885-2010 [%]

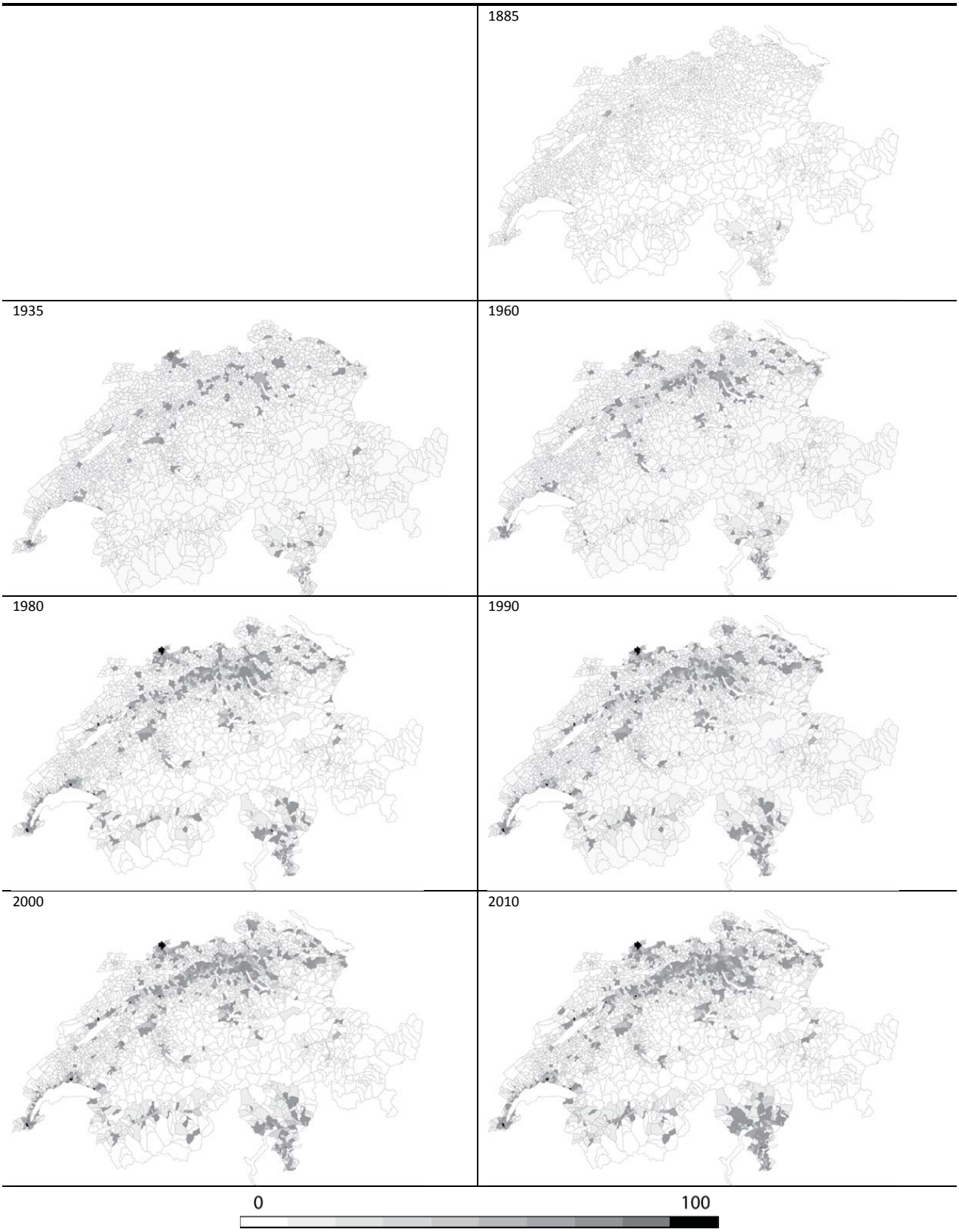


Figure 2: Value of utilisation density [UD] for Switzerland 1885-2010 [number of jobs and persons]

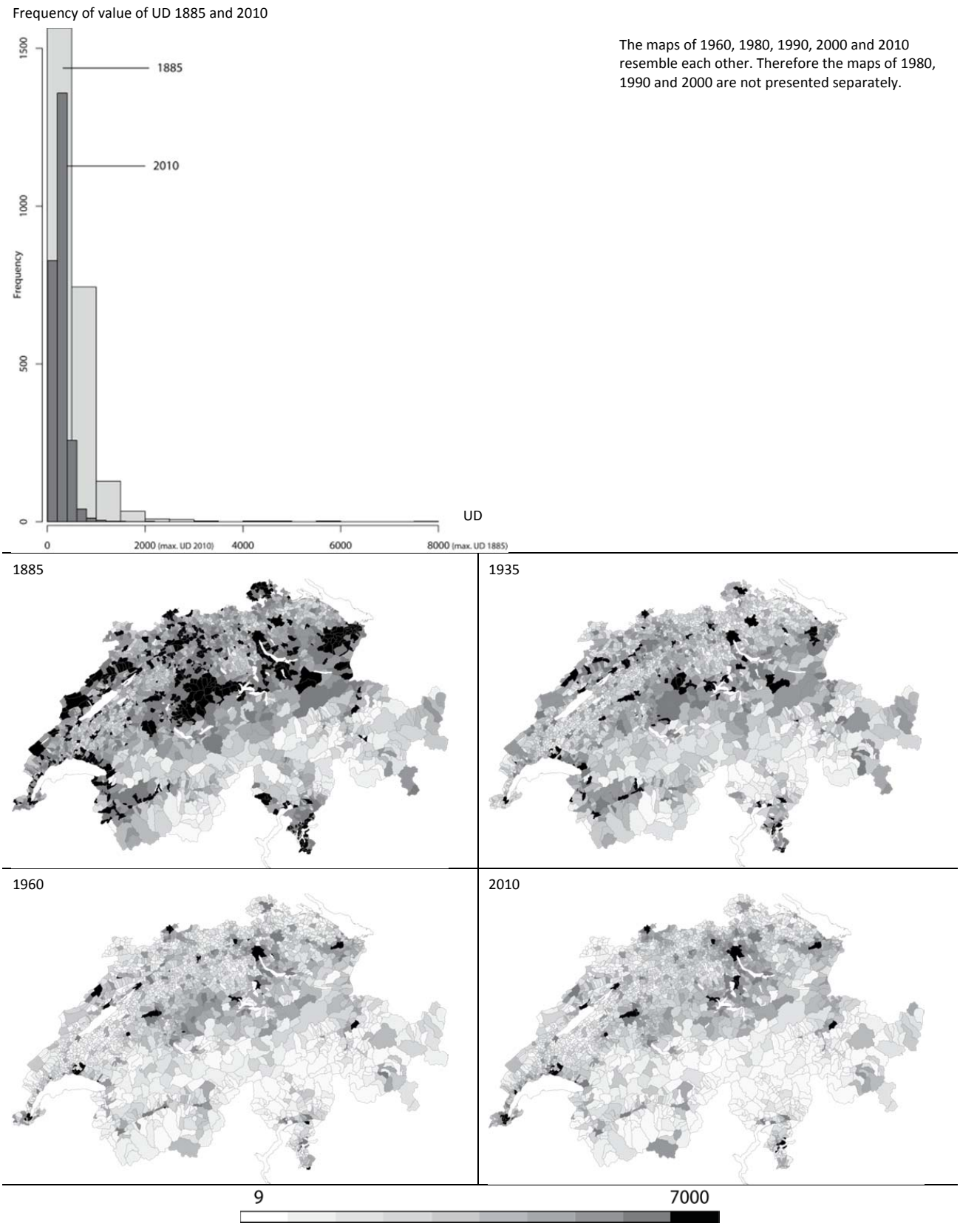


Figure 3: Value of per capita land consumption [PCLU] [m²] for Switzerland 1885-2010

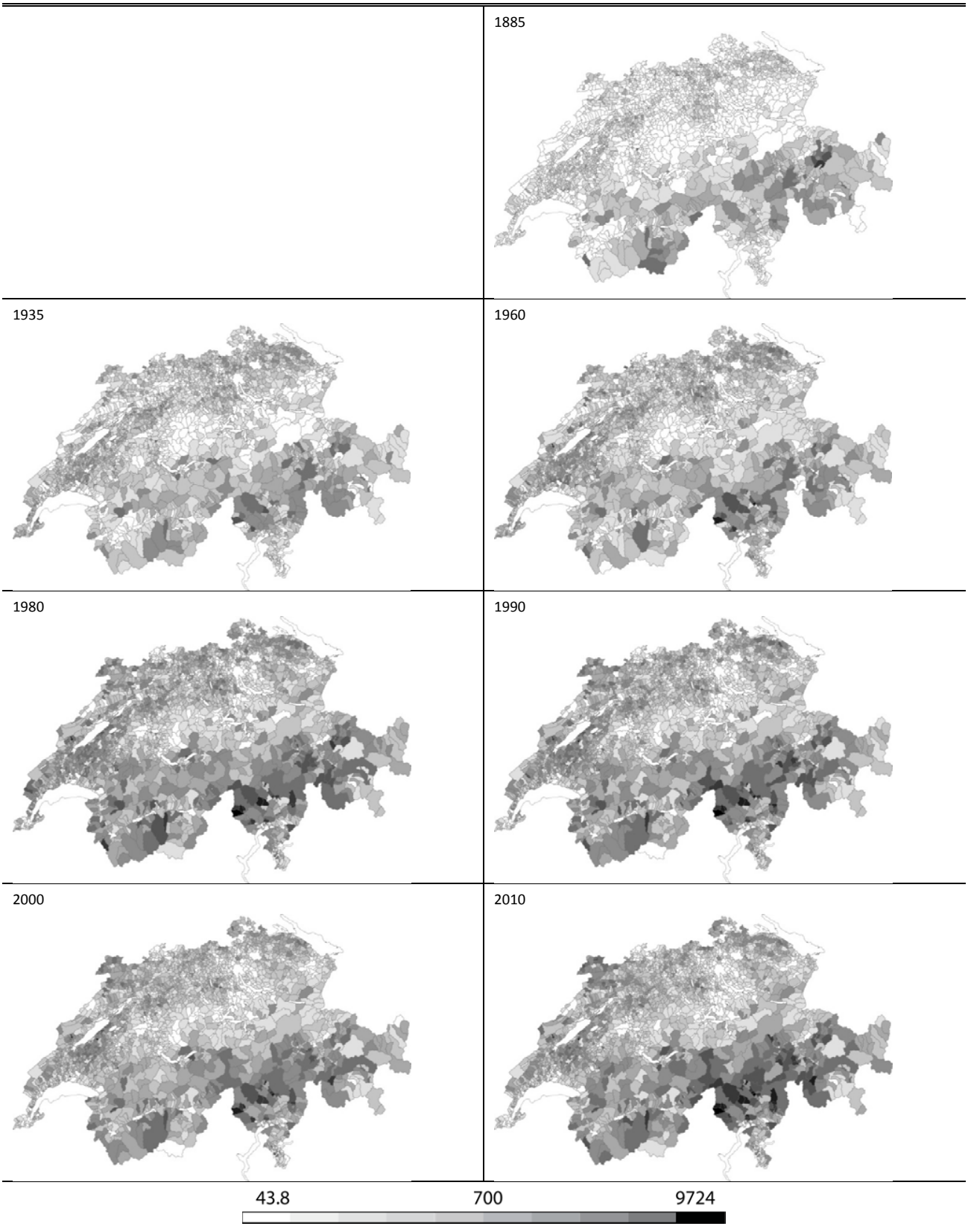


Figure 4:Value of dispersion [DIS] for Switzerland 1885-2010

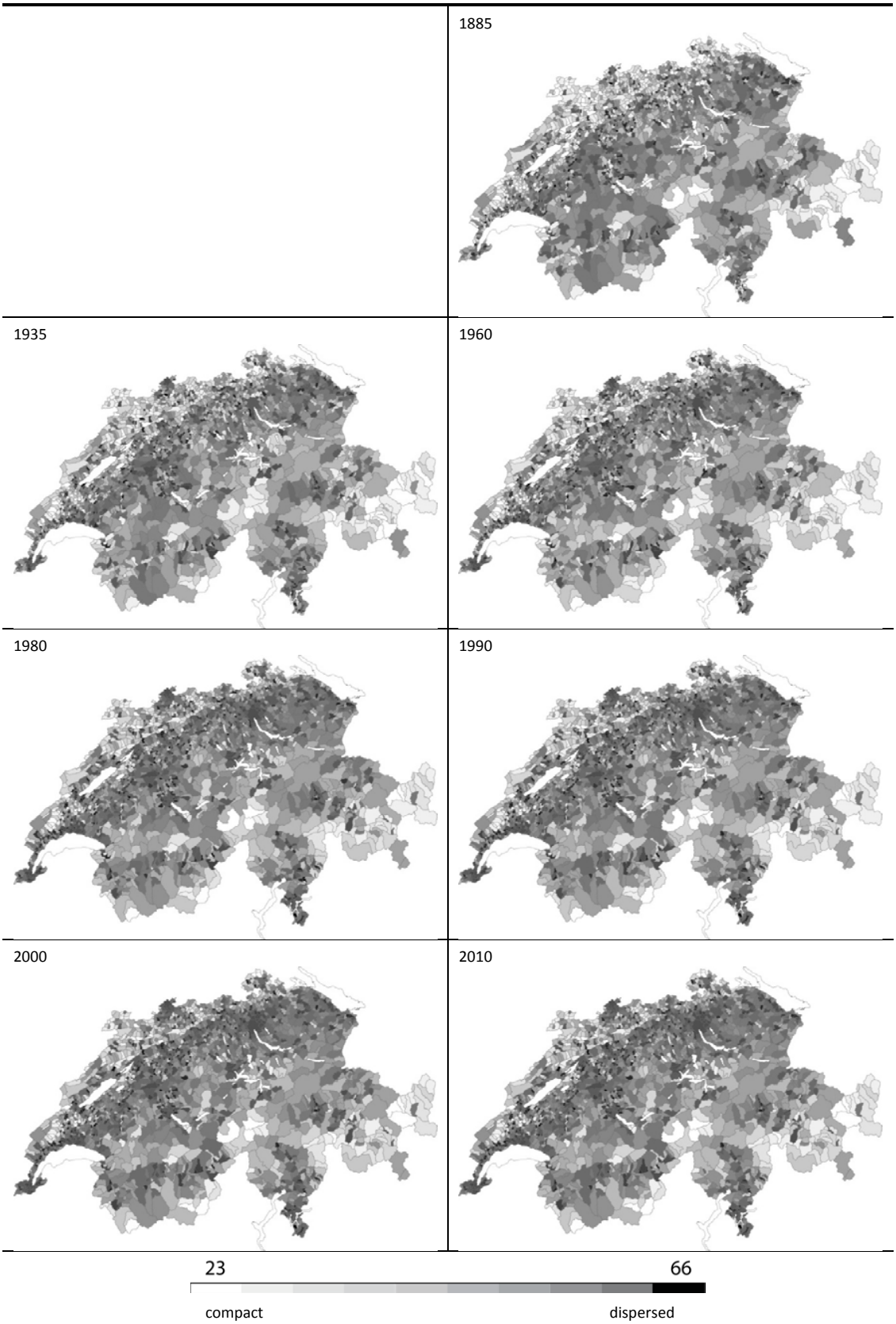
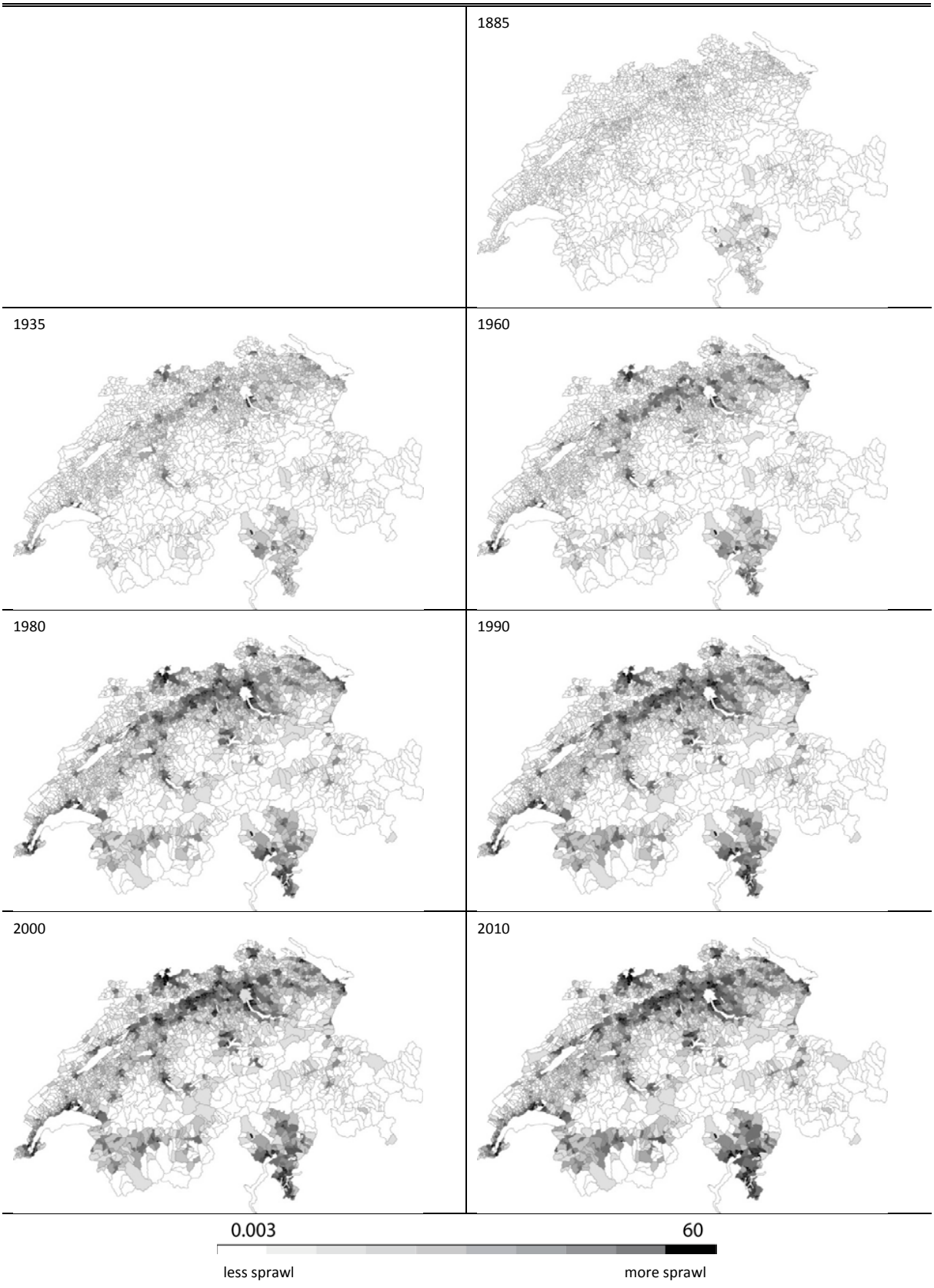


Figure 5:Value of weighted urban proliferation [WUP] for Switzerland 1885-2010



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Chapter 3: Socio-economic determinants of urban sprawl between 1980-2010 in Switzerland

Abstract

Sprawl, as a particular characterisation of spatial extension of urbanised areas, is a contested issue. In this paper we provide an analysis of the major socio-economic determinants of changes in those urban patterns considered as sprawl in Switzerland. Our analysis covers the years 1980 to 2010, and has been conducted for all of the 2495 Swiss municipalities. The spatially explicit model gives evidence of the importance of spillover effects. Employing regression modelling of different urban sprawl metrics that capture urban development patterns we show that the socio-economic explanatory variables yield different results in explaining those metrics and thus give insights in the highly complex matter that is sprawl. These metrics which include the extent of built-up areas, dispersion of settlements and utilisation density provide a composite metric for urban sprawl. Our results show that the densification of built-up areas gains increasing influence in shaping urban patterns and that, in Switzerland, accessibility is a key determinant of sprawl.

3.1. Introduction

Urban sprawl is receiving increased public attention both by policy makers and in scholarly literature. Urban areas, it is claimed, take up space, encroaching excessively on valuable agricultural land (Brueckner, 2000; Coisnon et al., 2013; Wissen et al., 2010). As a consequence of sprawl, aesthetic benefits of open space are lost, natural ecosystems get disrupted and local communities change their structure (Brown et al., 2005; Gagné & Fahrig, 2010; Lopez & Hynes, 2006; Polyzos et al., 2013).

Some authors link sprawl directly to economic development and the resulting distribution of population and urban land. Accordingly, negative socio-economic effects of sprawl are considered as market failure. It is the externalities of traffic congestion, unvalued suburban infrastructure, and unvalued open-space amenities that may make suburban living and urban growth economically inefficient and ecologically unsustainable (Brueckner & Helsley, 2011; Hersperger & Bürgi, 2009; Nechyba & Walsh, 2004; Pflieger & Ecoffey, 2011).

The scientific discussion on urban sprawl is not conclusive, however. It appears that the concept of sprawl lacks both an accurate, generally accepted definition and appropriate measurements (Cutsinger et al., 2005; Ewing, 1997; Galster et al., 2001; Pirotte & Madre, 2011; Siedentop, 2005). Thus, researchers working on urban sprawl usually

define it depending on either the context or the function of the term, while its operationalisation critically hinges on the availability of appropriate data (Herold et al., 2003; Irwin, Cho, & Bockstael, 2007; Paulsen, 2013; Sutton, 2003).

The absence of a common understanding of sprawl on the one hand, and the lack of data on the other seems to have constrained investigations of underlying causal processes, and the determinants of sprawl. For example, although land use change is recognised to be a spatio-temporal process (Anas et al., 1998; Duranton & Puga, 2014; Irwin & Bockstael, 2004), in regression analyses the spatial characteristics of urban growth have long been neglected (Yu and Ng, 2007). However, to clarify the discourse about urban sprawl and its determinants, it is essential to improve the quantitative knowledge-base through valid and reliable data, especially regarding projections of future land use (Burchfield et al., 2006; Oueslati et al., 2013; Paulsen, 2012; Siedentop, 2005).

The analysis on the causes of urban sprawl presented in this paper is carried out in Switzerland, a country where national land use policies have been established in the 1970s and adjustments thereof have been prompted in recent years. After half a century of economic and population growth and of internal migration, Switzerland today has an urbanisation level of about 73% and an average population density of 188 inhabitants/km2. However, the spatial distribution of the urbanised areas is very uneven. The average population density in the Swiss plateau, a relatively flat part of the country's surface which covers about 30% of the country, is over 400 inhabitants/km2 (SFSO Swiss Federal Statistical Office, 2014b). A recent study of Hennig et al. (2015) which looks at the level of urban sprawl in Europe ranks the Swiss plateau in the upper tercile in terms of sprawl, comparable to other densely populated and economically successful regions in Europe, like the south of England, northwest Germany, or the north of Italy.

Considering that the major Swiss cities are small (Zurich, the largest city, has 400'000 inhabitants although greater area of Zurich includes 1.66 m inhabitants), urban development is dispersed, putting pressure on open spaces in a polycentric network of cities. Not surprisingly, strong sentiments against urban sprawl have developed, and in Switzerland these are rooted in the perception that urban growth has gone awry. Over the last three decades, the Swiss settlement area has increased by 23 percent while the population increased by only 17 percent (SFSO, 2013). At the same time, the annual population growth rate of 1.2 percent for the period of 2011-2015, makes Switzerland one of the few growing regions in Europe (World Bank, 2016). In the Swiss strategy for sustainable development, a clear boundary to spatial growth was set: limiting the settlement area at 400 m2/head. However, recent statistics indicate that land consumption today is already at 406.9 m2/head (SFSO, 2013). In spring 2013, the issue of urban growth and high land consumption was on the national agenda and the topic of a public vote. In an unexpectedly high turnout (63 percent) the Swiss population endorsed a tightening of the national law on spatial development.

This paper is intended to improve the understanding of determinants of urban sprawl conceptualised by four different dimensions of urban growth. In particular, we explore the determinants of urban sprawl in Switzerland and compare our findings with those in the existing literature. Special attention is given to the analysis of socio-economic (economic, demographic and social) determinants (cf. 3.3.2.). In contrast to previous studies on urban sprawl, we investigate sprawl at the level of the municipalities (cf. 3.2.2.) and for the surface of an entire country (Switzerland). The analysis is conducted for 1980, 1990, 2000, and 2010.

In a cross-sectional analysis, we employ four different metrics able to depict multiple characteristics of urban sprawl (cf. 3.3.1.). Our hypothesis is that the socio-economic determinants of sprawl exert different influences on the different metrics. Furthermore, we assume that the sprawl pattern surrounding a municipality spills over to its

neighbouring jurisdiction (Irwin & Bockstael, 2004; Vance & Iovanna, 2008). We therefore expand our analysis with a model that controls spatial interdependence in the data.

Based on an overview of the international literature, section 2 gives a synthesis of methods to measure urban sprawl, determinants of urban sprawl, and discusses the implications of our choice of the unit of analysis. Section 3 provides details about the operationalisation of the set of variables we consider in this study and gives some information about the model specifications. Section 4 presents and section 5 discusses the results of the analysis. Finally, the conclusion in section 6 provides a synthesis as well as policy recommendations.

3.2. How to understand urban growth and determinants of urban sprawl

3.2.1. Methods of Measurements

Despite disagreements and contradictions in defining urban sprawl, it is agreed that not all spatial development is sprawl (Cutsinger et al., 2005; Galster et al., 2001), and that all sprawl is not the same. A rough common understanding is that sprawl is the uncontrolled outwards growth, i.e. an overly space-consuming expansion of urban land area that is usually considered as a problematic and unsustainable form of urban growth.

Just as sprawl is defined in various ways, so too there are multiple methods to measure sprawl empirically: It is a matter of definition at which point of which scale the negative effects of urban growth may be called urban sprawl and which dimension of urban growth, such as spatial growth, discontinuity or population and housing unit density should be considered. In order to measure sprawl, the metrics that have been developed often focus on only one dimension. The respective variable that is employed is very often a measure of density or the spatial extension of the settlement area (Brueckner & Fansler, 1983; Fulton et al., 2001; Spivey, 2008; Sutton, 2003; Wassmer, 2008). This focus on a single dimension stands in contrast with more elaborate, so called multidimensional measurements of urban sprawl, that have been proposed in recent years. In these, different characteristics of sprawl, such as expansion, density and dispersion are measured separately but sometimes combined into a single index of sprawl (Cutsinger et al., 2005; Ewing et al., 2003; Hamidi & Ewing, 2014; Jaeger et al., 2010a; Jaeger & Schwick, 2014; Torrens, 2008). Paulsen (2013) offers a good overview and discussion on multi- and uni-dimensional measurements as do Hamidi and Ewing (2014). In our analysis we use a multidimensional metric that combines three characteristics of urban patterns (Jaeger & Schick, 2010a; 2014) (cf. 3.3.1.). Also we do not explicitly set limits for sprawl/no sprawl, but we compare our results over space and time and hence are able to evaluate developments of urban patterns.

3.2.2. Determinants of sprawl: The classical Monocentric city model and the Tiebout model

The understanding and measurement of what drives urban sprawl is hotly debated in the literature (Burchfield et al., 2006; Irwin & Bockstael, 2004; Oueslati et al., 2013; Polyzos et al., 2013; Yue et al., 2012). A theoretical model that provides a basic explanation of urban spatial structure is the monocentric city model of Muth (1969) and Mills (1972) which identifies changes in population, income, transportation cost and agricultural land prices as essential determinants of changes in urban patterns (Brueckner & Fansler, 1983; Glaeser & Kahn, 2003; Nechyba & Walsh, 2004). The model, however, does not account for other household characteristics than income and acts on the assumptions that households are identical in the characteristics that influence their land use preference (R Wassmer,

2008). Thus, although the model has long been the standard economic approach to studying the development of urban areas, it is also under constant debate for its simplicity and reductionism (Anas et al., 1998; McMillen, 2006; Polyzos et al., 2013).

A second important school of explaining urban land use change, the Tiebout (1956) model, suggests that residential location choices are made on the basis of many factors other than transportation costs, income, and land price. It considers sprawl as a consequence of a so-called Tiebout sorting, which implies that people move to another place based upon the desire to maximise their individual utilities by either avoiding real and perceived disadvantages, such as tax burden, or by seeking advantages like housing space or amenities (Nechyba and Walsh, 2004). The Tiebout model does not primary focus on the causes of sprawl, but more on the causes of population growth and the degree of homogeneity of population structure. Sprawl would then rather be a particular structure of the built-up area resulting from a certain population structure which in turn is caused by mobile households' desire to segregate based on preferences for policies, public services, amenities etc.. The empirical extent to which sprawl is caused by sorting, however, is somewhat difficult to grasp and not well understood (Nechyba and Walsh, 2004).

Authors that have used statistical analyses to investigate urban sprawl in terms of spatial extension and density measurements usually base on both, the relatively few variables proposed by the monocentric city model and, if available, additional variables that capture to some extent economic structures, demographic characteristics or people's preferences (Burchfield et al., 2006; Cutsinger et al., 2005; Mann, 2009; Oueslati et al., 2013; Pirotte & Madre, 2011).

3.2.3. Choosing a suitable spatial unit of analysis

Few sprawl analyses extensively discuss the spatial scale of the study area, the ensuing variables used, and the influence on the results of both (Davis, 2006; Irwin & Bockstael, 2004; Paulsen, 2013; Torrens & Albertin, 2000). However, measuring urban sprawl is a highly scale and space dependent undertaking. As Davis (2006) and others point out, whether or not a region is considered as sprawled very much depends on the extent and scale of the analysis (Brown et al., 2005; Davis, 2006; Hasse & Lathrop, 2003; Herold et al., 2003; Wassmer, 2008).

Paulsen (2013) emphasises that if sprawl is investigated in a certain area of study, the socio-economic, demographic and policy variables that are used to explain sprawl should be measured at the scale of the study area. Most studies based on the monocentric city model operate at the level of a metropolitan area (Burchfield et al., 2006; Spivey, 2008), i.e. a large area consisting of many municipalities. Focusing on such a level implies using single mean values for the entire area of study, such as the average household income (Brueckner & Fansler, 1983), while the values might actually vary considerably within the area (Hasse & Lathrop, 2003).

In our study, most of the independent variables we use (Table 1 & 2) are measured at the level of the municipality. At the same time, the municipality is also the level of aggregation for our dependent variables (cf. 3.3.1.). As in Switzerland, much of the land use and planning decision making authority is vested at either the municipal level or the second-tier political level of the cantons (Jaeger et al., 2010b; Wissen et al., 2010), our choice of scale allows us to directly link socio-economic variables and their scope of influence on development patterns. Consequently, and in contrast to all previous studies we are aware of, we have chosen to work at the municipality level.

Since we look at the totality of the municipalities in Switzerland rather than at isolated areas, we have to take into consideration spillover effects: (a) built-up areas spill across administrative borders, (b) neighbouring municipalities share a similar employment market and mobility infrastructure, and (c) neighbouring municipalities might coordinate when it comes to spatial planning. Based on these assumptions about spatial spillover effects, we consider the influence of neighbouring municipalities in our statistical models (cf. 3.3.3.).

3.3. Effects and sources of urban growth: Dependent and independent variables

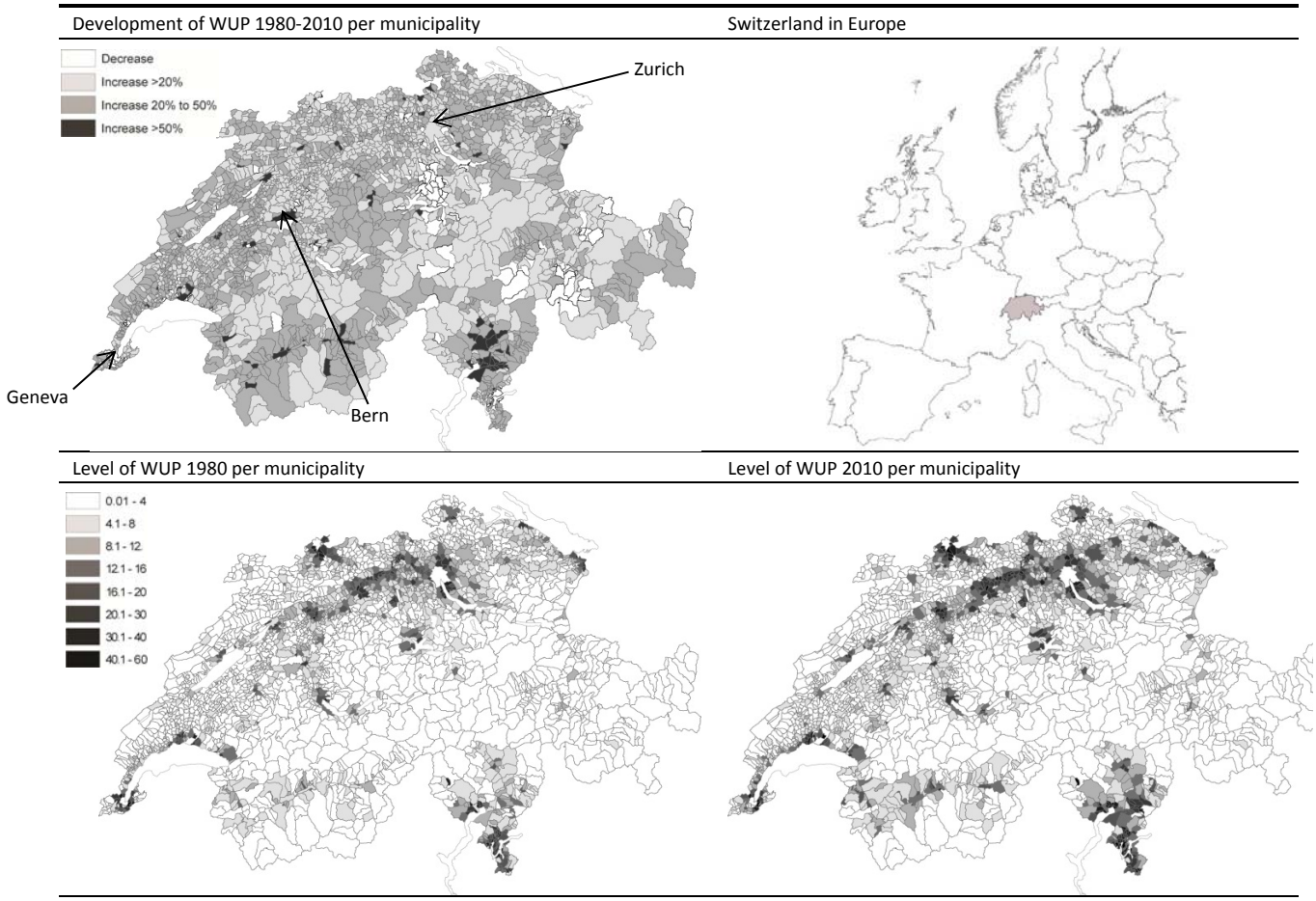
3.3.1. Sprawl measurements used as dependent variables in this paper

For the analysis we chose to work with metrics developed by Jaeger et al. (2010a) that measure and quantify three distinct dimensions of sprawl at the level of municipalities: built-up areas as a share of the total area of the municipality (PBA, for percentage of built-up area), dispersion of settlements (DIS), utilisation density of a built-up area (UD), resulting in the composite sprawl metric (WUP, for weighted urban proliferation), which integrates the three measurements into one single metric. Figure 6 shows the development of the composite sprawl metric (WUP) in the last 30 years in Switzerland. The next paragraph briefly introduces the four metrics

The first dependent variable, the **percentage of built-up area (PBA)**, emphasizes visible land consumption as used in the studies by Herold et al. (2003) or Loibl and Toetzer (2003). The data for the built-up area (PBA) has been derived from maps provided by Swisstopo (see Jaeger et al., 2014). The maps measure the spatial extent of built-up areas in each municipality independent of function, form, utilisation and spatial location of the buildings. Jaeger et al. (2010a) calculate for each municipality the percentage of developed area by using the actual area of development divided by the area that could potentially be developed. Similarly to Anthony (2004), Cutsinger et al. (2005) and Paulsen (2013), areas where construction is impossible, such as bodies of water, protected areas, unstable soil, forests or steep slopes, are excluded from the potentially developable area.

The second dependent variable, **dispersion of settlement (DIS)**, captures the dispersed spatial arrangement, and irregular and discontinuous fragmentation of urban development. Dispersion as an important characteristic of sprawl is addressed by other authors such as Burchfield et al. (2006), Cutsinger et al. (2005), Galster et al. (2001) and Torrens and Alberti (2000). The variable we use measures dispersion from a geometric perspective: The value of DIS is the highest within an area of calculation, when the buildings are distributed evenly within this area and the lowest when the buildings are arranged close to each other in the shape of a circle (Jaeger et al., 2010a).

Figure 6: Level of Sprawl (WUP) & development of Sprawl (WUP) in Switzerland



Source: data coming from Schick et al. (2014), own illustration

The third dependent variable, **utilisation density (UD)**, refers to sprawl as a phenomenon of low density settlements (also discussed by Antony, 2004; Burchfield et al., 2006; Ewing, 1997; Huang et al., 2007; Lopez & Hynes, 2006; McGrath, 2005; Paulsen, 2012; Pirotte & Madre, 2011; Torrens, 2008; Wassmer, 2008). We assume that the more people and jobs are located in a built-up area, the better its utilisation and hence the higher the value of the variable. To calculate the UD, Jaeger et al. (2010a) count the number of inhabitants and work places of each municipality and divide these by the developed area of each municipality (Cutsinger et al., 2005 and Galster et al., 2001 employ similar calculations).

The fourth dependent variable is the **composite sprawl metric (WUP)**, combining the three variables presented above. The formula established for the calculation of this metric takes into account that the perception of sprawl is often non-linearly related to the level of land uptake per inhabitant or job, which is measured by the density (UD), and to the level of dispersion (DIS). Hence, these two metrics are weighted in a way that prevents them from increasing (or decreasing) too much at the extremes of the possible range of sprawl (for detailed explanations see Jaeger et al., 2010a; 2014). Intuitively, this means for both measures that the differences in perception are more pronounced at intermediary values of their corresponding scales compared to their extreme values. This translates into a metric that is below average for both the inner cities where utilisation density (UD) is very high and for rural areas with traditionally scattered settlements with very low UD and a low proportion of built-up area (PBA). In

contrast, the composite sprawl metric (WUP) is above average in suburban regions where the perceived level of urban sprawl is usually high and UD is low.

The composite sprawl metric (WUP) and the proportion of built-up area (PBA) highly correlate with a value of $r > 0.9$ for the Pearson correlation coefficient. The other two dependent variables, DIS and UD, while positively correlated, do not exhibit such a high correlation with the composite sprawl metric (WUP). The dependent variables proportion of built-up area (PBA), utilisation density (UD), and composite sprawl metric (WUP) were transformed applying a cubic root transformation in order to approximate the data to a normal distribution.

3.3.2. Determinants of urban growth: independent variables

As often, the difficulty in testing models empirically lies in the availability of appropriate data to measure the theoretically proposed variables (Mueller, 2004). The way we set up our analysis is such that we use data on the municipality level for the entire sample period of 40 years (including 10 years' time lag, cf. 3.3.2). This makes it difficult to include information on local regulation of land use, local subsidies and local services since such information is mostly lacking at that level of detail. Consequently, the choice of variables we employ is oriented along the line of the monocentric city model rather than the Tiebout model (cf. 3.2.2).

Models that rely on the monocentric city model usually include a variable that captures the price of agricultural land. However, in Switzerland, the value of the land for construction can be assumed to be independent of the value of agricultural land as the agricultural land market is highly regulated and agricultural land cannot immediately be converted into construction land. Since there are no data on the price of construction land in Switzerland, we could not employ a variable for land prices.

Table 1 and 2 summarise the independent variables used in our analysis, and Table 3 gives the descriptive summary statistics for the four dependent variables (cf. 3.3.1.) and for the independent variables (cf. 3.3.2.). Table 4 presents an overview on the expected influence of the independent variables on the dependent variables and the corresponding references in the literature.

Population or population growth is the most intuitively comprehensible and widely used variable in models that capture urban growth (Burchfield et al., 2006; Mann, 2009; Mc Grath, 2005; Paulsen, 2012; Spivey, 2008; Wassmer, 2006). Most of the authors use the total number of inhabitants of the study area and confirm a positive influence on the dependent variable that measures sprawl. Following the approach of Burchfield et al. (2006), we use population growth rate rather than the absolute number of inhabitants.

As formulated by Broitman and Koomen (2015), population growth processes can lead to two types of spatial development: the construction of new housing units within existing built-up area, and thus to densification (UD), e.g. in the highly urbanised cities, or the construction of new housing on the green land, that is an expansion of the built-up area (PBA), e.g. at the outer fringe of metropolitan areas. Depending on how pronounced the effect of population growth is on density (UD) and dispersion (DIS), the level of sprawl (WUP) might actually decrease with a growing population (Wissen et al., 2010).

Table 1: Description of Independent Variables

Variables	Description	Source
Population growth $((x-x_{t-10})/x_{t-10})*100$	Population residing in the municipality measured as population growth rate within 10 years	Census
Federal Tax_{t-10}	Per capita federal taxes collected, 10 years lagged	Census
Accessibility $_{t-10}$	Potential to which land-use transport system enables reaching a municipality (public & private transport), 10 years lagged	Tschopp & Fröhlich, 2006
Commuters (out) $_{t-10}$	Outbound commuters as share of total employed residents per municipality, 10 years lagged	Census
Commuters (in) $_{t-10}$	Inbound commuters as share of total employees working in the municipality, 10 years lagged	Census
Homeowners $_{t-10}$	Ratio of homeowners, 10 years lagged	Census
Retired Inhabitants	Percentage of retired inhabitants	Census
Single Households	Percentage of single households as share of total households	Census
Employees Tertiary Sector	Ratio employees working in the tertiary sector	Census
Change Employees Primary Sector $x-x_{t-10}$	Ratio employees working in the primary sector as difference (increase/decrease) of 10 years. This variable gives evidence of the structural changes in the employment market.	Census
Employees Primary Sector	Ratio employees working in the primary sector	Census
Buildings before 1919	Buildings built before 1919 as share of total building of reference year	*Building statistics

Source: Federal statistical office (FSO), Census 1970, 1980, 1990, 2000, Statpop 2010, *the building statistics is part of the census

As far as economic wealth is concerned, the variable used in the literature is usually the median household income (Paulsen, 2012; Paulsen, 2013; Spivey, 2008) or real per capita income (McGrath, 2005). The measure we use to estimate wealth is the total amount of direct federal tax revenue per head, as did Waltert et al., (2011) in a Swiss study. Since this tax has been imposed since 1947 in a unitary manner at the national level, it allows consistent wealth estimation across municipalities and time. Theory predicts that increasing wealth has a positive influence on sprawl. In line with this theory, we expected that richer municipalities develop faster and thus sprawl more in WUP and built-up area (PBA). Since richer people can afford it, they tend to live in more spacious residential properties; hence, we would expect a higher value in dispersion (DIS). Also, wealthier people can be expected to prefer low-density settlements, which adversely affects utilization density (UD).

The question of how to operationalise transportation costs is much debated in the literature (Brueckner & Fansler, 1983; McGrath, 2005; Paulsen, 2012; Spivey, 2008; Wassmer, 2008). Usually, the percentage of commuters using public transport (Brueckner & Fansler, 1983) or the average travel time to work (Paulsen, 2013; Spivey, 2008) are chosen as proxy. Although these variables do not directly express monetary costs, the assumption is that more and longer commutes are positively correlated with opportunity costs. However, we consider a measurement for the accessibility of each municipality. Accessibility here is the potential of public or private transport to enable a commuter to reach a destination from every other destination. This was calculated by Frohlich et al. (2005) for all Swiss municipalities and for the different time periods we focus on. Accessibility stands as a proxy for traffic infrastructure, and demonstrates attractiveness for commuters. Besides this variable, we additionally employ two variables to operationalise commuting patterns, namely the share of in- and outgoing commuters per municipality. The commuting patterns act as measurements of the use of this infrastructure. For inbound commuters as well as for accessibility, we expect a positive influence on all of the metrics. However, outbound commuters could have a negative effect on utilisation density (UD) because in Switzerland, municipalities with high shares of outbound commuters tend to be wealthy dormitory towns with low density settlement patterns. Since data distribution for accessibility is skewed, we applied a cubic root transformation.

Table 2: Description of Control Variables

Variables	Description	Source
Rural areas	Municipalities declared as rural (in a rural/urban dichotomy)	Schuler et al., 2005
Agricultural areas*	Municipalities with a very strong focus on agriculture (primary sector > 23.5%): 167 out of 2495 municipalities	Schuler et al., 2005
Economic centres*	Municipalities that fulfil a principal central function of an agglomeration with > 30'000 inhabitants : 5 out of 2495 municipalities	Schuler et al., 2005
Medium centres*	Municipalities that fulfil a central function of an agglomeration/region (defined by a certain number of inhabitants): 22 out of 2495 municipalities	Schuler et al., 20055
Small centres*	Municipalities that are principal towns of smaller regions (defined by a certain number of inhabitants): 44 out of 2495 municipalities	Schuler et al., 2005
High income areas*	Municipalities that belong to an agglomeration and have a particularly high income per capita: 86 out of 2495 municipalities	Schuler et al., 2005
*Controlling for Political Entities**:*		
Swiss cantons	26 cantons: 25 dummies, the reference category is the canton of Ticino	Schuler et al., 2005
Swiss planning regions	129 regions: 128 dummies, the reference category is the region Jura	Schuler et al., 2005
Metropolitan areas	5 metropolitan areas: 5 dummies	Schuler et al., 2005

*Note: In this selection of classification of municipalities, municipalities are assigned exclusively to one category but do not have to be assigned to one. The classification is for the year 2000 and derives from a study done by Schuler et al., 2005.
** For the two entities that, as a sum, include all of the municipalities, we use as many dummies as there are categories minus 1. For the entity that does not include all of the municipalities, we use as many dummies as there are categories.

In addition, we consider three variables that indicate important aspects of both the change of lifestyle and demographic in our timeframe: The homeownership ratio (Glaeser & Kahn, 2003; Paulsen, 2013), the rate of single households per municipality (Mann, 2009) and the share of retired inhabitants per municipality (Mann, 2009; Paulsen, 2013; Wasmer, 2008):

Paulsen (2013) finds that a higher ratio of homeowners is correlated with a higher consumption of land per net new housing units and thus decreases density. We are not considering only net new housing units, but rather the entity of housing units which includes the respective share of residential property. Following Fischel's (2001) 'homevoter hypothesis' we consider it as possible that homeowners might have an incentive to lobby against uncontrolled building activity in their neighbourhood to protect their property values. However, the data we dispose of to measure the share of residential property also includes ownership of condominium apartments. While it is very likely that a single house in a rural area has a higher share of built-up area per inhabitant than an apartment in an urban environment, homeowners' incentives to organise and combat sprawl are likely to be stronger in the countryside when compared to more densely built agglomerations. Correspondingly, we had no strong expectation about the effect of the homeowner rate on the various sprawl metrics.

By including the share of single households in our model, we account for the increased demand for residential space. The number of single households should thus be positively related to the built-up area (PBA), the composite sprawl metric (WUP) and dispersion (DIS), while utilisation density (UD) should be negatively affected.

We further assume that the share of elderly people has a positive impact on the built-up area (PBA): Senior citizens might not set up residence at the urban fringe and thus do not contribute to urban sprawl directly. Rather, we assume that they tend to occupy the existing housing stock (Mann, 2009) and thus prevent to some degree the provision of more modern residential structures. Accordingly they indirectly contribute to the newer households' decision to settle at the urban fringe which, correspondingly, increases the level of sprawl (WUP).

Furthermore, to include information on the local economic structure, we employ the share of employees in the primary and tertiary sectors as well as the change of employees in the primary sector. We expect that a reduction of employees in the primary sector corresponds to the abandonment of agricultural pursuits, which makes land available for built-up areas (PBA). In Burchfield et al. (2006) we see that cities which specialise in centralized sectors are more compact. We expect a similar effect with municipalities that have a high share of employees in service based industries: the larger the share of employees in the third sector, the higher the utilisation density (UD).

We are aware that the change from a non-urban land-use to an urban land-use can also involve other than the construction of dwellings, for example industrial areas or shopping malls. In terms of urban sprawl, these commercial constructions have certainly a high impact (Fulton et al., 2001). The subject of commercial land use is worth closer attention, however, outside the scope of this article.

Finally, by using the respective typologies of municipalities provided by the Swiss Federal Statistical Office, we allow for municipalities declared as agricultural, for municipalities that fulfil a central function in their region, and for municipalities that have a particularly high income per capita. Furthermore, we take into account three greater political entities: the cantons, the metropolitan areas, and the Swiss planning regions. In fact, Switzerland mainly controls growth on the regional level (e.g. via Richtpläne on the cantonal level), and hence it is vital to control for this levels. Unlike the other variables, and due to greater consistency in this field, these six grouping variables remain constant for all four periods (Schuler et al., 2005).

3.3.3. Avoiding simultaneity bias

Some of the variables do not have an immediate influence on the dependent variables, especially since construction itself is a process requiring time. Hence, in our analysis, federal tax revenue and the homeowners' ratio are lagged by one period, i.e. 10 years. Similarly, we employ lagged variables to take up the issue of simultaneity as raised by Duranton and Puga (2014). Simultaneity refers to the question of cause and effect - does for example accessibility cause urban growth or does urban growth lead to an expansion of the mobility infrastructure? The variables we also lag include accessibility, commuters, and population growth.

An additional remedy against simultaneity bias was to include a variable that captures historical information about development patterns in order to control for preconditions of urban development (Paulsen, 2013). Accordingly, for each period, we employ the share of buildings in a municipality that were constructed before 1919 compared to the existing stock. 1919 was chosen because this is the first time an inventory was made and includes all buildings planned before the common usage of cars. This variable implicitly measures construction activity since 1919 and hence signals differing development paths and thus preconditions for urban sprawl across municipalities. However, we do expect that the pre-conditions and the development paths would differ between rural and urban areas. Cities, in comparison with the suburban hinterland, exhibit a relatively high share of old buildings but sprawl significantly less due to their high density. In the model, we combine the differentiation between urban and rural municipalities with our proxy representing buildings before 1919. This allows for an interaction effect; while we expect a high share of old buildings to be associated negatively with sprawl, this effect should be stronger for urban and central municipalities.

Overall we used 12 independent variables (Table 1) and 9 control variables (Table. 2).

Table 3: Descriptive Statistics of the Variables

Year			1980				1990				2000				2010			
Variables	**Transf.**	**Obs.****	**Mean**	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**
WUP	third root	2495	4.49	0.19	0.02	58.86	4.83	0.21	0.004	58.41	5.09	0.23	0.006	59.78	5.74	0.24	0.003	57.96
UD	third root	2495	234	0.97	15.81	1809	245	1.03	11.54	2030	263	0.86	27	1952	246	1.06	9	2053
DIS		2495	44.30	4.59	22.35	56.22	44.36	4.56	22.35	55.93	44.46	4.52	22.35	55.98	44.56	4.45	23.08	55.93
PBA	third root	2495	15.37	16.6	0.39	100	16.61	17.6	0.39	1.01	17.59	18.6	0.40	1.01	19.18	19.7	0.41	1.01
Population growth $((x-x_{t-10})/x_{t-10})*100$		2495	7.20	22.51	-61.79	206.84	14.67	17.99	-41.23	293.58	11.03	13.31	-48.68	124.47	9.27	12.36	-45.45	109.24
Federal Tax t-10[¤]		2495	7.81	3.43	0.47	51.94	12.50	3.81	1.35	73.96	20.11	5.84	6.77	77.06	80.89	86.02	4.39	1174.7
Accessibility t-10[¤]	third root	2495	15719	13475	252	192267	19370	16059	200	192267	21657	17953	166	228755	22820	18593	183	229500
Commuters (out) t-10		2495	0.38	0.18	0.00	0.88	0.48	0.18	0.00	0.87	0.60	0.17	0.02	0.94	0.66	0.15	0.01	0.93
Commuters (in) t-10		2495	0.19	0.15	0.00	0.82	0.27	0.18	0.00	0.95	0.378	0.20	0.00	0.96	0.43	0.19	0.00	0.94
Homeowners t-10		2495	0.55	0.18	0.02	1.00	0.57	0.18	0.03	1.00	0.55	0.16	0.04	1.00	0.23	0.12	0.00	0.85
Retired Inhabitants		2495	0.13	0.05	0.00	0.50	0.13	0.05	0.02	0.55	0.14	0.04	0.03	0.49	0.16	0.04	0.05	0.67
Single Households		2495	0.20	0.06	0.00	0.48	0.24	0.06	0.00	0.56	0.29	0.06	0.06	0.59	0.31	0.05	0.05	0.90
Employees Tertiary Sector		2495	0.44	0.14	0.03	0.89	0.58	0.12	0.07	0.94	0.63	0.11	0.00	0.91	0.49	0.21	0.00	1.00
Change Employees Primary Sector x-x t-10		2495	-0.05	0.07	-0.5	0.27	-0.07	0.08	-0.68	0.21	-0.02	0.05	-0.36	0.31	0.13	0.16	-0.25	0.91
Employees Primary Sector		2495	0.19	0.16	0.00	0.97	0.12	0.12	0.00	0.90	0.1	0.09	0.00	0.73	0.23	0.22	0.00	1.00
Buildings before 1919		2495	0.32	0.19	0.01	0.93	0.26	0.17	0.01	0.92	0.23	0.16	0.01	0.88	0.27	0.15	0.01	0.88
Buildings before 1919 in rural areas		2495	0.26	0.25	0.00	0.93	0.22	0.21	0.00	0.92	0.19	0.19	0.00	0.88	0.21	0.2	0.00	0.88

[¤]With this two variables, the method of data acquisition has changed compared to the previous periods. The results for 2010 are therefore not directly comparable to 1980, 1990, 2000.

** All the data was aggregated based on the number of municipalities as at 1 January 2012 in order to conduct the statistical analysis. Thus for all periods, the number of observations is 2495.

Table 4: Expected Influence of Independent Variables and Reference in Literature

	Expected influence				Literature review: Influence of independent variables				
Study Area	CH				U.S.A.			CH	
Dependent Variables	PBA	WUP	UD	DIS	Urbanized Area*	Sprawl Index**	Paulsen 2013 a,b,c,d***	Residential Building area pc****	Source
Independent Variables (**those used in this study are shown in bold**):									
Population growth ($(x-x_{t-10})/x_{t-10}$)*100	+	+	+	+					
Total number of inhabitants					+				Brueckner & Fansler 1983, Spivey 2008, Paulsen 2012
Log number of population					+				Mc Grath 2005, Wassmer 2006
Historical population growth (1920-1970)						-			Burchfield 2006
Std.dev.decennial historical population growth (1920-1970)						+			Burchfield 2006
Actual population growth (1970-1992)						-			Burchfield 2006
Number of inhabitants								-	Mann 2009
Federal Tax $_{t-10}$	+	+	-	+					
Average household income					+				Brueckner & Fansler 1983
Real per capita personal income					+				Mc Grath 2005
Median household income					+		a)- b)- c)+ d)+		Paulsen 2012, Paulsen 2013
Log median household income					+				Wassmer 2006
Median family income					-				Spivey 2008
Accessibility $_{t-10}$	+	+	+	+					
Commuters (out) $_{t-10}$	+	+	-	+					
Commuters (in) $_{t-10}$	+	+	+	+					
Ratio commuters using public transport					-				Brueckner & Fansler 1983, Spivey 2008
Ratio households owning one or more cars					+				Brueckner & Fansler 1983, Spivey 2008
Adj. private transportation consumer price index					-				Mc Grath 2005
Commuter (out)								-	Mann 2009
Homeowners $_{t-10}$	-	-	-	-					
% housing units owner-occupied							a)- b)+ c)- d)-		Paulsen 2013
Retired Inhabitants	+	+	-	+					
Log % population greater or equal 65 years					+				Wassmer 2006
% population greater or equal 65 years								+	Mann 2009
% residents over 65							a)+ b)- c)+ d)-		Paulsen 2013
Single Households	+	+	-	+					
% single households								-	Mann 2009
Employees Tertiary Sector	-	+	+	+					
Change Employees Primary Sector x-x $_{t-10}$	+	+	-	-					
Employees Primary Sector	-	-	+	-					
Centralized-sector employment						-			Burchfield 2006
Buildings before 1919	-	-	+	-					
Buildings before 1919 in rural areas	-	-	+	-					
% housing units built before 1950							a)- b)+ c)- d)+		Paulsen 2013

* Paulsen 2012 adapts this category compared to other authors, ** Sprawl (scatteredness) Index as calculated by Burchfield 2006, *** Paulsen 2013 uses measurements for a) change in urban housing unit density, b) marginal land consumed per net new urban household, c) density of housing units in newly urbanized areas and d) percent of net new urban housing units in previously urbanized areas. The results reported here are for the full models presented in Paulsen 2013,****as used in Mann 2009

3.3.4. Method: Specification of the OLS and spatial econometric model

Our approach was to first calculate ordinary least square models employing the variables listed in Table 1. To that end, 16 OLS models, one for each dependent variable and for each time period, were estimated. Based on these initial OLS regressions, we added the control variables (Table 2).

We examined each OLS model for standard model violations. The variance inflation factor (VIF) indicated that multicollinearity is a problem with the variables that we use to control for the rural-urban dichotomy, for the share of old buildings, and in 1980 and 2010 also for the share of employees in the primary sector. Since part of these are control variables and since the other variables have a VIF value below 3, we proceeded with all of the variables in the model. Furthermore, tests indicated the presence of heteroskedasticity, so we estimated the OLS regressions with standard errors impervious to heteroskedasticity using the White's estimator (White, 1980).

One definite source for the heteroskedasticity is that the error variance is affected by spatial dependence in the data (Kim and Sun, 2011). Since we assumed a strong spatial neighbourhood effect in our data, we applied a Moran's I test that measures spatial autocorrelation (Anselin and Rey, 1991). For the weight matrix that defines the type of neighbourhood relation used in the test, we used a first-order, Queen's based row standardised spatial weight matrix that gives each direct neighbour an equal weight.

The significant statistic for the Moran's I for our dependent variables indicates a problem with positive spatial autocorrelation, most prominent for the dependent variables composite sprawl metric (WUP) and built-up area (PBA), both resulting in a test statistic of around 0.6. The positive and significant values of the global Moran's I indicate the presence of clusters of municipalities where high values of the dependent variables for one municipality correlate with high values of the respective variables of its neighbours and vice versa.

To identify which spatial regression specification should be used, Lagrange multiplier and the Robust Lagrange multiplier tests were applied (Anselin & Rey, 1991). The values of the robust lag test were significant, thus a spatial lag model, estimated via maximum likelihood, was chosen. The spatial lag model measures the potential spill-over effect that occurs in a dependent variable if this variable is influenced by the value of the dependent variable of the neighbouring municipality (Anselin et al., 2006, see also Song et al., 2014).

3.4. Results and Discussion

3.4.1. Models

In Tables 5 to 8 we present the results for the OLS model including the control variables. Alongside each OLS model we also report the results for the respective spatial lag model. For the interpretation of the coefficient estimates of the spatial lag model, it is important to keep in mind that it is an autoregressive model. Thus, the coefficient estimates for the OLS and the spatial lag model are not directly comparable. Also, by employing dummy variables (cf. 3.3.2.), we controlled for all differences in the level of our dependent variables between the Cantons, the metropolitan areas, and the Swiss planning regions.

With regard to the OLS model and the spatial lag model, we see a relatively constant picture as far as the algebraic sign of the coefficients and their statistical significance is concerned. Considering the explanatory power over time, the adjusted R2 of the OLS model shows that, depending on the dependent variable, 65% to 80% of the variation can be explained by our set of variables. Moreover, the models do not seem to lose predictive power for the 40 years of our timeframe. As expected, the various fit statistics, especially the LR test, indicate that the spatial lag model fits the data better than the OLS model. The spatial coefficient Rho, is positive and highly significant. Moreover, the value of Rho remains relatively constant over time. The Breusch-Pagan test indicates remaining heteroskedasticity in the residuals also for the spatial lag model.

As such, the results suggest that for a single municipality the dependent variables are influenced by the mean values of the corresponding dependent variables in the neighbouring municipalities and hence that urban growth is a highly spatially interdependent matter. The spatial interdependence is most pronounced for the composite sprawl metric (WUP) and least pronounced for the level of dispersion (DIS).

Looking at the dependent variables, it is evident that the model does not fit comparably well for dispersion (DIS). Burchfield et al. (2006) who measure sprawl in terms of compactness of residential development, which is quite similar to the measurement of dispersion (DIS), put a strong emphasis on physical geographic information. They assume that topographical characteristics of the terrain determine dispersion to a great extent. In their model, five geographical variables, capturing the role of aquifers, terrain, and climate, explain 23.5 % of the variation in their sprawl index. In our model, we do not include any geographical information since the focus lies on the socio-economic variables. Yet, because dispersion (DIS) is part of the composite sprawl metric (WUP), we have kept dispersion (DIS) in the model.

Table 5: Regression Results for 1980

	OLS	spatial lag	OLS	spatial lag	OLS	spatial lag	OLS	spatial lag
	PBA	*PBA*	*WUP*	*WUP*	*UD*	*UD*	*DIS*	*DIS*
Population growth ((x-x t-10)/xt-10)*100	-0.0001	-0.00002	-0.001**	-0.001**	0.002***	0.003***	-0.018***	-0.019***
	(0.0001)	(0.0001)	(0.0004)	(0.0004)	(0.001)	(0.001)	(0.006)	(0.005)
Federal Tax t-10	0.004***	0.003***	0.019***	0.016***	-0.023***	-0.026***	0.067**	0.066*
	(0.001)	(0.001)	(0.003)	(0.003)	(0.007)	(0.006)	(0.030)	(0.036)
Accessibility t-10	0.005***	0.004***	0.012***	0.007***	0.036***	0.031***	0.085***	0.062**
	(0.001)	(0.0005)	(0.002)	(0.002)	(0.005)	(0.004)	(0.025)	(0.025)
Commuters (out) t-10	0.040***	-0.015	0.575***	0.373***	-0.362***	-0.559***	10.641***	10.046***
	(0.015)	(0.012)	(0.059)	(0.050)	(0.114)	(0.103)	(0.676)	(0.665)
Commuters (in) t-10	0.139***	0.117***	0.608***	0.516***	0.136	0.047	3.461***	3.031***
	(0.016)	(0.013)	(0.062)	(0.054)	(0.114)	(0.113)	(0.678)	(0.732)
Homeowners t-10	-0.112***	-0.097***	-0.216***	-0.166***	-2.584***	-2.422***	-1.851**	-1.684**
	(0.019)	(0.015)	(0.079)	(0.064)	(0.170)	(0.133)	(0.929)	(0.857)
Retired Inhabitants	0.244***	0.244***	0.822***	0.844***	-1.355***	-1.213***	-1.808	-1.869
	(0.059)	(0.043)	(0.265)	(0.181)	(0.458)	(0.378)	(3.012)	(2.445)
Single Households	0.127***	0.097***	0.092	0.001	-0.213	-0.242	-1.554	-1.580
	(0.036)	(0.032)	(0.154)	(0.133)	(0.350)	(0.278)	(1.980)	(1.797)
Employees Tertiary Sector	0.012	-0.015	0.206**	0.135*	-0.259	-0.359**	3.428***	3.445***
	(0.022)	(0.018)	(0.090)	(0.074)	(0.176)	(0.155)	(1.125)	(1.002)
Change Employees Primary Sector (70-80)	-0.063*	-0.073**	-0.232	-0.268**	-0.321	-0.306	0.265	0.021
	(0.035)	(0.031)	(0.160)	(0.128)	(0.284)	(0.267)	(2.258)	(1.729)
Employees Primary Sector	-0.132***	-0.177***	-0.104	-0.246***	-0.386*	-0.612***	13.472***	12.836***
	(0.023)	(0.020)	(0.100)	(0.083)	(0.206)	(0.174)	(1.346)	(1.124)
Buildings before 1919	-0.348***	-0.309***	-0.984***	-0.855***	-0.994***	-0.862***	1.757	2.201*
	(0.031)	(0.023)	(0.117)	(0.095)	(0.219)	(0.197)	(1.175)	(1.274)
Buildings before 1919 in rural areas	0.219***	0.187***	0.586***	0.495***	1.248***	1.119***	-1.996*	-2.143*
	(0.029)	(0.023)	(0.114)	(0.095)	(0.212)	(0.199)	(1.211)	(1.281)
Rural areas	-0.097***	-0.080***	-0.352***	-0.285***	-0.400***	-0.316***	-0.270	-0.180
	(0.009)	(0.008)	(0.038)	(0.033)	(0.070)	(0.069)	(0.414)	(0.441)
Agricultural areas	0.017***	0.019***	0.051*	0.062**	0.320***	0.306***	0.505	0.560
	(0.006)	(0.007)	(0.028)	(0.027)	(0.079)	(0.057)	(0.468)	(0.367)
Economic centres	0.039	0.029	-1.781***	-1.912***	2.520***	2.576***	5.212***	5.378***
	(0.026)	(0.035)	(0.184)	(0.147)	(0.270)	(0.307)	(0.860)	(1.980)
Medium centre	0.050**	0.053***	-0.249***	-0.283***	1.104***	1.146***	3.950***	3.944***
	(0.020)	(0.015)	(0.096)	(0.064)	(0.130)	(0.133)	(0.615)	(0.860)
Small centres	0.020	0.035***	0.043	0.083*	0.500***	0.561***	2.070***	2.036***
	(0.014)	(0.011)	(0.053)	(0.045)	(0.077)	(0.094)	(0.405)	(0.604)
High income areas	0.044***	0.036***	0.236***	0.215***	-0.099	-0.155**	0.046	-0.034
	(0.012)	(0.009)	(0.049)	(0.037)	(0.087)	(0.078)	(0.371)	(0.502)
Controlling for Political Entities	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2495	2495	2495	2495	2495	2495	2495	2495
R^2	0.830		0.765		0.677		0.383	
Adjusted R^2	0.818		0.749		0.655		0.341	
Log Likelihood		3344.4		-231.0		-2050.9		-6702.2
Rho		0.30***		0.37***		0.27***		0.25***
$sigma^2$		0.004		0.069		0.299		12.492
Akaike Inf. Crit.	-6160.9	-6362.8	1043.5	788.0	4557.3	4427.8	13798.6	13730.5
Residual Std. Error (df = 2333)	0.068		0.289		0.585		3.728	
F Statistic (df = 160; 2333)	71.178***		47.390***		30.601***		9.066***	
Wald Test (df = 1)		252.1***		323.8***		152.3***		85.2***
LR Test (df = 1)		203.8***		257.5***		131.5***		70.1***
LM Test		0.27 (0.602)		0.73 (0.390)		5.24 (0.022)		5.24 (0.022)

Note: *p **p ***p<0.01

Table 6: Regression Results for 1990

	OLS	spatial lag	OLS	spatial lag	OLS	spatial lag	OLS	spatial lag
	PBA	*PBA*	*WUP*	*WUP*	*UD*	*UD*	*DIS*	*DIS*
Population growth ((x-x t-10)/xt-10)*100	-0.0001	-0.0001	0.0002	0.0003	0.0004	0.0005	0.006	0.006
	(0.0001)	(0.0001)	(0.0004)	(0.0004)	(0.001)	(0.001)	(0.006)	(0.005)
Federal Tax t-10	0.003***	0.003***	0.013**	0.011***	-0.017***	-0.019***	-0.013	-0.013
	(0.001)	(0.001)	(0.005)	(0.002)	(0.005)	(0.004)	(0.038)	(0.029)
Accessibility t-10	0.004***	0.003***	0.009***	0.005***	0.025***	0.021***	0.080***	0.060***
	(0.001)	(0.0004)	(0.002)	(0.002)	(0.004)	(0.003)	(0.023)	(0.023)
Commuters (out) t-10	0.074***	0.017	0.657***	0.441***	-0.079	-0.346***	11.388***	10.689***
	(0.016)	(0.013)	(0.066)	(0.056)	(0.116)	(0.103)	(0.716)	(0.720)
Commuters (in) t-10	0.118***	0.102***	0.516***	0.433***	0.379***	0.323***	2.494***	2.050***
	(0.015)	(0.012)	(0.058)	(0.049)	(0.110)	(0.089)	(0.626)	(0.633)
Homeowners t-10	-0.153***	-0.133***	-0.301***	-0.250***	-2.706***	-2.497***	-2.003**	-1.830**
	(0.018)	(0.015)	(0.076)	(0.065)	(0.155)	(0.121)	(0.915)	(0.849)
Retired Inhabitants	0.260***	0.241***	0.821***	0.823***	-0.812*	-0.863**	0.144	0.177
	(0.062)	(0.044)	(0.252)	(0.186)	(0.442)	(0.342)	(2.786)	(2.418)
Single Households	0.157***	0.121***	0.219	0.113	-0.766**	-0.798***	-0.124	-0.062
	(0.042)	(0.033)	(0.179)	(0.142)	(0.347)	(0.261)	(2.272)	(1.845)
Employees Tertiary Sector	-0.003	-0.022	0.099	0.069	-0.197	-0.321**	1.281	1.598
	(0.025)	(0.021)	(0.106)	(0.088)	(0.183)	(0.162)	(1.329)	(1.146)
Change Employees Primary Sector (70-80)	0.039	0.087***	-0.107	0.056	0.480*	0.710***	-11.648***	-10.851***
	(0.034)	(0.027)	(0.150)	(0.115)	(0.258)	(0.211)	(1.857)	(1.493)
Employees Primary Sector	-0.203***	-0.248***	-0.335**	-0.454***	-0.645**	-0.908***	14.901***	14.439***
	(0.035)	(0.026)	(0.139)	(0.112)	(0.270)	(0.206)	(1.667)	(1.456)
Buildings before 1919	-0.483***	-0.428***	-1.384***	-1.189***	-0.953***	-0.764***	1.581	2.454
	(0.041)	(0.030)	(0.156)	(0.128)	(0.250)	(0.235)	(1.526)	(1.660)
Buildings before 1919 in rural areas	0.331***	0.290***	0.860***	0.735***	0.904***	0.760***	-3.373**	-3.824**
	(0.039)	(0.031)	(0.154)	(0.129)	(0.242)	(0.238)	(1.553)	(1.680)
Rural areas	-0.107***	-0.091***	-0.368***	-0.302***	-0.331***	-0.254***	0.132	0.253
	(0.009)	(0.008)	(0.039)	(0.034)	(0.062)	(0.062)	(0.414)	(0.439)
Agricultural areas	0.033***	0.033***	0.110***	0.114***	0.224***	0.213***	0.395	0.420
	(0.007)	(0.007)	(0.030)	(0.029)	(0.075)	(0.054)	(0.496)	(0.382)
Economic centres	0.062**	0.044	-1.667***	-1.813***	2.703***	2.706***	6.581***	6.571***
	(0.029)	(0.036)	(0.194)	(0.152)	(0.361)	(0.278)	(0.850)	(1.968)
Medium centre	0.061***	0.060***	-0.169*	-0.218***	1.073***	1.081***	4.836***	4.725***
	(0.020)	(0.016)	(0.095)	(0.066)	(0.116)	(0.121)	(0.588)	(0.856)
Small centres	0.028**	0.041***	0.092	0.121***	0.461***	0.513***	2.659***	2.596***
	(0.014)	(0.011)	(0.058)	(0.046)	(0.069)	(0.085)	(0.407)	(0.604)
High income areas	0.046***	0.036***	0.303***	0.276***	-0.111	-0.171**	0.812*	0.674
	(0.014)	(0.009)	(0.061)	(0.039)	(0.080)	(0.071)	(0.445)	(0.502)
Controlling for Political Entities	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2495	2495	2495	2495	2495	2495	2495	2495
R^2	0.835		0.759		0.739		0.376	
Adjusted R^2	0.824		0.743		0.722		0.333	
Log Likelihood		3299.121		-318.398		-1818.358		-6699.919
Rho		0.28***		0.36***		0.26***		0.25***
$sigma^2$		0.004		0.074		0.248		12.441
Akaike Inf. Crit.	-6086.5	-6272.2	1196.0	962.7	4101.2	3962.7	13793.1	13725.8
Residual Std. Error (df = 2333)	0.069		0.298		0.533		3.720	
F Statistic (df = 160; 2333)	73.956***		46.022***		41.382***		8.796***	
Wald Test (df = 1)		229.2***		297.2***		163.0***		85.0***
LR Test (df = 1)		187.7***		235.2***		140.5***		69.3***
LM Test		0.89 (0.344)		1.80 (0.179)		10.86 (0.00)		2.67 (0.101)

Note: *p **p ***p<0.01

Table 7: Regression Results for 2000

	OLS	spatial lag	OLS	spatial lag	OLS	spatial lag	OLS	spatial lag
	PBA	*PBA*	*WUP*	*WUP*	*UD*	*UD*	*DIS*	*DIS*
Population growth ((x-x t-10)/xt-10)*100	-0.0003*	-0.0002	-0.002***	-0.001***	0.002**	0.003***	-0.017**	-0.014**
	(0.0002)	(0.0001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.008)	(0.007)
Federal Tax t-10	0.002***	0.002***	0.013***	0.011***	-0.013***	-0.015***	0.049**	0.048**
	(0.001)	(0.0004)	(0.002)	(0.002)	(0.004)	(0.003)	(0.022)	(0.022)
Accessibility t-10	0.004***	0.003***	0.010***	0.005***	0.027***	0.022***	0.099***	0.078***
	(0.0005)	(0.0004)	(0.002)	(0.002)	(0.004)	(0.003)	(0.023)	(0.023)
Commuters (out) t-10	0.067***	0.014	0.615***	0.394***	-0.137	-0.388***	11.225***	10.576***
	(0.016)	(0.014)	(0.063)	(0.058)	(0.111)	(0.103)	(0.734)	(0.721)
Commuters (in) t-10	0.097***	0.083***	0.463***	0.388***	0.333***	0.284***	2.437***	2.075***
	(0.012)	(0.011)	(0.052)	(0.046)	(0.097)	(0.083)	(0.595)	(0.586)
Homeowners t-10	-0.208***	-0.191***	-0.427***	-0.391***	-2.334***	-2.103***	-0.162	-0.044
	(0.021)	(0.017)	(0.091)	(0.070)	(0.168)	(0.126)	(0.955)	(0.883)
Retired Inhabitants	0.337***	0.327***	0.858***	0.966***	-0.681	-0.785**	-4.478*	-3.874
	(0.072)	(0.047)	(0.289)	(0.199)	(0.433)	(0.357)	(2.682)	(2.515)
Single Households	0.108***	0.061*	0.182	0.008	-1.095***	-1.021***	1.348	1.588
	(0.037)	(0.033)	(0.162)	(0.139)	(0.314)	(0.250)	(2.085)	(1.760)
Employees Tertiary Sector	-0.005	-0.027	0.063	0.012	0.177	0.058	1.581	1.856
	(0.028)	(0.025)	(0.117)	(0.106)	(0.213)	(0.190)	(1.614)	(1.336)
Change Employees Primary Sector (70-80)	0.141***	0.185***	0.108	0.266*	-0.571*	-0.175	-15.949***	-15.239***
	(0.040)	(0.035)	(0.167)	(0.148)	(0.343)	(0.267)	(2.254)	(1.877)
Employees Primary Sector	-0.287***	-0.331***	-0.527***	-0.668***	-0.571	-0.765***	16.508***	15.965***
	(0.048)	(0.033)	(0.181)	(0.139)	(0.354)	(0.250)	(2.086)	(1.762)
Buildings before 1919	-0.574***	-0.512***	-1.684***	-1.439***	-1.023***	-0.789***	1.812	2.834
	(0.052)	(0.036)	(0.186)	(0.150)	(0.296)	(0.269)	(1.807)	(1.892)
Buildings before 1919 in rural areas	0.400***	0.347***	1.077***	0.898***	0.854***	0.663**	-3.214*	-3.736*
	(0.051)	(0.036)	(0.189)	(0.151)	(0.296)	(0.272)	(1.848)	(1.909)
Rural areas	-0.115***	-0.097***	-0.399***	-0.322***	-0.364***	-0.289***	0.098	0.212
	(0.010)	(0.008)	(0.039)	(0.034)	(0.061)	(0.061)	(0.410)	(0.427)
Agricultural areas	0.048***	0.047***	0.166***	0.163***	0.223***	0.191***	0.591	0.612
	(0.009)	(0.008)	(0.034)	(0.032)	(0.075)	(0.057)	(0.527)	(0.402)
Economic centres	0.058**	0.044	-1.604***	-1.727***	2.496***	2.514***	5.959***	5.958***
	(0.027)	(0.037)	(0.210)	(0.154)	(0.336)	(0.278)	(0.822)	(1.952)
Medium centre	0.058***	0.060***	-0.093	-0.132**	0.970***	0.998***	4.436***	4.320***
	(0.020)	(0.016)	(0.095)	(0.067)	(0.113)	(0.121)	(0.585)	(0.848)
Small centres	0.029**	0.042***	0.150***	0.188***	0.366***	0.407***	2.655***	2.598***
	(0.015)	(0.011)	(0.054)	(0.048)	(0.065)	(0.086)	(0.417)	(0.601)
High income areas	0.043***	0.034***	0.236***	0.211***	-0.142*	-0.187**	-0.047	-0.164
	(0.013)	(0.010)	(0.055)	(0.042)	(0.086)	(0.075)	(0.430)	(0.527)
Controlling for Political Entities	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2495	2495	2495	2495	2495	2495	2495	2495
R^2	0.836		0.768		0.700		0.376	
Adjusted R^2	0.825		0.752		0.680		0.333	
Log Likelihood		3233.157		-370.692		-1821.176		-6681.582
Rho		0.27***		0.36***		0.29***		0.24***
$sigma^2$		0.004		0.077		0.248		12.264
Akaike Inf. Crit.	-5968.9	-6140.3	1313.4	1067.3	4123.0	3968.3	13753.9	13689.1
Residual Std. Error (df = 2333)	0.071		0.305		0.536		3.691	
F Statistic (df = 160; 2333)	74.605***		48.198***		34.098***		8.794***	
Wald Test (df = 1)		210.9***		316.9***		185.3***		81.9***
LR Test (df = 1)		173.3***		248.0***		156.7***		66.8***
LM Test		3.35 (0.066)		0.22 (0.637)		2.76 (0.096)		3.18 (0.074)

Note: *p **p ***p<0.01

Table 8: Regression Results for 2010

	OLS	spatial lag	OLS	spatial lag	OLS	spatial lag	OLS	spatial lag
	PBA	*PBA*	*WUP*	*WUP*	*UD*	*UD*	*DIS*	*DIS*
Population growth ((x-x t-10)/xt-10)*100	0.0005**	0.0005***	0.001	0.001*	0.003**	0.003***	-0.013	-0.011
	(0.0002)	(0.0001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.008)	(0.007)
Federal Tax t-10	0.00002	0.00000	0.0003**	0.0002**	-0.0002	-0.0002	0.003**	0.003**
	(0.00003)	(0.00003)	(0.0001)	(0.0001)	(0.0002)	(0.0002)	(0.001)	(0.001)
Accessibility t-10	0.005***	0.003***	0.019***	0.011***	0.040***	0.031***	0.194***	0.165***
	(0.001)	(0.0005)	(0.002)	(0.002)	(0.004)	(0.003)	(0.024)	(0.023)
Commuters (out) t-10	0.036*	-0.001	0.455***	0.311***	-0.054	-0.236**	7.650***	7.280***
	(0.022)	(0.018)	(0.083)	(0.073)	(0.139)	(0.118)	(0.926)	(0.884)
Commuters (in) t-10	0.101***	0.085***	0.467***	0.368***	0.127	0.090	2.905***	2.427***
	(0.016)	(0.013)	(0.067)	(0.055)	(0.102)	(0.089)	(0.696)	(0.670)
Homeowners t-10	-0.286***	-0.257***	-0.527***	-0.456***	-2.444***	-2.270***	0.098	0.173
	(0.021)	(0.017)	(0.088)	(0.069)	(0.148)	(0.112)	(0.859)	(0.836)
Retired Inhabitants	0.393***	0.328***	0.989***	0.853***	-1.553***	-1.598***	-2.536	-2.482
	(0.065)	(0.046)	(0.245)	(0.190)	(0.331)	(0.305)	(2.398)	(2.296)
Single Households	0.002	0.002	0.0002	0.0005	0.010	0.014	-0.113	-0.132
	(0.001)	(0.003)	(0.008)	(0.012)	(0.011)	(0.019)	(0.109)	(0.139)
Employees Tertiary Sector	0.029**	0.022**	0.067	0.065	0.039	-0.007	-0.010	0.093
	(0.013)	(0.010)	(0.052)	(0.040)	(0.072)	(0.065)	(0.525)	(0.488)
Change Employees Primary Sector (70-80)	0.297***	0.290***	0.809***	0.737***	0.877***	0.884***	-5.274**	-5.311***
	(0.053)	(0.036)	(0.196)	(0.149)	(0.340)	(0.241)	(2.181)	(1.809)
Employees Primary Sector	-0.317***	-0.332***	-0.753***	-0.781***	-1.317***	-1.402***	11.103***	10.715***
	(0.047)	(0.031)	(0.177)	(0.128)	(0.302)	(0.207)	(1.863)	(1.556)
Buildings before 1919	-0.409***	-0.356***	-1.355***	-1.132***	-0.384*	-0.186	1.116	2.147
	(0.048)	(0.032)	(0.172)	(0.131)	(0.224)	(0.211)	(1.334)	(1.583)
Buildings before 1919 in rural areas	0.235***	0.198***	0.710***	0.586***	0.343	0.161	-3.560**	-4.065**
	(0.048)	(0.033)	(0.175)	(0.136)	(0.235)	(0.219)	(1.472)	(1.645)
Rural areas	-0.107***	-0.088***	-0.414***	-0.331***	-0.311***	-0.235***	0.066	0.210
	(0.011)	(0.009)	(0.043)	(0.036)	(0.059)	(0.058)	(0.411)	(0.432)
Agricultural areas	0.049***	0.046***	0.171***	0.164***	0.278***	0.257***	0.769	0.782**
	(0.009)	(0.008)	(0.034)	(0.032)	(0.069)	(0.052)	(0.506)	(0.390)
Economic centres	0.140***	0.118***	-1.412***	-1.546***	2.243***	2.266***	3.311***	3.305*
	(0.031)	(0.038)	(0.239)	(0.157)	(0.411)	(0.253)	(0.891)	(1.899)
Medium centre	0.088***	0.089***	-0.082	-0.127*	0.926***	0.963***	2.824***	2.729***
	(0.022)	(0.017)	(0.105)	(0.069)	(0.111)	(0.111)	(0.549)	(0.836)
Small centres	0.044***	0.061***	0.177***	0.224***	0.321***	0.378***	1.629***	1.607***
	(0.015)	(0.012)	(0.053)	(0.049)	(0.066)	(0.079)	(0.398)	(0.594)
High income areas	0.062***	0.049***	0.346***	0.320***	-0.306***	-0.360***	0.123	0.036
	(0.013)	(0.010)	(0.054)	(0.042)	(0.071)	(0.068)	(0.431)	(0.514)
Controlling for Political Entities	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2495	2495	2495	2495	2495	2495	2495	2495
R^2	0.826		0.765		0.790		0.385	
Adjusted R^2	0.814		0.748		0.775		0.343	
Log Likelihood		3115.817		-426.963		-1593.072		-6626.228
Rho		0.3***		0.38***		0.24***		0.23***
$sigma^2$		0.005		0.080		0.208		11.740
Akaike Inf. Crit.	-5716.7	-5905.6	1434.0	1179.9	3630.2	3512.1	13638.5	13578.4
Residual Std. Error (df = 2333)	0.075		0.313		0.485		3.606	
F Statistic (df = 160; 2333)	69.208***		47.379***		54.785***		9.129***	
Wald Test (df = 1)		235.4***		332.1***		136.5***		75.8***
LR Test (df = 1)		190.8***		256.1***		120.1***		62.0***
LM Test		3.84 (0.049)		0.00 (0.93)		29(8.1e-08)		1.04 (0.307)

Note: *p **p ***p<0.01

3.4.2. Comparing dimensions of sprawl

We hypothesised that working with different measurements of sprawl, such as proposed by the sprawl metric (WUP) and by its components, would add valuable information to the analysis.

It is interesting to see that the explanatory variables which are the most significant predictors of the value of built-up area (PBA) turn out to be significant predictors for the utilisation density (UD) as well. Furthermore, the variation in utilisation density (UD) over the decades can be increasingly better explained, (especially for the period of 2000 to 2010), and, thus also for the sprawl metric (WUP). We find a related pattern when looking at the control variables identifying centres: Not really surprisingly, economic centres and medium centres are characterised by a larger built-up area (PBA) on average but also by a higher utilisation density (UD).

3.4.3. Referring to the classical variables population growth, wealth and accessibility

As previously stated the results of the OLS and spatial lag models are consistent for the different dependent variables across the four time periods (30 years). Hence, we concentrate the discussion on the few variables that stand out. First, we pursue the question of how the classical variables (population growth, level of wealth, and accessibility) behave in our model and contribute to the different dimensions of sprawl.

The variable that indicates population growth creates a complex picture. While the expectation would be that growth in the number of inhabitants has a positive influence on the level of sprawl (confirmed by Burchfield et al., 2006; McGrath, 2005; Paulsen, 2012; Spivey, 2008; Wassmer, 2008), we find a negative influence of population growth on the share of built-up area (PBA), at least for the first three decades. For the years of 1990 and 2000 we see that negative influence also on the sprawl metric (WUP). Indeed, our findings are consistent with the results of Mann (2009) who looks at land consumption in Swiss municipalities and finds negative correlations with population and population growth. Nevertheless, we cannot find a satisfying explanation for the pattern yielded by our models. In a reduced model with the dependent variables only regressed on population growth, a positive effect results, except for the year 2000. Furthermore, if we use the absolute numbers of population rather than the growth rate, the effect is also always positive. Therefore, we suspect that the expected positive influence of population growth is better explained by some other independent variables in the models on which population growth seem to depend to some extent or with which it is at least correlated. In the full model, utilisation density (UD) being positively correlated with population growth remains the only constant result over time.

Finally, the last decade (2000 to 2010) gives results in accordance with the expectations of the monocentric city model: population growth is positively and significantly correlated with utilisation density (UD), an increased share of built-up area (PBA) and a higher composite sprawl metric (WUP).

Also consistent with the expectations is the influence exerted by the lagged federal tax revenue, which captures the level of wealth: The variable is always positively associated with a higher built-up area (PBA), a higher composite sprawl metric (WUP), and lower utilisation density (UD). Similarly, and in support of these results are the coefficients yielded by the 88 municipalities (out of 2495) that are declared as high income areas. All over Switzerland, the

impact of tax on dispersion (DIS) is not very consistent across decades but generally the degree of dispersion (DIS) is, as expected, higher in richer municipalities.

The variable measuring the accessibility (lagged) of a municipality has a significant positive and very consistent influence on all four dependent variables, even on the utilisation density (UD).

In order to better understand the role of each of the three classical variables (wealth, growth in population, and accessibility) in the process of urban growth in Switzerland, we looked at their independent as well as their joint contribution to the explanation of sprawl. For that purpose we estimated a reduced model, regressing the dependent variables on the three explanatory variables population change, federal tax revenue and accessibility. Following Mac Nally and Walsh (2004), we then applied hierarchical partitioning for all dependent variables although we only report the results for the built-up area (PBA). The distribution of joint effects shows the relative contribution of each variable to the shared variability in the model. This allows ranking the importance of the covariates in explaining the dependent variable independently of the other covariates. For the built-up area (PBA) we see that population growth does not yield much explanatory power, neither in 1980 nor in 2010 (3.3% in 1980 and 2.6% in 2010). As far as the federal tax revenue is concerned, we see a massive decline in its importance (35.2% in 1980 and 12.4% in 2010) and, accordingly, an increase in the contribution of the variable accessibility (61.3% in 1980 and 84.9% in 2010). In this reduced model, population change seems to play a more marginal role than initially expected. Accessibility on the other hand is the primary explanatory variable for an increase in the built-up area (PBA).

3.4.4. Results for selected variables: commuters, homeowners, building stock

As expected, the results in the OLS model show that the share of commuters (lagged) per municipality has significant influence on the four dependent variables. In differentiating between the share of in- and outgoing commuters, we gained more differentiated insights.

Inbound commuters are positively correlated with all the dependent variables, also when controlling for spatial interdependence with neighbouring municipalities. In this way, inbound commuters exert a very similar effect to accessibility and could be considered as drivers of sprawl.

For the share of outbound commuters, we see two different patterns. First, as expected, a high share of outbound commuters leads to a decrease in utilisation density (UD). Since UD includes also the number of workplaces, this finding makes sense. However, the effect is only significant if we control for spatial interdependence, that is, if we take the average level of UD of each of the surrounding municipalities into account. Second, outbound commuters are positively correlated with the extent of built-up area (PBA) but only if we do not control for spatial interdependence. Thus, although the extent of built-up area (PBA) is growing with a higher share of outbound commuters, this growth seems to be more importantly influenced by the growth of PBA of the neighbouring municipalities than by the actual share of outbound commuters.

Contrary to our expectation, we find a surprisingly consistent result across all decades for the share of homeowners. All four dependent variables are negatively correlated with an increasing share of homeowners per municipality and thus support Fischel's homevoter hypothesis (cf.3.3.2.).

A very consistent result can also be found for the variable measuring the share of buildings before 1919 and its interaction with the rural municipality indicator. The result confirms the expectation that the main effect of the share of old buildings, which applies for a zero value of the rural indicator and thus for urban municipalities, is negative for share of the built-up area (PBA), the composite metric (WUP) and also negative for utilisation density (UD).

3.5. Discussion

In this study, we systematically examined the relationship between urban spatial structures - ranging from highly compact and dense to land consuming and sprawling - and socio-economic factors that determine these spatial structures. The intention of the study was to derive insights into sprawl by employing a multidimensional conceptualisation and operationalisation of the pattern of settlement area development over a long timeframe (1980 to 2010) and by controlling spatial interdependence at the municipal level.

We built the analysis on a set of independent variables associated i.a. with the monocentric city model but extended it further with variables that capture the changes in socio-economic structures. The analysis reveals spatial interdependence between neighbouring municipalities for all of our dependent variables but it also reassures that for most of the variables the substantial results are not strongly dependent on spatial interdependence. Generally, the same set of socio-economic variables yields good results in explaining the two variables, built-up area (PBA) and the composite metric (WUP), but cannot equally well explain dispersion (DIS).

Furthermore, we notice a shift over time in how well the model fits the data regarding utilisation density (UD). It does so particularly well for the last period of measurement (2000 to 2010): whereas in all periods, the model explains over 80% of the variation of the extent of built-up area (PBA), in 2010 it explains over 75% of the variation of utilisation density (UD) (compared to 65% in 1980). The increasing explanatory power for UD over time could be due to better utilisation of existing buildings, that is an increasing number of people and jobs, at a constant extension of settlement area. This can be interpreted as an in-fill process. The higher utilisation density (UD) for economic and medium centres in turn gives evidence that this development takes place mostly in municipalities with high economic activity where the pressure on land is high.

Considering the Swiss context, our results show a strong face validity. On the one hand, the Swiss economy is undergoing structural changes with a further shift away from agriculture, as exemplified by the number of people employed in the primary sector falling by 19% between 2000 and 2010. At the same time the total amount of agricultural area under cultivation decreased by 21'428 ha (SFSO Swiss Federal Statistical Office 2015). Furthermore, almost 90% of the newly developed built-up area between 1985-2009 used to be farmland (SFSO Swiss Federal Statistical Office 2013). In 2010, 4.3% of the labour force worked in the primary sector, while 71.2% were employed in the third sector (SFSO, 2011). Our results indicate the shift away from agriculture involves abandonment of agriculturally used areas, which enables spatial growth of the settlement area since the vacant area can be used for construction. On the other hand, the growth of the service based economy, such as banks, leads to pressure and densification in the urban areas (Burchfield et al., 2006) and thus seems to encourage in-fill processes. However, this process does not apply to municipalities that support land intensive commerce, like shopping malls, in the open countryside. While such strategies are common, our model is not differentiated enough to identify the underlying structural conditions at the municipal level. Nevertheless, in our study, we see that utilisation density (UD) is positively correlated with the centre function of a municipality (economic-medium and small centres). The results

show that densification is, in turn, also positively correlated with inbound commuters and accessibility, in terms of public and private transport.

In general, the models highlighted the importance of accessibility as a factor to explain the variation in the dependent variables. A higher degree of accessibility is not only positively correlated with the composite metric (WUP) and the amount of built-up area (PBA) but also with an increase in the utilisation density (UD). This means that better accessibility improves the efficient use of the available built-up area. In a model that used only the three variables of the monocentric city model, population growth, income and accessibility, the importance of accessibility actually increased over time. Whereas also wealth is positively correlated with our sprawl metrics, we found that population growth is not an equally important determinant of sprawl.

Again, the importance of accessibility must be assessed from within the Swiss context. Swiss do not mind commuting, accessibility is generally high in Switzerland, and living in the rural areas is very often not particularly restricting because easy access to the city centres is provided. In favour of such conditions, the Swiss have consistently voted for the extension of public transport and private traffic infrastructure during the last decades.

Furthermore, our findings showed that the share of single households and retired inhabitants have equally caused sprawl. Thus, we confirm preceding studies pointing out that changes in social and demographic patterns influence changes in spatial patterns (Æro, 2006; Mann, 2009).

Also, we find that the higher the ratio of buildings built before 1919 the lower urban sprawl, this negative relationship is, however, less pronounced in rural areas. The pattern, although with the opposite consequence for sprawl, also holds for utilization density (UD); in urban regions, the higher the share of old buildings, the less densely these regions are built, while this effect is less apparent in rural regions.

One last finding we want to underline is that an increasing share of homeowners per municipality is negatively correlated with all four dependent variables. Nevertheless, we have some reservations with respect to this result. The mixture of the different types of ownership in Switzerland captured in our variable makes the coefficient harder to interpret. Hence, this finding certainly needs further and deeper examination which, however, goes beyond the scope of this article.

3.6. Conclusion

We are confident that we were able to demonstrate that the municipality is a meaningful unit of analysis for the examination of sprawl: Not only did we use a political entity that takes decisions for urban spatial development but we were also able to show that such an analysis is feasible and generates valuable insights provided that sufficient data is available at that level for the entire surface of a country or some other jurisdiction. As such, our study provides an analysis of the bigger spatial developments in the last 30 years.

Considering urban sprawl for the whole country involves the inclusion of not only urban but also suburban and rural regions. While we have tried to capture as much of the extant heterogeneity as possible and to account for spatial interdependence, we suggest that increased attention should be given in future research to regional developments and also to regional cooperation between municipalities in order to further advance the understanding of sprawl.

As far as policy recommendations are concerned, we suspect that our results contrast with a certain common underestimation of the extent to which urbanisation processes in Switzerland are shaped by accessibility. Today, Switzerland is in a situation where urban growth still means a continuous increase in the amount of land which is used. At the same time, the current growth of urbanised areas seems to be increasingly decoupled of population growth. In parallel, the big cities seem to increase their attractiveness in terms of place of residence leading to an increased density along a rural-urban gradient which basically follows the level of accessibility: the highest contribution to urban sprawl is to be expected in highly accessible areas that are not yet fully urbanised. It is particularly in this areas where incentives and prescriptions for higher density should be implemented. Such policies could be negotiated and implemented based on a cooperation among all municipalities belonging to a certain region that is defined by accessibility criteria. In Switzerland, first attempts to implement such innovative planning cooperation exist with the so-called 'agglomeration programs'. Such new functionally defined administrative entities should be strengthened and receive more political responsibility and planning authority in the future. In this regard, it is also important to consider that there is a time lag in spatial planning and that effective spatial planning has to be far-sighted. If for example accessibility is increased, spatial planning should anticipate an effect on sptrawl.

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Chapter 4: The effect of local tax on urban and rural land consumption in Swiss municipalities

Abstract

This analysis aims at shedding light on the role of local tax in the process of urbanisation. Tiebout predicted that differences in taxes and public services would motivate citizens to migrate to their preferred jurisdiction. We thus investigated how the land consumption of a municipality – measured as per capita uptake of settlement areas and as growth of the settlement area – related to local income tax levels. We assumed that municipalities with low taxes attract people and business which would foster local urban growth. However, the effect on the structure of the settlement depends on whether the jurisdiction lies within in an agglomeration or a rural area. Within these larger areas we further expected the more accessible jurisdictions to be the first to experience growing development pressure, because the effect of tax on urban structure is contingent on accessibility.

We used data for all 2,495 municipalities in Switzerland, a federal country that grants its municipalities considerable autonomy, in particular with respect to the taxation of income. We have found evidence that tax attractiveness is associated with a denser usage of settlement area in both urban areas and more accessible rural municipalities. However, in rural, remote municipalities, we find that an attractive tax scheme is associated with a growth of per capita land consumption. Possible endogeneity between urban structure and population growth was mitigated by using a two-step instrumental variable approach.

4.1. Introduction

In recent years there has been growing interest in the critical role of competition between jurisdictions (e.g. municipalities, states, cantons) in shaping urban growth and settlement development (e.g. Brueckner, 1998; Delattre et al., 2015; Oueslati et al., 2014). Tiebout's (1956) residential choice theory has been an important contribution because it treats competition as a decisive factor in the outcome of urban growth (Byun and Esparza, 2005). Essentially, the argument is that in location decisions, households select among different jurisdictions offering different combinations of public goods and services. By voting with their feet individuals group together in jurisdictions of homogeneous tastes (Hill, 1999). Indeed, jurisdictions are providers of services and facilities, such as schools, of varying quality and costs, the latter including property prices, housing rents, taxes, and commuting costs. (Carruthers and Ulfarsson, 2002).

In this way, the very existence of many independent jurisdictions which have discretion over their tax rates and public services expenditure creates competition and can reinforce separation among these jurisdictions (Brueckner, 2004; Vedder, 1990). Such rivalry may arise particularly in situations where each local government is using taxes, services, or regulations as competitive tools trying to maximise the economic and political benefits. Being attractive for newcomers is the key for development of a settlement area to be profitable (Heubeck, 2009; Savitch, 2003). Local governments might want to attract certain classes of newcomers in order to yield higher tax revenue (Fulton et al., 2001), foster economic development or maintain high residential property values (Baum-Snow, 2007; Downs, 1994; Lewis, 1996; Logan and Molotch, 1987). At the same time, they might want to avoid the influx of less desirable inhabitants who involve high costs for e.g. social security or social infrastructure (Savitch, 2003). Downs (1998) argues that municipalities want to protect single-family home values and keep poorer people, associated with multi-family housing, out. Thus, taxation and levy policies of local governments are definitive factors for settlement growth, as they influence population structure and, thus have intended or unintended effects on the settlement structure (Fang and Knox, 2015). Fernandez Milan and Creutzig (2016) suggest that in Europe, fiscal policies, together with land-use policies, are more important for urbanisation dynamics than transport costs and income.

In this study, we concentrated on the three-way relationship between local taxation, per capita land consumption of population and workplaces (which is one possible approximation for density), and the growth of settlement area. In contrast to many countries, Switzerland – our study area – does not rely on property tax but mainly on a (progressive) income tax. Furthermore, only about 22% of total personal and business income taxes are collected by the federal government regardless of the place of residence (cf. 4.2.1.).

We based our analysis on a data set that includes all municipalities of Switzerland as of 2010, covering the area of the entire country. In doing so, the presented study is on a much more detailed scale compared to previous studies considering local tax effects on urbanisation in either metropolitan areas or so-called urbanised areas (e.g. Wassmer, 2016). The question at the centre of the analysis was how local tax has influenced local land consumption in the period of investigation (2000-2010). To address the question, we divided the study sample into rural and urban municipalities, and further distinguished using a gradient of accessibility.

This article is organised as follows: chapter 4.2 gives an overview of the relevant research, gives reasons why Switzerland is particularly appropriate for investigating the effects of local taxation on land consumption, and formulates the hypotheses. Chapter 4.3 comprises an overview over the data and discusses the econometric approach. Chapter 4.4 presents and discusses the results of the analysis and sets out the limitations of the study. This is followed by concluding remarks and recommendations in chapter 4.5..

4.2. Background: Taxes and development of settlement areas in Switzerland

4.2.1. Background research

Examples of investigations on the relationship between jurisdictional-specific tax attractiveness on the one hand, and urban growth dynamics on the other hand are to be found mainly in the North American context. Hamidi and Ewing (2014), Savitch (2003) and Squires (2002) cite the mortgage-interest deduction on the federal income tax as one of the causes of extensive suburbanisation – sprawl – in the U.S.. Consequently, low density development is attributed to housing affordability by putting homeownership within reach of more people. Furthermore, in order to lower their housing expenses, people acquire houses further from central cities. However, as Hamidi (2015) finds, the latter

relationship may not necessarily hold true when other costs e.g. transport, are factored in. One of the rare qualitative studies that assesses the question whether relocation decisions are driven by considerations on availability of low-cost mortgages, is provided by the Maine State Planning Office (Richert, 1997). Based on anecdotal evidence, Richert (1997) found that mortgage deduction in rural communities may indeed have contributed to household relocation from central to rural areas.

Property tax regimes are at the centre of an influential study by Brueckner & Kim (2003) who offer a theoretical analysis to investigate the connection between urban density and local taxation. They state property tax can have two countervailing effects on urban density: the so-called improvement effect suggests a reduction in density because where the tax is levied on the value of property, any investment that increases the value of the property will be taxed. Thus higher property taxes give rise to less dense development. In contrast, the so-called dwelling-size effect takes place if the tax is partially shifted onto consumers (e.g. tenants) because house prices increase, thus increasing the demand for smaller housing units, leading to a more compact development of the urban area (Brueckner and Kim, 2003). Song and Zenou (2006), in their empirical investigation on the effect of property tax on city size, unambiguously show that increasing property taxes reduces urban expansion – and they thus provide evidence for a prevailing dwelling size effect. In a later study, Song and Zenou (2009) explicitly consider property tax rate differentials between urban and suburban areas. While the higher property tax rate in the central city (relative to the suburbs) seemingly results in denser population or employment, the results of their second study (2009) also confirm their assumption that lower suburban property tax (relative to the central city), drives households and firms outwards, so inducing more scattered development.

In contrast to empirical investigation on the influence of property tax and mortgage-interest reduction on urban compactness, the empirical literature that relates local income tax to land use patterns is scarce (Blöchliger et al., 2017; RW Wassmer, 2008). Wildasin (1985), considering the impact of income taxes on urban density - though restricted to a monocentric city model - argues that taxes on income lower the implicit value of time, and hence transportation costs. This, in turn, may result in larger, more dispersed urban areas and less intense usage of land. In a report on the effect of tax policies on land use, Eschwege (1978) posits that the reduction of the taxpayer's purchasing power through income tax may force some consumers to switch to less expensive or more intensive land use (see also Currier, 1975). At the same time, favourable local tax schemes may also be capitalised into higher property values (for capitalisation of income tax in the Swiss housing market see Morger, 2013; Stadelmann and Billon, 2012), reinforcing the effect (Eschwege, 1978).

4.2.2. Tax autonomy of municipalities in Switzerland

Switzerland is a country that relies predominantly on income tax to provide the services that citizens require. Income tax rates vary according to the canton and municipality. The so-called simple state tax (national) is multiplied by the cantonal tax multiplier as well as by the respective municipal tax multiplier[1]. By choosing the tax multiplier, the municipalities have considerable political and fiscal autonomy (Schmidheiny, 2006). 31% of the direct taxes are collected by the municipalities, 47% by the cantons, and thus only 22% of taxes are independent of location (FTA,

[1] However, Switzerland has both national and cantonal fiscal equalisation, which aim to mitigate the differences between the cantons and municipalities in terms of financial capacities.

2016) which is a high share compared to other European countries (see Ferry et al., 2015). In the UK, e.g., the local share lies around 5% and in the EU average at about 11% (Eurostat, 2014).

This analysis investigated the lowest administrative unit, that is the municipalities. In 2012, the year of our investigation, there were 2495 municipalities, each with an average population of 3154 inhabitants. This is relatively strong fragmentation compared with other OECD countries (Brülhart et al., 2015). According to Boyne (1996) or Brülhart et al. (2015), such a situation of high jurisdictional fragmentation and high taxing power autonomy creates a fertile environment for tax competition.

4.2.3. Hypothesis and specification

Overall, the empirical findings on the influence of local taxation on urban land density are not entirely conclusive (Blöchliger et al., 2017; Wassmer, 2016). Nevertheless, given the high variation in local income tax and the high fragmentation in Switzerland (cf. 4.2.2.), we had expected to find local variations in the influence of tax on land consumption. Based on Tiebout's theoretical concept of sorting, we hypothesised that a lower local tax would attract people and business, fostering local urban growth. If the land availability was limited, this process would lead to a lower level of per capita land consumption and thus a denser usage of land.

However, urban growth is a very heterogeneous and evolving process (Fotheringham et al., 2000), differing from place to place, both spatially and temporaly. Song and Zenou (2009) considered the effects of tax differences between suburbs (rural) and central areas on settlement development in order to gain more precise information on the influence of tax on urban growth in those different areas. Similarly, in this study, we were interested in whether the effect of low tax on land consumption would be different in rural than in urban areas. An important difference could have been that urban municipalities – absorbing most of the population growth and providing most of the workplaces – would have less land reserves and thus might be limited in their outward growth of settlement area and generally could also exhibit higher land rent. We thus divided our sample of the total of Swiss municipalities into two subgroups: rural and urban municipalities (urban municipalities include central cities and their agglomerations), and isolated cities. For the division of the sample we referred to Schuler et al. (2005).

It has to be noted that the rural/urban dichotomy we applied is crude and it mostly depicts economic structures rather than a gradient of accessibility. Accordingly, some rural municipalities far from the populous major centres but connected to them by mass transit systems, are much more accessible than urban municipalities close to a middle-sized or small centre. This is because the major centres themselves are rated as much more accessible than intermediate centres. To be able to capture those rural but still fairly accessible municipalities, as well as those urban but fairly remote municipalities, we employed a population weighted measurement of accessibility (as explained in Frohlich et al., 2005) and introduced an interaction term between tax and accessibility. Such an interaction term allowed us to model those middle-range types of municipalities that are neither clearly rural nor clearly urban due to their accessibility, and thus not fully compatible with their urban/rural classification.

4.3. Data

4.3.1. Dependent variables

To measure per capita land uptake (PCLU), the growth of per capita land uptake (ΔPCLU) and the growth of settlement area (ΔSE), we use data provided by Jaeger and Schwick (2014).

> The **per capita land uptake (PCLU)** is the developed area [m^2] divided by the number of inhabitants and work places. Across municipalities, a higher PCLU indicates that more settlement area is used per inhabitant or workplace than in areas of low PCLU values, i.e. the higher PCLU, the lesser the density.
>
> The **growth of per capita land uptake (ΔPCLU)** is measured as growth in the percentage between per capita land uptake in 2000 and 2010.
>
> The **growth in settlement area (ΔSE)** is measured as growth in the percentage between settlement area [m^2] in 2000 and 2010. In practise, SE rarely reduces in size since deconstruction is not a common feature in Swiss urban planning.

A very similar approach to measure values of PCLU is used in a comparative study for European Nuts-2 regions, though this analysis relies on a different set of data (EEA European Environment Agency and FOEN Federal Office for the Environment, 2016). Drawing on the results of the EEA/FOEN report, compared to the overall value for 32 European countries, Switzerland exhibits a lower than average level of PCLU.

4.4. Independent variables

4.4.1. Measurement of tax attractiveness

For the year 2000, official measurements on tax at the municipal level in Switzerland are only available for 813 municipalities with more than 2000 inhabitants. To be able to include data also on the additional 1682 municipalities (out of a total of 2495) with fewer than 2000 inhabitants, we relied on data provided by Waltert (2011). Waltert estimated the tax for a married couple with a joint income of 70,000 CHF in all municipalities, using data on tax rates from the tax administration offices of the Swiss cantons. In our models, we used the amount [CHF] that a married taxpayer with a gross income of CHF 70,000 pays for cantonal and communal taxes. Furthermore, since we were interested in the attractiveness of a municipality's tax scheme, to ease the interpretation, we reversed the vector: the higher the number, the less the tax amount [CHF] and thus the higher the tax attractiveness.

Two important limitations should be mentioned and borne in mind when interpreting the results (cf. 4.4). First, the income tax system is progressive, and takes a larger percentage from high-income earners than from low-income earners. We checked the available data for those municipalities with more than 2000 inhabitants and found that taxes for married taxpayers without children and with an income of 60,000 CHF to 150,000 CHF are highly correlated (>0.8 Pearson). However, our findings based on tax for an income of 70,000 CHF are not generally transferable to other income classes (<60,000 CHF, >150,000 CHF).

Second, due to a lack of adequate data, we only used data on tax on personal income but not for companies, firms or other legal bodies. Changes in the number of workplaces are, however, an important determinant of per capita land uptake (PCLU), our dependent variable. However, Brülhart and Jametti (2006) found that in Switzerland, between 1985 and 2001 personal income taxes contributed over 70% of municipal tax revenue and expected the municipal tax rates on personal income to be most sensitive to economic and political incentives. Brülhart et al. (Brülhart et al., 2012), in a study on location choice decisions of firms in Switzerland, found that the importance of agglomeration effects reduced the importance of tax differentials for firms' location choices, and lessened the intensity of corporate tax competition. Furthermore, self-employed persons are taxed under the same tax rate as private persons.

4.4.2. Further independent variables

To further model the determinants of urban land consumption, we employed a series of other factors deemed to affect urbanisation, such as population growth (cf. 4.3.3 on the possible endogeneity between urban growth and population growth), accessibility (cf.4.2.3. on the introduction of an interaction term between accessibility and tax), economic wealth (McGrath, 2005; Paulsen, 2014), commuter patterns (Mann, 2009), homeownership (Paulsen, 2013), demography (Mann, 2009; Wassmer, 2006), local economic conditions (Burchfield et al., 2006a), changes in lifestyle, namely the trend to one-person households (Hoymann, 2011; Mann, 2009), and historically determined structures of the settlement area, namely the age of the buildings (Glaeser and Shapiro, 2001; Paulsen, 2013). In addition we considered the dependent variables per capita land uptake (PCLU, Δ PCLU) as well as the growth in settlement areas (Δ SE).

Since the independent variables might not have an immediate influence on the dependent variables (on the subject of endogeneity and simultaneity see Duranton and Puga, 2014, but also chapter 4.3.3.), especially because building houses and infrastructure takes time, we measured all independent variables 10 years prior to the level of the dependent variable PCLU respectively in the beginning of the considered time span for Δ PCLU and Δ SE.

Furthermore, our models comprised a set of dummy variables (region indicators, compare Table 9) to take into account the deliniations of the most important greater administrative regions, i.e. the 26 Swiss cantons, which are part of the federalistic political system of Switzerland (comparable to U.S. federal states).

Table 9: Description of Independent Variables and Region Indicators

Variables	Year	Description	Source
Tax Attractiveness	2000	Inverse of the amount of income tax (cantonal and communal taxes) for married taxpayer with gross income of CHF 70,000[a]	FSO
Accessibility [b]	2000	Extent to which land-based transport systems permit reaching a municipality (public & private transport).	Tschopp & Fröhlich, 2006
Population growth	90/00/10	Difference between population $((x-x_{t-10})/x_{t-10})$	Census
Affluence	2000	Per capita federal taxes on income collected in 2000 as proxy for wealth	FTA
Retired Inhabitants	2000	Percentage of retired inhabitants	Census
One-person households	2000	Percentage of one-person households as share of total households	Census
Employees Primary Sector	2000	Ratio of employees working in the primary sector	Census
Commuters (out)	2000/10	Outbound commuters as share of total employed residents per municipality	Census
Commuters (in)	2000	Inbound commuters as share of total employees working in the municipality	Census
Homeowners	2000	Ratio of privately owned single-family homes/total buildings.	Building statistics*
Buildings pre 1919	2000	Buildings built before 1919 as share of total building 2000	Building statistics*
Rural Areas	2000	Classified as rural municipalities	Schuler et al., 2005
Cantons	2005	26 cantons: 25 dummies, the reference category is the canton Zurich	

[a] Tax data is only available for municipalities with more than 2000 inhabitants. For the other municipalities, we rely on data provided by Waltert (2011) who estimated the tax using data on tax rates from the tax administration offices of the Swiss cantons.

[b] We thank Kai Axhausen and his collaborators Martin Tschopp and Philipp Fröhlich for kindly providing us with the data.

Source: Federal statistical office (FSO), Federal tax administration (FTA), Federal Office of Topography (Swisstopo), Census 2000, * part of the census.

Table 10: Descriptive statistics of variables (if not indicated otherwise year 2000)

Variables	Mean	St. Dev.	Min	Max	Units	Adjustment in analysis
Per capita land uptake (PCLU)	441.5	360	43.8	9725	m^2	third root[a]
Rural: Per capita land uptake (PCLU)	528	420	135	9725		
Urban: Per capita land uptake (PCLU)	291	118	43.8	918		
Growth ΔPCLU	9.8	23	-53	298	%	
Rural: Growth Δ PCLU	14	25	-51	298		
Urban: Growth ΔPCLU	1.6	17	-53	202		
Growth Settlement Area (Δ SE)	10.7	11.7	-16.96	118.5	%	
Rural : Growth Settlement Area (Δ SE)	10.7	11.4	-16.96	93		
Urban: Growth Settlement Area (Δ SE)	10.7	12	-3	118.5		
Tax Attractiveness	4113	1228	688	6085	CHF	Reverse of the scale[b]/1000
Rural: Tax Attractiveness	4394	1081	870	6085		
Urban: Tax Attractiveness	3313	1313	688	5938		
Accessibility	22820	18593	183	229500	Scale	/10000
Rural: Accessibility	15820	11091	183	72890		
Urban: Accessibility	35060	22355	2119	229500		
Population growth (2000-2010)	9.26	12.366	-45.45	109.2	%	/100
Rural: Population growth (2000-2010)	7.44	13	-45.45	109.2		
Urban: Population growth (2000-2010)	12.47	10.6	-12.82	75.74		
Urban: Population growth (1990-2000)	13.92	13.93	-16.18	124.5		
Affluence	808.9	860	43.9	11750	Swiss francs	/10000
Rural: Affluence	564	500	43.9	7418		
Urban: Affluence	1240	115	250	11750		
Retired Inhabitants	13.9	4.4	2.5	48.6	% total population	/100
Rural: Retired Inhabitants	14.7	4.6	4.7	48.6		
Urban: Retired Inhabitants	12.3	3.6	2.5	31.4		
One-person households	28.5	6.4	5.6	59.1	% total households	/100
Rural: One-person households	28	6.2	5.6	59.1		
Urban: One-person households	29.5	6.7	15	54		
Employees Primary Sector	9.8	9.4	0	73.3	% total employees	/100
Rural: Employees Primary Sector	13.3	10	0	73.3		
Urban: Employees Primary Sector	3.6	2.7	0	28		
Commuters (out) growth (2000-2010)	5.7	6.46	-44.5	46.5	%	/100
Rural: Commuters (out) growth (2000-2010)	7.1	7	-44.5	46.5		
Commuters (in)	42.8	19.3	0	94.4	% total employees	/100
Rural: Commuters (in)	35.5	17	0	86.6		
Urban: Commuters (in)	55.5	16	9.4	94.4		
Homeowners	58	13	0	97	% resident in municipality	/100
Rural: Homeowners	56	13	0	97		
Urban: Homeowners	61	13.6	9.1	97		
Buildings pre 1919	23.4	16	0.6	88	% total buildings	/100
Rural: Buildings pre 1919	30	15.4	1.4	88		
Urban: Buildings pre 1919	11.5	7.7	0.6	52		
Number of observations: 2495 (total), 1587 (rural municipalities), 908 (urban municipalities)						

[a] After examining the variables for distortion, PCLU was transformed in order to approximate the data to a normal distribution.
[b] to reverse the scale [tax] we calculated (max(x)+1)-x, (cf. 3.2.1.)

4.4.3. Endogeneity: in search of an instrumental variable for population growth

Estimating the impact of population growth and workplaces on land consumption is complicated by an endogeneity problem. On the one hand, land consumption is a function of people's residential location decisions and thus population growth. High demand for housing from outsiders or people wanting to improve their situation triggers construction. On the other hand, population growth can also be a result of construction activity, as an increased offer of housing opportunities might attract people that were not actively in search of housing in that area. Accordingly, the underlying assumption about the direction of causation between population growth and land consumption remains debatable.

To address the problem of endogeneity, we employed instrumental variable (IV) regression, based on a two-stage least-square regression procedure (2sls) (see e.g. Howley et al., 2015). As the instrument we used two different variables, one for the subsample of rural municipalities – namely the growth of the share of outgoing commuters per municipality (a) – and one for the subsample of urban municipalities – namely the 10 years lagged variable of population growth (b).

(a) The trend of decoupling workplace and residential location is increasing as is the proportion of daily commuters (SFSO Swiss Federal Statistical Office, 2014a). As Switzerland is a relatively small and very decentralised country, distances between cities and municipalities are rather short and commuting is popular and very common even in less accessible and rural places. Thus, we reckoned that the growth in outgoing commuters from the year 2000 to 2010 reflected population growth in the same period to a certain degree. However, we also expected the number of outgoing commuters to be less correlated with land consumption, as commuting involves both richer and poorer strata of society.

(b) However, in urban and central areas, the number of outgoing commuters is less correlated within population growth since workplaces are largely also available in the municipalities themselves. The big cities which provide the most workplaces, experienced population growth but exhibited a lower proportion of outgoing commuters. As the IV for population growth in urban municipalities, we used a lagged population growth variable, simply assuming that those municipalities which grew in the past would also grow in the future. This is plausible since it is the agglomeration and central municipalities, included in the subset of urban municipalities, which grew more in population than the rural municipalities. The assumption is, however, that the lagged population growth was not induced by construction activity taking place 10 to 20 years later.

To confirm our assumption about the IV, we employed the a) weak instrument test (Staiger and Stock, 1997) to check whether the first-stage partial F-test is less than 10 and thus to confirm that the instruments are sufficiently correlated with population growth, and b) the Wu-Hausman test, to confirm the consistency of the instrumental variable approach. For those models where the Hausman statistics were not significant, we referred to OLS models, assuming them to be more consistent than the IV approach. To calculate the two-stage least-square regression models (2sls), we used the IVREG command in the AER package in R (Kleiber and Zeileis, 2008). Test statistics are presented in Table 11.

4.5. Results and discussion of the analysis

4.5.1. The effect of tax attractiveness in rural and urban municipalities, and its contingency on accessibility

Table 11 lists the results for the models 1 to 6 that distinguish between rural and urban municipalities and additionally includes the interaction between tax attractiveness and accessibility (cf. 4.2.3.). This interaction helps to further distinguish the heterogeneity of our sample. The coefficients of the conditioned variables in Table 11 have to be interpreted as the effect of tax attractiveness on the dependent variable when accessibility is zero and vice versa. We calculated the models without the condition of tax attractiveness on accessibility and present the coefficients of the two variables for the unconditioned model in Table 12.

Table 11 and the marginal effect plots (Brambor et al., 2006) displayed in Figure 7, show that the higher tax attractiveness the higher the level of land consumption (PCLU) in rural areas, and the lower the level of PCLU in urban areas. However, two important distinctions can be made: 1) as suspected, this relationship is contingent on accessibly. Tax attractiveness is associated with a higher level of land consumption in either very remote (Figure 7a) or very central municipalities (Figure 7b), although for the latter it is not significant. 2) In contrast, in municipalities that are neither very remote nor very central in terms of accessibility, an attractive tax scheme lowers the level of land consumption (Figure 7a&b). In the urban municipalities, the negative coefficient for tax attractiveness on PCLU is reduced in size with rising accessibility (Figure 7b). It thus appears as a general trend among those municipalities which are part of an agglomeration but are not highly accessible, that tax attractiveness is associated with a less densely built up structure (lower PLCU) – compared to similarly accessible municipalities in rural areas.

The results for the model depicting the growth of the per capita land uptake (ΔPCLU) display similar tendencies. Accessibility restricts the growth of land consumption induced by lower taxes in such a manner that tax attractiveness significantly fosters densification in the more accessible rural municipalities (Figure 7c). However, this influence ceases to be significant in municipalities considered as urban (Figure 7d).

Furthermore, a low tax is significantly associated with a decrease of the settlement area (ΔSE) in rural, remote municipalities (Figure 7e). However, although the marginal effect increases with accessibility and eventually becomes positive, it is not significant for more accessible rural municipalities. In urban municipalities (Figure 7f), changes in settlement extension in a municipality are never significantly associated with tax attractiveness.

The results illustrate an ambiguous effect of tax attractiveness; attractive tax schemes attract people. Urban areas have little leeway to extend the settlement area (which would be indicated by an increasing SE), hence density will increase, i.e. the value of PCLU will decrease. This is what we expected to see (cf. 4.2.4. Hypothesis). However, in remote areas, the pressure on the land lessens, and so does the incentive to reduce land uptake (rising PLCU). In those areas, people attracted by low taxes, have larger mansions and larger land plots (though the causality could also go the other way; municipalities with more high-income households in large mansions can also lower their tax rate). Furthermore, once settled, the residents might opt against further increase regarding both density and the extension of the settlement area (Fischel, 2001), indicated by the negative coefficient for ΔSE. However, there could also be a complementary explanation for the low density in remote, rural, tax attractive municipalities. Given that lower taxes can be an indication of a low level of public services, low density settlement areas in remote rural

municipalities might also represent ancient structures and depopulation. The lack of expansion of the settlement area would then also be a consequence of structural weakness.

The interaction terms attenuate the ambiguous effects of tax attractiveness on land consumption for municipalities that are not so far from important cities. Clearly, in more accessible rural areas, the pressure to build more densely increases (Figures 7a & 7c, models 1 & 3). In these intermediate types of municipality, between rural and urban, tax attractiveness leads to densification. In that way, they follow the pattern of the urban municipalities rather than that of the rural remote municipalities.

Obviously, the past accessibility level is a good predictor for the current level of per capita land consumption: municipalities with greater accessibility have a more intense use of the settlement area and thus a lower per capita land consumption (PCLU). Table 12, showing the unconditioned effect of accessibility on PCLU, reveals that this is also the case in rural municipalities (which is not visible from the coefficients presented in Table 11.). Moreover, between 2000 and 2010, accessibility hindered the growth of PCLU only significantly in rural but not in urban municipalities (Table 12). In urban municipalities (where, in general, accessibility is higher), this growth of PCLU induced by increasing accessibility most probably took place before the year 2000, providing evidence for a so-called saturation effect, as shown e.g. by Axhausen and colleagues who studied population growth. They found that having reached a certain level of accessibility, any increase in accessibility ceased to have the same pronounced influence on population growth as previously (Axhausen, 2008). In other words, at a certain point, further improvement of the accessibility has no effect on population growth anymore. This saturation effect could provide an explanation why an increase in accessibility does not continue to significantly lower the per capita land consumption in urban areas.

4.5.2. Results for the control variables

The results for population growth create a complex picture about the relationship between the significant control variables and the three variables depicting land consumption: - per capita uptake of land (PCLU), growth of PCLU, and growth of settlement area (ΔSE) -. As explained in chapter 4.3.3. we took into consideration the possible endogeneity between population growth and urban growth. For that reason, for the level of PCLU in rural areas (Table 11, model 1) as well as for ΔSE in both rural and urban areas (Table 11, model 5 and 6), we have relied on the 2sls estimations. The results show that in rural municipalities, population growth significantly reduces the level and growth of the per capita land uptake (PCLU), resulting in a denser use of the settlement area. In urban areas population growth does not significantly influence the level of PCLU, but it significantly reduces the growth in per capita land consumption (ΔPLCU). Finally, population growth significantly fosters the growth in settlement areas (ΔSE) in both rural and urban areas.

Further, affluence – proxied by per capita federal tax revenue per municipality – is correlated with a higher level of PCLU in urban areas but, in our models, does not influence either the growth of PCLU or of SE. The more retired inhabitants a municipality accommodates, the higher its level of PCLU will be. However, it is only in rural municipalities that a high share of retired inhabitants also significantly contribute to a growth in PCLU and reduce the growth in settlement area (ΔSE). One explanation could be that the rural exodus of the younger population increases the per capita land uptake, while construction activity, and thus growth in settlement area, ceases. A high share of one-person households fosters the level of PCLU in rural but not in urban municipalities. In rural municipalities, a high share of one-person households also contributes to the growth of per capita land uptake (ΔPCLU) but reduces the growth in settlement area (ΔSE). This gives evidence that in rural areas, one-person households are settled in the

already overbuilt area but use more space per capita. Considering both variables, the share of elderly people and the share of one-person households , it would be plausible that in rural areas, the retired inhabitants and the persons living in one-person households coincide to some degree. However, the rural municipalities do not have a particularly high share of elderly people living in one-person households. In 2000, in rural municipalities the share of retired inhabitants living alone was about 2.5% (of all one-person households) but around 3.4% in urban areas (SFSO Swiss Federal Statistical Office, 2000).

The presence of employees in the primary sector (independent of the share of agricultural land per municipality) results in a higher level of per capita uptake (PCLU) resulting in less dense usage. This presence of primary sector employees in rural areas also fosters the growth of PCLU, but reduces the growth of settlement area. Also, the number of incoming commuters significantly reduces the level of land uptake per capita (PCLU), however, does not contribute to the growth of PCLU. Further, a high number of incoming commuters reduces the level and growth of PCLU but contributes to the growth of settlement area. In contrast, a high share of homeowners of single-family homes fosters the level of PCLU in all the municipalities and also contributes to the growth of per capita land uptake. However, in rural municipalities, homeowners of single family homes also reduce the growth in settlement area. Furthermore, the share of buildings in a municipality constructed pre 1919 compared to the existing building stock, a marker which we employed to control for preconditions for urban development before the heavy urbanisation of Switzerland, shows that the higher the ratio of buildings built before 1919, the higher the level of land uptake per capita (PCLU).

Table 11: Results for ols and 2sls model with IV

Rural/Urban Distinction	(1) **rural**	(2) **urban**	(3) **rural**	(4) **Urban**	(5) **rural**	(6) **urban**
Type of Model	**2sls**	**ols**	**ols**	**Ols**	**2sls**	**2sls**
Dependent Variable	**PCLU**		**ΔPCLU**		**ΔSE**	
Tax attractiveness	0.625**	-0.205**	-0.030	-1.669	-3.734***	-0.145
	(0.270)	(0.083)	(1.576)	(1.758)	(1.202)	(1.453)
Accessibility	0.142**	-0.118***	0.958	0.142	-1.295**	0.039
	(0.071)	(0.020)	(0.971)	(0.423)	(0.577)	(0.350)
Tax attractiveness* Accessibility	-0.147*** (0.031)	0.012** (0.006)	-1.246*** (0.476)	0.097 (0.131)	0.987*** (0.279)	-0.124 (0.110)
Growth in Settlement area	0.011*	0.006***	1.096***	0.992***		
	(0.007)	(0.002)	(0.037)	(0.036)		
Growth in PCLU					0.401***	0.562***
					(0.040)	(0.043)
Population Growth IV	-5.982*				75.762***	97.050***
	(3.618)				(17.322)	(21.663)
Population Growth		-0.001	-97.967***	-71.040***		
		(0.193)	(3.549)	(4.083)		
Affluence	-0.083	0.085***	0.191	0.163	0.863	-0.392
	(0.059)	(0.021)	(0.897)	(0.455)	(0.537)	(0.367)
Retired Inhabitants	2.153	1.773**	54.931***	23.325	-22.279**	-10.959
	(1.817)	(0.713)	(11.851)	(15.114)	(9.340)	(15.396)
One-person households	2.972***	-1.667***	28.120***	-2.489	-22.482***	2.652
	(0.765)	(0.470)	(8.045)	(9.966)	(5.307)	(8.278)
Employees Primary Sector	3.937***	3.209***	66.829***	32.506	-27.137***	-9.757
	(0.374)	(0.991)	(5.477)	(21.001)	(4.535)	(18.650)
Commuters (in)	-1.124***	-0.709***	-7.536**	-6.124**	7.662***	3.813
	(0.274)	(0.134)	(3.035)	(2.847)	(1.891)	(2.318)
Homeowners	3.502***	1.391***	24.767***	9.667**	-12.413***	-6.865
	(0.459)	(0.199)	(3.804)	(4.215)	(3.426)	(4.268)
Buildings pre 1919	0.774**	1.923***	7.677*	8.165	-0.630	2.663
	(0.336)	(0.349)	(4.094)	(7.394)	(2.447)	(6.037)
Constant	3.383***	6.648***	-23.970***	-3.575	24.650***	1.914
	(0.744)	(0.344)	(5.993)	(7.295)	(4.098)	(6.218)
Region Indicators[a]	YES	YES	YES	YES	YES	YES
Observations	1587	908	1587	908	1587	908
Weak Instruments[b]	6.3**	(13***)	(14***)	(13***)	27***	22***
Wu-Hausman	2.2*	(0.020)	(0.2)	(0.7)	0.038*	9**
Adjusted R2	0.41	0.61	0.62	0.56	0.36	0.45

Note: *p<0.1; **p<0.05; ***p<0.01

[a]Region Indicators are Cantons regions (cf. 4.4.2)

[b]the values in (brackets) give the test statistics for the OLS models if specified as 2sls, IV variable Model (1), (3), (5): growth in outgoing commuters, IV variable Model (2), (4), (6): population growth 1990-2000

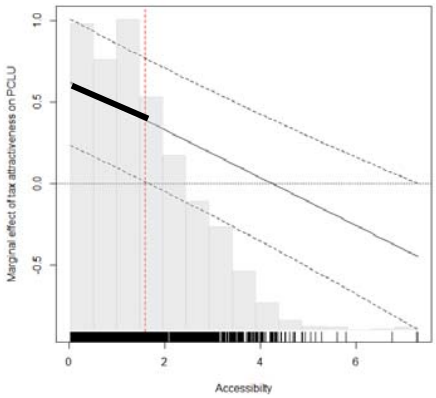
Table 12: Results for tax attractiveness and accessibility (unconditioned version of the models of Table 11)

Rural/Urban Distinction	(1) rural	(2) urban	(3) rural	(4) urban	(5) rural	(6) urban
Type of Model	2sls	ols	ols	ols	2sls	2sls
Dependent Variable	PCLU		ΔPCLU		ΔSE	
Tax attractiveness	0.5*	-0.16*	-1.31	-1.32	-2.72**	-0.45
	(0.27)	(0.08)	(1.5)	(1.7)	(1.17)	(1.33)
Accessibility	-0.1**	-0.08***	-1.16*	0.39	0.4	-0.28
	(0.04)	(0.011)	(0.53)	(0.24)	(0.31)	(0.19)

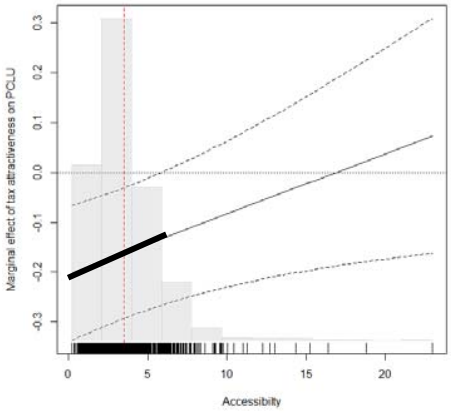
Note: *p<0.1; **p<0.05; ***p<0.01

Figure 7: Marginal Effect Plots for Interaction between Accessibility and Tax attractiveness

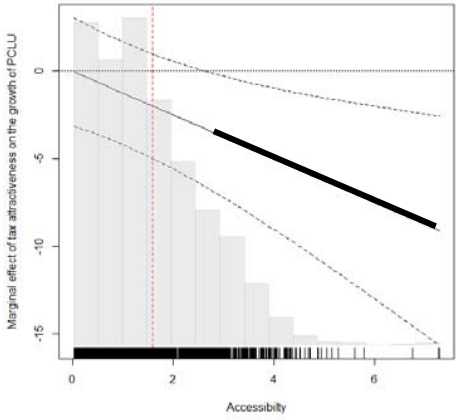
a (model 1): PCLU rural 2sls



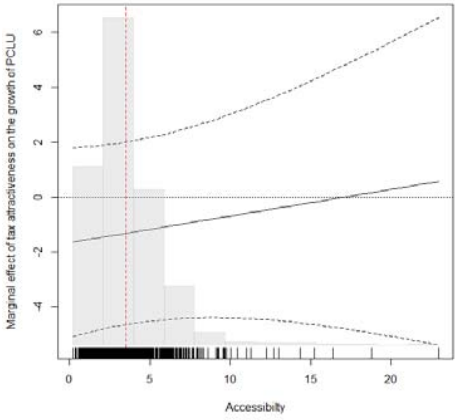
b (model 2): PCLU urban ols



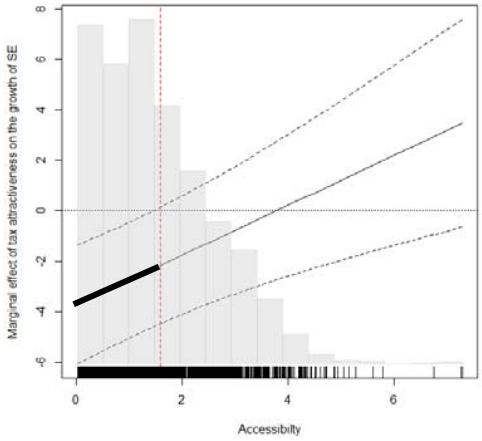
c (model 3): ΔPCLU rural ols



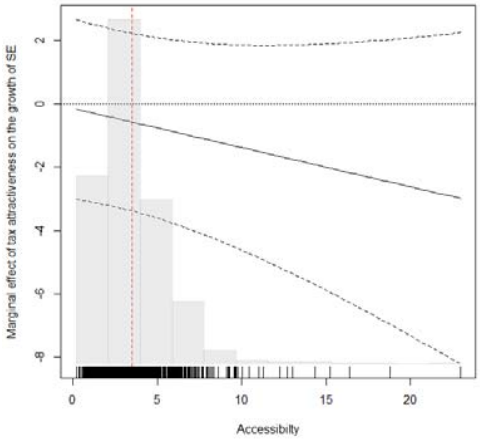
d (model 4): ΔPCLU urban ols



e (model 5): Δsettlement area 2sls



f (model 6): Δ settlement area urban 2sls



Note: The bars represent the frequency distributions of the municipalities per accessibility value, the graph is thicker if the value is significant.

4.5.3. Limitations of this study

Some important caveats of this study must be mentioned. As it stands, the consensus in the literature on the influence of tax for attracting people to certain locations for residence in Switzerland is that it is the affluent households who are most tax-sensitive (Liebig and Sousa-Poza, 2006; Schaltegger et al., 2011; Schmidheiny, 2006). However, in this study, due to lack of availability, we used only data on tax for average income households (60,000 to 150,000 CHF). We found that the variation of local income tax for average income households influences urban density mostly in the rural and intermediate municipalities. It is very likely though, that the effect of tax for affluent households on land consumption is different, e.g. more visible, in the urban and very accessible municipalities. Our results indicate a slight trend that in these municipalities low taxes foster per capita land consumption. Furthermore, in concentrating on tax for middle income persons rather than for high income persons, the analysis can say little about whether local governments' competition to attract high income residents effects local land consumption, a question pondered in the literature (Fernandez Milan and Creutzig, 2016; Razin, 2000). Nevertheless, the presented results should contribute to the ongoing research on the subject. We find that both the distinction of the effect of tax on land consumption between rural and urban municipalities, and the effects' contingence on accessibility reveal important information which should be taken into account in further studies.

In this paper, we proceeded from the assumption that population growth is possibly endogenous to land consumption as it affects land consumption but is itself affected by construction activity. We controlled for this endogeneity by using population growth as an instrument in the equations (cf. 4.3.3.). The results suggest that the relationship between population growth and the growth of per capita land consumption (PCLU) in rural areas, and settlement area (ΔSE) in both rural and urban areas, is not unidirectional. It would seem increasing construction activity attracts population. However, and despite promising test results, we have not further delineated these effects in the present analysis. Nevertheless, we urge the discrepancy between urban- and population growth is taken into consideration for any future research, and for urban growth planning policies.

4.6. Conclusion

Despite a comprehensive and limiting regulatory framework, the settlement areas in Switzerland have increased dynamically in recent decades. This has taken place in the context of the Swiss spatial planning legislation which grants a relatively high level of autonomy at the municipal level. In addition, Swiss municipalities have the authority to levy their own taxes and thus have the possibility to establish their own taxation level. Hence, in this study we wanted to assess how variations in tax are related to variations in urban land consumption.

Explicitly considering how accessible a municipality is – in terms of public and private transportation – and considering land consumption in rural and urban areas, we have found that tax variation between municipalities influences land consumption in two ways. Either, it leads to a densification (reduction of per capita land uptake, with reduction of growth of settlement area) – this effect is more visible in urban, accessible municipalities – or it leads to a growth in per capita land uptake – an effect visible in rural, remote municipalities. Municipalities that are rural in structure but fairly accessible from the populous centres, follow the trend of the urban areas and tend to densify their settlement structure. That is, sprawling urban structures seem to be more frequent among remoter municipalities with favourable tax schemes. In such cases, the benefits of disaggregated governance and local autonomy, such as efficiency gains from the possibility to freely choose the preferred mix of taxes and amenities (Bucovetsky, 1991)

may be diminished by higher fiscal and environmental costs. This can occur in spite of a disciplining effect on local public finances (Feld and Kirchgässner, 2001), due to asymmetric urban development among municipalities.

The clearest policy recommendation from this research is that steering development patterns with taxes is contingent on the accessibility of a municipality/region. Hence, coordination of planning policies and transportation systems remains particularly important for influencing spatial development. Also, the results of the analysis support the intention to confine functionally defined administrative entities, in particular entities related to accessibility. Within these administrative entities, coherent planning policies could take place. Furthermore, since 2013 the Swiss cantons are obliged to levy a surplus value tax on gains resulting from local zoning decisions ("Mehrwertabschöpfung"). By federal law, the money has to be used to either compensate owners of private property for revoked or modified building rights or to “promote sustainable urban growth” (which means more or less equal to socially acceptable densification). One way for the cantons to use the money could be a compensation mechanism to balance the advantages and costs of land consumption. Redistributing some of the revenue from low- to high-tax municipalities within regions of similar accessibility would not add to a redistribution between affluent and less affluent municipalities, as there are fiscal equalization mechanisms between municipalities of the same canton (and between cantons) already active in Switzerland. Rather, such additional redistribution should be earmarked for land use planning and urban development projects. This would encourage better designed densification, by supporting planning and implementation capacities as well as revoking building zones and withdrawing certain land from the urbanisation process.

4.7. References

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Chapter 5: Densification versus continuation of land consuming settlement structure: the role of land scarcity and affluence

Abstract

In the view of many households, low density settlement structure enabling open spaces in the neighbourhood are amenities. In places endowed with these desirable amenities - all else being equal –positive growth is shown in land prices. Households living in such an environment have a certain interest to secure the low density structure of their neighbourhoods. However, limiting the supply of land for construction, e.g. through planning policy, theoretically also has a price-enhancing effect, leading to more intensively used land so as to maximise profit. This in turn devalues low-density residential areas with open spaces.

This paper shows that together with the affluence of the inhabitants of a municipality, land scarcity can play a critical role in how settlement structure extends. We find that in the Canton of Zurich, Switzerland, between 1990 and 2010, land scarcity increasingly explains the growth of per capita land consumption, the spatial extension of settlement areas, and the building density in residential areas in all the municipalities. In general, land scarcity reduces per capita land consumption and the extension of the area, and thus fosters densification. Yet in municipalities with larger areas left for construction, densification dynamics may be undermined by the tendency to grow outwards rather than inwards or upwards. However, in the very affluent municipalities – in terms of affluence of their inhabitants – land scarcity has no impact on the reduction of land uptake. We assume this is due to affluent people avoiding further densification.

5.1. Introduction

During the last two decades, the demand for land for residential development has risen consistently in Europe (EEA European Environment Agency and FOEN Federal Office for the Environment, 2016), the U.S. (Moura et al., 2015), and on a global scale (Seto et al., 2011). This demand was stimulated most notably by an increase in personal income, together with improved transport, enabling people to seek housing farther from their employment (Bassett and Zaninovich, 2008). Typically, a part of the growing demand for residential land is being met through greenfield development, and another part through densification in the already built-up parts of the urban areas (Broitman and Koomen, 2015; Haase and Nuissl, 2010).

The extension of settlement areas is often seen as a serious problem because of its social and especially environmental effects (see e.g. EEA and FOEN, 2016; Polyzos et al., 2013), and in consequence, planning usually urges densification, e.g. through limiting the supply of land for construction (Guastella et al., 2017). Such land constraints are intended to have an impact on settlement patterns, to become less sprawling but more compact (Bassett and Zaninovich, 2008). Furthermore, since the supply of land is limited, sustained demand also increases land prices. At the same time, with high land prices, it may become profitable to utilise the land more intensively, that is to build denser settlements (Evans, 1988; Evans and Unsworth, 2008).

Studies that deal with the impact of settlement structure on the real estate market draw attention to the fact that land and housing prices are strongly influenced by the use and characteristics of neighbouring plots of land (Cheshire, 2009). Densification and diminishing open spaces within settlement areas can generate externalities, typically negative ones (Hilber and Robert-Nicoud, 2006), which are likely to drive prices down. This results in decreasing land and housing prices (Geoghegan, 2002; Song and Knaap, 2004). That is, in a situation where spatial extension of settlement areas is restricted and the supply of land scarce, favourable settlement structures such as low density or generous open space, will likely be capitalised in the price, all else being equal (Strong and Walsh, 2008).

At the same time, settlement structures are influenced by the spatial distribution of amenities (Buckman et al., 2017): spatial sorting along a gradient of affluence of households correlates with local attributes such as accessibility or environmental and public amenities (Cheshire et al., 2014; Hilber, 2015). Thus, in places that are desirable because of certain amenities, e.g. easy accessibility, and that exhibit favourable settlement structures, such as low-density, affluent households will outbid lower willingness-to-pay households, driving up the price for land and housing. Those affluent households, however, who live in high amenity places will also probably want to ensure the continuation of the low density structure of the housing estates e.g. through supporting restrictive building prescriptions and similar spatial planning regulations (Brueckner et al., 1999; Fischel, 2001), or by buying undeveloped land.

In this paper, we use three patterns of settlement growth as dependent variables - namely the growth of per capita land consumption (persons and workplaces), the growth of the settlement area, and the growth of density of buildings in residential areas. First, we want to assess empirically, based on a spatial regression analysis, how land scarcity influences settlement growth and settlement structure. Land scarcity is measured as the amount of land designated for construction per capita. Second, we suspect that settlement growth patterns differ for municipalities accommodating affluent inhabitants, who might have an interest in keeping density low. The answer to the second question involves investigating the interaction between land scarcity and affluence. To control for the influence of high amenity places on settlement growth patterns as described above, we included variables capturing natural amenities, land prices, accessibility, and public expense for planning, all measured at the level of the single municipality (cf. 5.3.5.). Furthermore, we assessed the presence of so-called indirect spatial effects on urban growth patterns and tackled spatial spillover by controlling for spatial correlation in the models (cf. 5.4.1.).

We argue that a better understanding of the mechanisms that lead to different settlement growth patterns, e.g. the influence of land scarcity or affluence, helps in adjusting policies that aim to steer urban development in a sustainable direction, as it enables decision-makers to identify unintended consequences.

The study area, the Canton of Zurich in Switzerland, is an area where in recent decades a large increase in the number of households has had to be accommodated in what is already one of the most densely settled regions in Switzerland: from 1990 to 2000, the population grew by 5 percent but from 2000 to 2010 by 14 percent. In 1996, around 82% of

the designated settlement areas was overbuilt, in 2010 already 89%. At the same time, the 169 municipalities show considerable variation in the affluence of their inhabitants with a median income ranging from around 41,400 CHF (about $41'400) to more than 80,300 CHF and the mean income from 41,000 CHF to 147,000 CHF in 2010. In the analysis, we considered data from 1990 to 2010.

In the next chapter, we further outline the theoretical reasoning as described above. Several topics in the literature on housing markets and real estate economics also deal with settlement growth patterns and will be discussed in more detail: housing price mechanisms (cf. 5.2.1.), urban structures representing amenities that capitalise into land and housing prices (cf. 5.2.2.), spatial sorting along an affluence continuum (cf. 5.2.3.), and the expectations we formulated for this analysis (cf. 5.2.4.).

This is followed by chapter 5.3 that introduces the study area and the data, and then by chapter 5.4 that covers the empirical methodology and the models. In chapter 5.5 we present the results and in chapter 5.6 we discuss them. A summary of the results as well as a policy recommendation, chapter 5.7, concludes the paper.

5.2. Settlement structure influenced by land scarcity and affluence

5.2.1. Price of land rises with rising demand and restricted land availability

Much of the literature establishes that if the demand for land exceeds supply, the resulting scarcity increases the price of land (i.a. Quigley and Rosenthal, 2005; Zorn et al., 1986). Also, if housing supply is limited because of land scarcity, increases of demand cannot be met, and prices will increase to choke off the excess demand (Evans, 1988; Stadelmann and Billon, 2012).

With high land prices, it becomes worthwhile to develop land more intensively (Bassett and Zaninovich, 2008; Evans and Unsworth, 2008; Watson, 2013): construction firms can minimise the land cost per house or apartment by constructing denser housing, e.g. flats and multi-storey buildings, and by allowing less space for surroundings. Indeed, as Evans (1988) described for England's housing market at the time, in the regions with high land prices, proportionately more dwellings were flats and maisonettes although the households were neither smaller nor poorer than elsewhere.

5.2.2. The presence of open space and low density capitalises into housing prices

Building housing more densely, as a reaction to land scarcity, economises on the use of land but might disturb the low-density structure of neighbourhoods and thus the value of the resulting built units. Evidence that low density housing, open spaces or a green park in the vicinity, is appreciated as has been documented in housing price studies (i.a. Dong and Wu, 2016; Geoghegan, 2002; Irwin, 2002). The resulting process of increasing prices is called capitalisation of amenities and is well described in the literature (i.a. Irwin and Bockstael, 2001; Morger, 2013; Stadelmann, 2010).

5.2.3. Land scarcity can strengthen capitalisation of amenities

Guilfoyle (2000) and Hilber (2015) suspect capitalisation of local amenities to be stronger when land availability is restricted. Such restrictions may be due to regulatory constraints or geographical conditions such as bodies of water and these make housing supply less flexible (Saiz, 2010). Furthermore, expectations of future land scarcity will likely be capitalised in house prices today (Watson, 2013).

Stadelmann and Billion (2012) conducted an empirical study in which they analyse changes in capitalisation over space due to land availabilty in the Canton of Zurich, Switzerland. They find that differentials in land availability do not affect the capitalisation of fiscal variables (tax rate, public expenditure) but that land availaiblty in general capitalises negatively. In a later study for the same area, Stadelmann and Billon (2015) focus more on the time dynamics of capitalisation of fiscal variables and find that the negative capitalisation of land availabilty is a long-time effect (over a period of 7 years). Watson (2013), in a report on behaviour of the Reserve Bank of New Zealand, supports the assumption that capitalisation effects of land availabilty are a long-run phenomenon. This is because developers do not necessarily immediately respond to changes in land availabilty. Rather, they hold on to land in anticipation of future capital gains.

5.2.4. Spatial sorting of households along the affluence continuum

Not surprisingly, income and wealth determine people's choice when selecting particular neighbourhoods to live in, as is well established in the literature (Basten et al., 2014; Brueckner et al., 1999; Cheshire et al., 2014). When amenities capitalise on land and housing prices, it is likely that the most affluent households who can afford it will live in the locations with the highest amenities, if other circumstances are constant (Hilber, 2015; Voith and Gyourko, 2002). Accordingly, sociodemographic variables are intrinsically correlated with location attributes or, as Brueckner et al. (1999) conclude, the location of different income groups are tied to a place's idiosyncratic characteristics.

As Brueckner et al. (1999) further explain, amenities, like low-density settlement structure, can be the cause for location choice but also its consequence. That is, affluent households with a positive willingness-to-pay for amenities might choose a location exhibiting low density structure but, at the same time, also ensure that this structure is not converted in the future e.g. by restricting construction in the neighbourhood (see also Hilber, 2015). Dubin et al. (1992) formulated the presumption that preferences over growth control are a function of material interests. This is especially so if the households are owners of their parcel of land and have a personal interest in securing the value of the land. As Fischel (2001) has argued, since houses are immobile and form a substantial element in people's asset portfolios, there is a stronger incentive to protect their value through preventing land in one's neighbourhood from being developed.

5.2.5. Expectation/hypothesis for the analysis

In a situation where land is scarce and the pressure on land is high, densification of the already overbuilt area is expected (cf. 5.2.1.), though it might reduce the value of the remaining surrounding settlement pattern (cf. 5.2.2.). In the Canton of Zurich, our study area, increasing demand for housing made construction a thriving business. Between 1990 and 2010 the dwelling stock increased by 28%, while the population grew by only 18%.

However, since residents that value low-density structures have an incentive to oppose new construction activity, and since capitalisation of amenities in housing values is stronger in amenity rich places (cf. 5.2.3.), scarcity of land can also result in sorting along the income gradient, with affluent people either settling in less dense neighbourhoods or engaging in securing the low density of their neighbourhoods. Fischel (2001) supports the assumption that high house prices, induced by land constraints, spur households to vote for regulations that decelerate construction activity (see also Balsdon, 2012; Hilber and Robert-Nicoud, 2013).

Considering such a dual development – densification of less amenity rich municipalities with less affluent inhabitants on the one hand and resistance against densification in amenity rich municipalities with more affluent inhabitants on the other hand – as is possible in the Canton of Zurich, we analyse in this paper how scarcity of land for construction has influenced settlement growth patterns over the 20 years from 1990 to 2010.

5.3. Data

5.3.1. Canton of Zurich

The Canton of Zurich is the most populous Canton of the 26 Swiss Cantons. Due to Switzerland's federalist system and the political areas vested in the Cantons, they are comparable to U.S. federal states. The Canton of Zurich had 1.37 million inhabitants in 2010. Forecasts predict a further population growth of more than 20% by 2040 (Bucherer, 2016). 42% of the Canton's area is used for agriculture, 30% is forest and woodland, 6% is unproductive area (such as bodies of water) and 22% is settlement area (Hofer, 2011).

The largest city is Zurich, with around 372,000 inhabitants in 2010; the agglomeration around Zürich is the largest urban agglomeration in Switzerland. The smallest municipality of the Canton has around 300 inhabitants while the mean lies at around 8,000 (2010). The municipalities further differ in their proximity to the two economic centres (the city of Zurich, which is likewise the main economic centre of Switzerland, and the city of Winterthur), their proximity to the Lake of Zurich (a 8,866 km2 body of water), and their elevation (ranging from 330 m to 1292 m). In the north, the Canton of Zurich shares a national border with Germany.

5.3.2. Exclusion of city centres from the analysis

We do not include the city of Zurich and the city of Winterthur in our analysis (similar to Stadelmann, and Billon (2012, 2015) mainly because of their structural divergence (area and population size, populations' socio-economic backgrounds, accessibility by a variety of transport, land price etc.) with respect to the rest of the sample. Because these two sample points have a very high leverage over the prediction of future settlement growth, the results of the analysis would differ if the two cities were included. However, we do control for the municipalities belonging to the agglomeration of either Zurich or Winterthur. In our analysis, we use data for 169 municipalities, which is all of the 171 municipalities as in 2012 minus Zurich and Winterthur.

5.3.3. Spatial planning in the Canton of Zurich

In Switzerland, in order to plan the desired future spatial development, each Canton has to provide a detailed regional development plan (Richtplan) covering the entire area. This plan is subject to approval by the Federal

council, the highest political executive tier. Furthermore, for each municipality the so-called land use plan (Nutzungsplan) lays down binding provisions on how land can be used in practice. A main element of these land use plans is to set the boundary between building zones and non-building zones; the plans are regularly adjusted for new demands and undergo a general revision every 10–15 years (Gennaio et al., 2009).

In the Canton of Zurich, there is an imbalance in supply and demand for undeveloped building zones: whereas in urban areas the expected demand exceeds the supply of current reserves of building zones, in remote areas the supply outstrips the demand (Building Department Kanton Zurich, 2016). However, overall there is an excess of demand. The excess of supply in remote areas mainly results from the generous designation of building zones in the mid-1980s, when the first law on spatial planning was applied (ARV, 1998). Today, the designation of new land for construction is strictly regulated but swapping construction land, also beyond municipalities, is possible in theory. For the interpretation of our analysis it is beneficial that the overall amount of land for construction (the sum of built-up and not yet built land) has been stable since the 1980s (ARV, 1998).

5.3.4. Dependent variables

We used three different measurements to study urban growth:

1. The **growth of per capita land consumption (PCLU)** measures the difference in settlement area taken up by people and workplaces in the time span considered. The fewer spatial units (e.g. m^2) per inhabitant/and or workplaces, the denser the use of the settlement area.
2. The **growth of the spatial extent of the settlement area (SE)** in the time span considered, independent of function, form, utilisation and spatial location of the buildings within the settlement area [m^2].
3. The **growth of building density of the residential zones (BD)** is the difference of the building volume in m3 per ha for the built-up residential zones. Measuring building volumes [m^3] implies a certain visual interpretation of density: the higher the value, the more space is taken by buildings, independent of the use of the buildings. Due to a lack of appropriate data for 1990, we cannot measure the growth of DE since 1990, and thus have had to limit it to 2000 -2010.

The measurements for **PCLU** and **SE** are provided by Jaeger and Schwick (2014), and the measurement for **BD** comes from the Canton of Zurich (ARE, 2017).

5.3.5. Independent variables

Table 13 and 14 indicate the sources of the data we used, and Table 15 presents the descriptive statistics.

Our main variables of interests are land scarcity per capita and affluence.

Land scarcity per capita. To assess land scarcity for each municipality, we took a variable that captures the amount of land designated for construction [m^2] – which is not yet built on – divided by the population[2]. However, to make the interpretation more intuitive, we reversed the scale: that is, the higher the value of

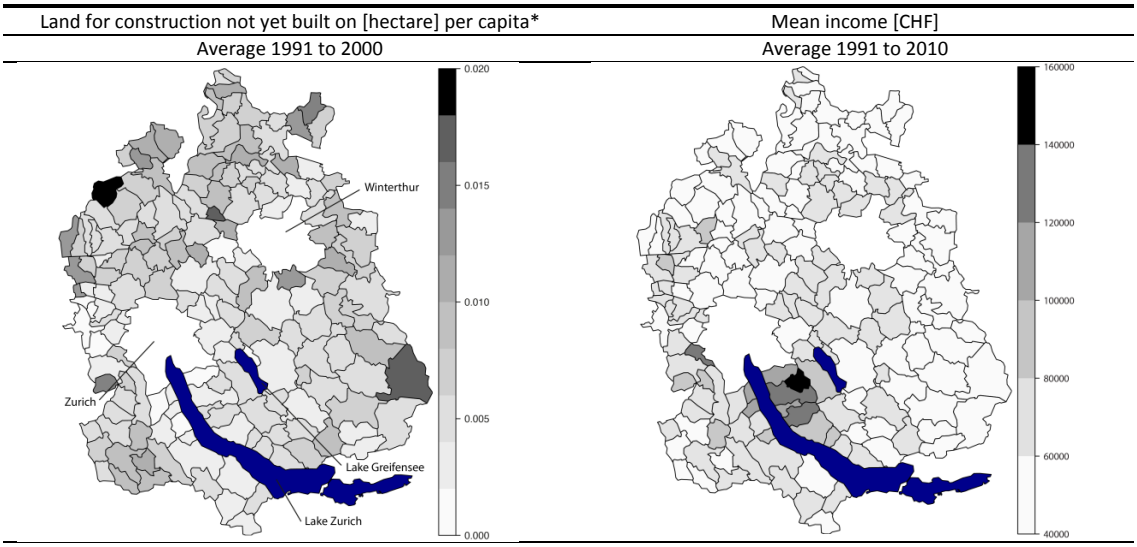
[2] To better capture the imbalance in the distribution of construction areas between relatively rural and urban areas (cf. 5.3.3.), we took the per capita measurement rather than the total supply of building zones.

the variable in a municipality, the less land for construction is available per capita and the scarcer land is (Figure 8).

Affluence of the households. We use data on the mean income (Figure 8). In the Canton of Zurich, the mean income is highly correlated with mean households' assets (Pearson correlation of < 0.95 for the year 2000 and 2010).

Furthermore, we employed a series of variables deemed to affect urbanisation and helping to discern the different preconditions, e.g. amenities of the municipalities, as described in Table 13. The Zurich based bank ZKB (2008) provides a hedonic model for land prices in the Kanton of Zurich, which we used as a reference.

Figure 8: Average land availability and average affluence per municipality (without Zurich & Winterthur)



*In the regression analysis, we reverse the scale of the variable as proxy for land scarcity per capita (cf. 5.3.5.). Rural municipalities have a lower amount of available land for construction in total but a higher amount of available land for construction per capita than the urban municipalities. Source: (Kanton Zürich, 2017), own illustration

Table 13: Description of independent Variables measured at the municipal level

Variables	Description	Source
Land scarcity	Designated construction land not yet built on [hectares]/capita. Reversed scale as proxy for land scarcity: the higher the number, the scarcer the land.	*Kanton Zürich, 2014, Census*
Affluence	Mean taxable income per capita.	*Kanton Zürich, 2017*
Level per capita land consumption (PCLU)	Settlement area/number of inhabitants and work places.	*Jaeger&Schwick, 2014*
Level settlement area (SE)	Spatial extent of the settlement area.	*Jaeger&Schwick, 2014*
Price of land (for construction)	The modelled mean price of land for construction in residential and combined residential and industrial zones (mixed zones) that is not yet overbuilt.	*Moser, 2008*
Public expenses planning	Expenditure of each municipality in terms of spatial planning and environment.	*Kanton Zürich, 2016*
Accessibility	Index expressing the potential to which the transport system (public & private) enables reaching a municipality.	*Tschopp and Fröhlich, 2006*
Commuters (out)	Outbound commuters as share of total employed residents.	*Census*
Commuters (in)	Inbound commuters as share of total employees.	*Census*
Tax rate	Tax rate including church tax.	*Kanton Zürich, 2011*
Population growth $((x-x_{t-20})/x_{t-20})*100$	Difference in population between 1990 and 2010. In chapter 4.1.1. we further consider the problem of endogeneity between population growth and urban growth.	*Census*
One-person households	Percentage of one-person households as share of total households.	*Census*
Retired inhabitants	Percentage of retired inhabitants.	*Census*
Theoretically constructible area	Total area of a municipality where construction is possible (excluding bodies of water, forest, protected areas, unsTable soil, steep slopes) minus area that is already built on.	*Jaeger&Schwick, 2014*
Share buildings pre 1919	Buildings built before 1919 as share of the total number of buildings. This variable controls for certain historical conditions before the sharp rise in urbanisation: 1919 was chosen because this is the first time an inventory was made and includes all buildings planned before the common usage of cars.	*Census*
Share detached houses	Single family houses as share of the total number of buildings.	*Kanton Zürich, 2017*
Agriculture building volume/building volume	Agriculture building volume as share of total building volume. This variable indirectly controls for the rural-urban differentiation of municipalities.	*Kanton Zürich, 2017*
Historical accessibility	Index expressing the potential to which the transport system (public & private) enabled reaching a municipality in the year 1950. We employ this variable to control for certain historical pre-conditions. As expected, accessibility of 1990 and 2000 and accessibility of 1950 are correlated exhibiting a Person value of around 0.75.	*Tschopp and Fröhlich, 2006*
Sun exposure in March	Attraction of areas of construction regarding amount of sun exposure in March (solar irradiation measured as combination of slope and orientation of the parcel).	*Zimmermann and Kienast, 1995*

Table 14: Description of dummy variables

Variables	Description	N/169
Townscape protection*	Municipalities with very strict building regulations	10
Cantonal Border	Municipalities bordering a Swiss Canton	51
National Border to Germany	Municipalities bordering Germany (as control for a group of remote municipalities)	11
Border to lake Zurich	Municipalities bordering lake Zurich (as geophysical amenity of a municipality)	16
Agglomeration Zurich	Municipalities belonging to the agglomeration of Zurich	103
Agglomeration Winterthur	Municipalities belonging to the agglomeration of Winterthur	11

**Source:* assigned as „schutzwürdiges Ortsbild" in the Richtplan Canton Zürich

Table 15: Descriptive statistics of variables

Variables	Year	Mean	St. Dev.	Min	Max	Unity	Adjustment in the model
Growth per capita land consumption (PCLU)	90-10	-16.87	52.8	-243.6	198.9	m^2	
Growth settlement area (SE)	90-10	236000	229414	1800	1554000	m^2	log(1+x/1000-min(x/1000))
Growth building density residential areas (BD)	00-10	0.7869	0.889	-5.9920	3.1020	m^3	
Land scarcity per capita	1991	0.009	0.0047	0.0003	0.03	Hectares/capita	Scale reversed ((max(x)+1)-x), scaled around mean
Affluence	1995	58710	12143	41790	123300	CHF	/1000, scaled around mean
Level per capita land consumption (PCLU)	1990	305.6	113	125.7	640	m^2	
Level per capita land consumption (PCLU)	2010	288	103.6	106.4	645	m^2	
Level settlement area (SE)	1990	1321000	1237913	101900	8112000	m^2	
Price of land (for construction)	1995	597	206.7	192	1357	CHF /m^2	/10
Public expenses planning	1995	44.22	67.31	-397	237	CHF /per resident	
Accessibility	1990	40360	20896	9449	134500	Scale (Tschopp and Fröhlich, 2006)	/1000
Commuters (out)	1990	68.6	9.95	37.4	88.2	% total employed residents	
Commuters (out)	2000	73.74	7.11	49.10	85.40	% total employed residents	
Commuters (in)	1990	46.56	16.50	5.60	85.40	% total employees in municipality	
Tax rate	1990	125.5	11.02	90.2	136.5	Multiple, in %, of the cantonal tax rate	
Population growth	90-10	29.6	20.4	-26	89.9	%	
One-person households	1990	23	6.60	11	47	% total households	
Retired inhabitants	1990	10	3.37	4	23	% total population	
Theoretically constructible area	1990	7685000	5965584	371700	48060000	m^2	/100000
Share buildings pre 1919	1990	20	16	0.08	74	% total buildings	
Share detached houses	1990	34	13.1	6.1	61.4	% total households	
Share agriculture buildings/building volume	1990	15.44	13.14	0.50	73.80	% total building volume	
Historical accessibility	1950	15830	7643.83	3820	46320	Scale (Tschopp and Fröhlich, 2006)	
Sun exposure in march	2000	2698	245.71	2220	3732	Scale (Zimmermann and Kienast, 1995)	

To assess the degree of spatial neighbourhood effects and heteroskedasticity induced by spatial dependence in the data (Kim and Sun, 2011), we applied (robust) Lagrange Multiplier Tests (Anselin and Rey, 1991). We tested several weight matrices, defining different types of neighbourhood relations3. Based on the results of the tests, we specified all the models (Table 17, model 1 to 5) as spatial autoregression (SAR) models. The W-matrices (W) giving the best results are different for each dependent variable (see Table 16). We equally calculated Moran's I for each dependent variable with the corresponding W. The results show that the spatial dependence is always positive, fairly high, and significant for all of the dependent variables.

5.4. Model specification

Table 16: Overview over w-matrices

Year	Dependent variable	Model	**W**-matrix	Morans'I
1990-2010	Per capita land consumption (PCLU)	1	10 nearest neighbours (KN10)	0.11***
1990-2010	Growth of settlement area (SE)	3	9 nearest neighbours (KN9)	0.28***
2000-2010	Growth of building density in residential areas (BD)	5	2 nearest neighbours (KN2)	0.22***

5.4.1. Spatial model

In the results (5.8. Appendix, Table 18), we further distinguished between average direct and average indirect effects (LeSage, 2008). The average direct effect (within a municipality) gives the impact arising from changes of an independent variable in a given municipality on the dependent variable of that municipality, e.g. the effect of land scarcity on the growth of its utilisation density (UD). Furthermore, LeSage and Pace (2009) point out that some feedback effect from adjacent municipalities comes into play in the direct effects estimates, which are also taken into consideration in the result (see e.g. also Golgher and Voss, 2015 for a description). The average indirect effect, in contrast, gives a measure of the impact on the dependent variable in a municipality arising from changes in an independent variable of the adjacent municipalities. The calculation of the impacts is done in the spdep package in R (Bivand and Piras, 2015). Note that it is always an average effect that is calculated, the ratio between the direct and indirect effects of the independent variables is always the same, and the magnitude of the effects depends on the specification of W (Elhorst, 2010).

5.4.2. Tackling endogeneity

In our specification, the causal relation between changes in settlement patterns and the amount of land for construction that is left is not unambiguously unidirectional: land scarcity influences settlement patterns but changes in settlement structures can also have an influence on land scarcity. Also, population growth is a potentially endogenous variable (Gómez-Antonio et al., 2016) for which the underlying assumption about the direction of causation remains equally debatable (Duranton and Turner, 2012). Increasing demand for housing causes settlement patterns to change, but an increased offer of housing opportunities might likewise attract new people in search of housing.

[3] Invert square distance matrix, queen and rock contiguity matrixes and k-nearest neighbours (KN1 to KN12): the W-matrices are row normalised.

A way of tackling endogeneity problems in cross-section data is to make use of an instrumental variable (IV) approach by identifying an instrument, i.e. an additional variable that is highly correlated with the potentially endogenous explanatory variable, in our case with land scarcity per capita and population growth respectively, but not with settlement structures. To assess land scarcity per capita, we tested a time lagged proxy for the same variable[4]. To assess population growth, we used the share of outgoing commuters in 1990 and 2000[5].

Approaches with IV are very tenuous when it comes to the selection of appropriate instruments since weak instruments might result in serious biases in the estimations (Murray, 2006). While our instrument fulfils the requirements of a weak instrument test we applied, a Durbin-Wu-Hausman test[6] indicates that an OLS estimation is just as consistent as the estimations employing the instrument identified (Davidson and Mackinnon, 1989). Due to the indication that OLS estimates should not be substantially biased, the following results have been based on the OLS methods, respectively set up as SAR (cf.5.4.1).

In this analysis we focus on two important variables, land scarcity and population growth, raising concerns of reverse causation. However, further such concerns could be raised for additional variables in the model and it would be impossible to consider all potential instances of endogeneity (Duranton and Puga, 2013). Thus, our analysis should be viewed with its limitations in mind.

5.5. Results

5.5.1. Interaction between land scarcity and affluence

To better understand the interaction between land scarcity and affluence, we made use of marginal effect plots (Brambor et al., 2006), presented in Figure 9, while Table 17 lists the regression results. Since we centred land scarcity and affluence around their means, the coefficients in the interaction models have to be interpreted as the effect of land scarcity on the dependent variable when affluence is at its mean, and vice versa. The results for a set of unconditioned models (1 to 3) yields very similar coefficients for land scarcity and affluence as the models presented here, hence we do not present them.

The results in Table 17 show that the scarcer the land for construction per capita, the less per capita land consumption (PCLU) grew in the following 20 years. The interaction effect completes the picture by differentiating the process according to affluence: the negative influence of land scarcity per capita decreases with the affluence of the municipality, converging to zero. However, the influence of land scarcity per capita on the growth of PCLU is not significant for the more affluent municipalities (Figure 9a).

[4] We used the amount of agriculturally used area (m2) in 1983/capita 1983, because there are no data available on the amount of area for construction before 1991. 1983 was taken because the land use statistic (Arealstatistik) was conducted in 1983.

[5] In Switzerland, the trend of decoupling workplace and residential location is increasing as is the share of daily commuters (SFSO, 2014). We reckon that the share of outgoing commuters reflects population growth to some extent. However, we also expect outgoing commuters to be less correlated with settlement structure since commuting involves all socio-economic backgrounds.

[6] The DWH test aims to test for endogeneity in a regression estimated via IV. The null hypothesis states that an OLS estimator of the same equation would yield consistent estimates. The calculations were turned out using the IVREG package in R (Kleiber and Zeileis, 2008).

This observation is confirmed by the results for growth of the settlement area (SE). The scarcer the land for construction per capita, the less a municipality will extend its settlement area (SE) in the next two decades. If we differentiate the influence of land scarcity on SE along the affluence of municipalities (Figure 9b), we see that with increasing affluence, scarcer land contains the growth of the settlement area (SE). However, again this relationship is significant for the municipalities with average affluence, but it is not significant for the most affluent ones (Figure 9d).

The results for the growth of the building density in the residential areas (BD) (2000-2010) show that an increase in scarcity per capita fosters BD while an increase in affluence actually hinders it, though the latter coefficient is not significant. The marginal effect plot (Figure 9c) differentiates that while in less affluent municipalities the influence of land scarcity on BD is positive and significant, it becomes negative but also less significant the more affluent the municipality is.

5.5.2. Convergence in per capita land uptake (PCLU)

Considering all the results, there is evidence that, all else being equal, those municipalities with an already high level of per capita land consumption (PCLU) in 1990, the beginning of the measurement period, experienced significantly less growth in PCLU (Table 17, model 1) and also less growth in the amount of settlement areas (SE) (Model 2) in the following two decades. Figure 10, showing the levels of PCLU in 1990 and 2010 per municipality, indicates a certain process of convergence in PCLU. This observation corresponds to other descriptions of urbanisation processes as an iterative progression of densification and extension of the area (Haase and Nuissl, 2010; Kabisch and Haase, 2011; Kasanko et al., 2006). However, our results also show that a high level of settlement area (SE) did not significantly influence the growth of land consumption (PCLU), but triggered a further growth of SE between 1990-2010 (Table 17, model 2). It is possible that municipalities which grew only moderately in SE until the measurement period did not have any incentive to reduce land consumption but rather to expand the settlement area. However, municipalities exhibiting a high growth of SE in the past, complemented with a low per capita land consumption (PCLU), would also grow outward, and thus follow the same iterative progression of densification and extension as described above.

5.5.3. Spatial information: spillover effects of land scarcity

The value of Rho, the parameter which measures the degree of spatial dependence while controlling for the effect of all other variables, shows that the growth of settlement area (SE) in municipalities depends on their neighbours' growth in SE. In contrast, the spatial coefficient for growth of per capita land consumption (PCLU) and of building density in residential areas (BD) is not significant.

The finding that rho is not significantly different from zero in equation 1 (PCLU) and equation 3 (BD) (although the growth of PCLU and BD are significantly clustered, cf. 5.4.1.) can be explained by the fact that some of the variables that are used in the models, capture some of the spatial clusters. For example, the level of PCLU itself has a significant Moran's I value of 0.39, and equally the controls for factors like border municipalities are clustered. That is, although the growth in PCLU and BD are clusters in space, the models include factors that control for this spatial relations. However, for the growth of SE, this spatial connection is captured by variables that are not included in the model. Such factors could be forests, good agricultural land or major infrastructure that are similar in neighbouring municipalities and influence the growth of SE. For example the development of inter-municipal transportation systems, such as the S-Bahn probably contributed to regional spillover effects (ARV, 1998).

Table 18 gives the direct and indirect effects. As expected – because of the non-significant value of Rho – there are only significant indirect effects for the growth in the settlement area (SE). In particular, the results give evidence that land scarcity in the neighbouring municipalities exhibits negative significant indirect spillover effects on the growth of the settlement area (SE) (Table 17, model 2). That is, the less land available in neighbouring municipalities, the less there will be of a certain municipality growth in the settlement area (SE). However, the larger the settlement area (SE) of surrounding municipalities, the more growth in SE in a specific municipality.

One explanation for the negative spillover effect of land scarcity on the growth of SE could be existing complementariness in local planning (e.g. through the Canton or "Spatial Planning Regions" such as the region Limmatthal) where individual municipalities already take into account the developments in a wider region. However, it is also possible that municipalities mimic measures of spatial planning of their direct neighbours as e.g. confirmed by Berli (2017).

5.5.4. Further variables

A rising share of incoming commuters will significantly increase a municipality's per capita land consumption (PCLU) – which includes land consumption of people and workplaces – its settlement area (SE) and its density of building (BD).

Population growth (cf. 5.4.2. on endogeneity) significantly decreases land consumption (PCLU) and increases building density (BD). However, we have found no significant influence of increasing population on the increase of the settlement area (SE). It is possible that population growth is better explained by some other independent variables in the models on which population growth seem to depend to some extent or with which it is at least correlated (however, we checked the correlations of the variables in the model (below 0.5 Pearson), as well as the variance inflation factor (VIF) factor (lower than 5)). In theory, population growth can lead to either a densification of an already present settlement area, or the extension of the settlement area. In a series of models where we tested an interaction between population growth and land scarcity, we found that, in municipalities with more reserves of construction land, population growth had no significant effect on SE. However, the scarcer the land reserves in a municipality, the more the settlement area (SE) will grow with a rising population. This is allegeable, if the municipalities with scarce land for construction are densely built (low PLCU) to such a degree, that any further growth of the urban areas has to take place through expansion (growth in SE), additionally because of resistance of the residents against further densification.

A rising share of one-person households negatively influences the growth of a settlement area (SE) but does not significantly influence the growth of per capita land consumption (which has a positive sign) nor of building density (which actually decreases). Municipalities with a higher share of theoretically constructible areas grow significantly more in settlement areas (SE). Furthermore, as visible in Table 18, a high share of theoretically constructible areas in neighbouring municipalities will equally increase the settlement area (SE). However, the share of theoretically constructible areas has no significant influence on the growth of PCLU or BD.

The share of old buildings (pre 1919) per Municipality has a large but not significant influence on land consumption (PCLU): the higher the share, the lower land consumption. Furthermore, and significantly, the higher the share of old buildings, the less a municipality's settlement area (SE) will grow. Surprisingly, a growing share of detached houses

hinders the growth in SE significantly. The result might be allegeable if the detached houses were constructed within the already built-up area (space between the buildings) rather than on the outskirts of the municipalities.

Finally, two of the dummy variables, bordering Germany and belonging to the agglomeration of Winterthur, also show significant influence. Those municipalities bordering Germany grew significantly more in both per capita land consumption (PCLU) and settlement area (SE) compared to the other municipalities. Thus their growth could be considered as sprawl, in contrast to densification. The respective municipalities are remote (with respect to the city of Zurich) but, with the introduction of the S-Bahn, are generally fairly accessible. In 1991, the year of measurement for the land scarcity variable, they had a share of 28% of construction land per municipality and thus around 20% more land for construction than the rest of the canton. In 2010, although their construction land reserves were depleted to 16% of the total land, they still had a relatively higher share of land for construction (+25%) than the rest of the Canton. The attraction of these bordering municipalities most probably lies in the availability of land reserves – allowing for land consuming settlement growth. Furthermore, other features like the S-Bahn, traditional village structure, the River Rhine and even the proximity to Germany (which entails cheaper shopping opportunities) could have attracted people in search of housing. A similar, although not so strong pattern can be observed with the municipalities belonging to the agglomeration of Winterthur, the second largest city in the Canton. These municipalities have a higher share of land reserves compared to the rest of the Canton, (10% in 1990 but only 3% in 2010) and grew significantly more in settlement area (SE) and (not significantly) also in PCLU.

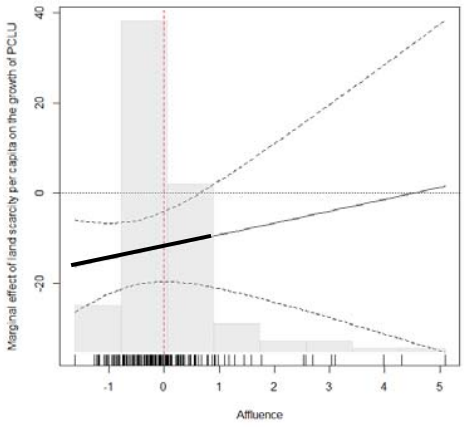
Table 17: Regression results

	PCLU90-2010	***SE90-10***	***BD00-10***
	(1)	(2)	*(3)*
	SAR	SAR	SAR
Land scarcity	-11.863***	-0.154**	0.176**
Affluence	-1.338	0.057	-0.045
Land scarcity*Affluence	2.628	-0.025	-0.072
Level per capita land consumption (PCLU)	-0.296***	-0.001**	0.0004
Level settlement area (SE)	-0.491	0.029***	-0.002
Price of land (for construction)	-0.227	-0.001	0.004
Public expenses planning	-0.023	0.0001	-0.001
Accessibility	0.101	-0.003	-0.009
Commuters (out)	-0.458	-0.009	-0.012
Commuters (in)	0.603**	0.014***	0.018**
Tax rate	-0.129	0.008	-0.006
Population growth $((x-x_{t-10})/x_{t-10})*100$			0.034***
Population growth $((x-x_{t-20})/x_{t-20})*100$	-1.705***	0.002	
One-person households	0.220	-0.034***	-0.037
Retired inhabitants	-0.287	0.003	0.030
Theoretically constructible area	0.046	0.006***	0.0002
Share buildings pre 1919	0.462	-0.019***	-0.017
Share detached houses	0.305	-0.010*	-0.006
Share agriculture buildings/building volume	0.616	0.002	0.013
Historical accessibility	-0.001	0.00000	0.00001
Sun exposure in march	0.016	0.0002	-0.0004
Townscape protection	-5.776	0.142	0.106
Cantonal Border	4.807	-0.075	-0.168
National Border to Germany	46.325***	0.503***	0.418
Border to lake Zurich	5.785	0.217	0.212
Agglomeration Zurich	1.142	-0.108	-0.077
Agglomeration Winterthur	16.550	0.368*	-0.017
Constant	84.978	1.598	2.852
Observations	169	169	169
W-matrix	Kn10	Kn9	Kn2
Pseudo R2[¤]	0.71	0.76	0.35
Akaike Inf. Crit. for spatial	1663	281	426
Akaike Inf.Crit for lm	1661	289	426
Wald Test (df = 1)	0.027	10.346***	2.65
Rho	-0.002	0.27***	0.12

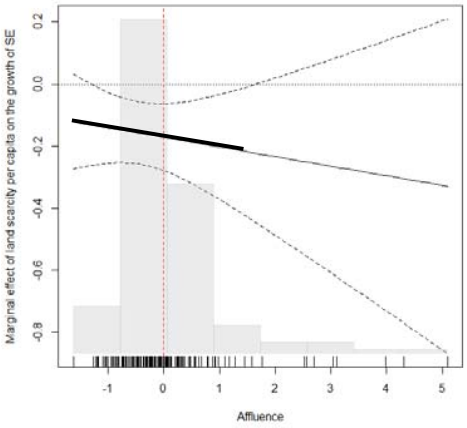
Note: *p<0.1; **p<0.05; ***p<0.01
[¤]Nagelkerke (1991)

Figure 9: Marginal Effect Plots for Interaction between land scarcity * affluence

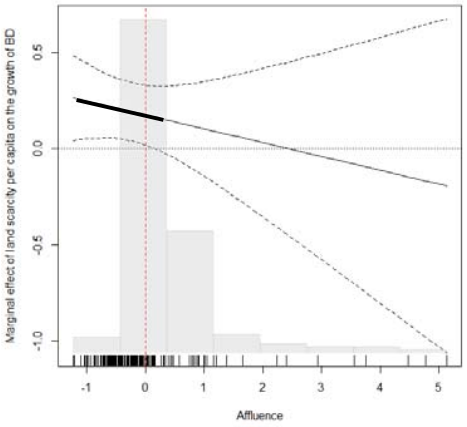
a (Table 17, model 1.): PCLU90-10



b (Table 17, model 2.): SE90-10

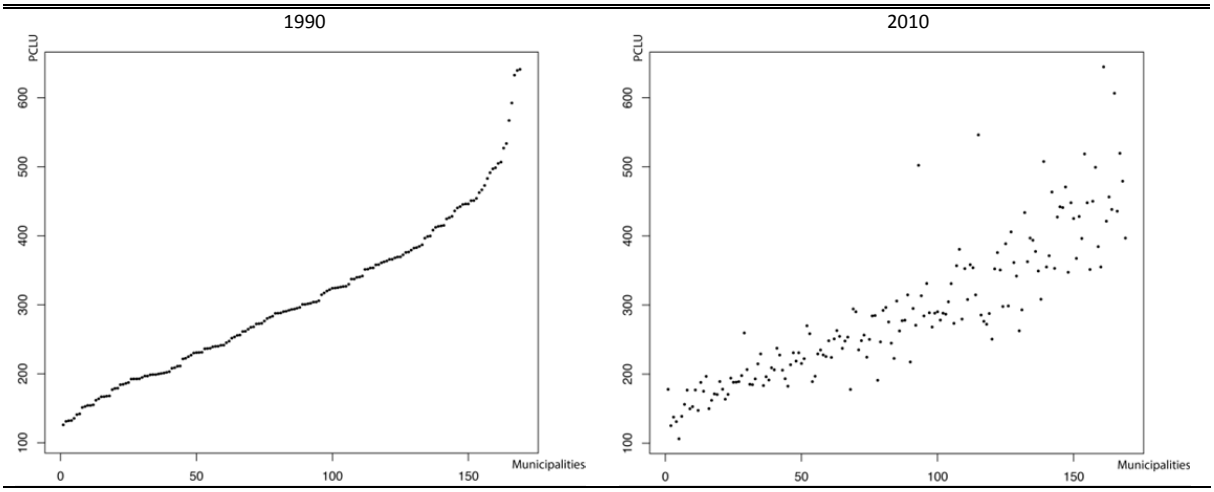


c (Table 17, model 3.): BD00-10



Note: The bars represent the frequency distributions of the municipalities per accessibility value, the graph is thicker if the value is significant.

Figure 10: Level of per capita land consumption (PCLU) 1990 and 2010 per municipality



The plot indicates some convergence in the level of per capita land consumption (PCLU) per municipality where municipalities with a low level in 1990 would probably grow in PCLU and vice versa. On average, the 85 municipalities with the lowest PCLU in 1990, had a reduction of 4.1 PCLU from 1990 to 2010, those 84 municipalities with the highest PLCU in 1990 one of 29.7.

Note: The municipalities are ordered in terms of their level of PLCU in 1990. The municipalities exhibiting a very high level of PCLU are, with some exceptions, rural municipalities. The ones exhibiting a low level of PCLU are, with exceptions, agglomeration municipalities or historical towns with a high level of old buildings.

5.6. Discussion

In this paper we studied if and how the scarcity of land for construction affects settlement growth patterns. Due to relatively strict spatial planning, undeveloped areas available for new construction of buildings in the Canton of Zurich in Switzerland, our study area, decreased by about 40% between 1996 and 2010, at a time when the population increased by more than 15% (Kanton Zürich, 2017). Scarcity of land for construction restricted the supply of particular settlement patterns, i.e. low-density neighbourhoods, and supposed increases in the price of land due to capitalisation of the amenity "low-density". Under these conditions, the main question of the analysis is how land scarcity affects the growth of settlement patterns, and whether in municipalities hosting affluent people, land scarcity provokes different – possibly less dense – patterns of settlement growth than in less affluent municipalities.

In our models, land scarcity is operationalised with land designated for construction, however, we control for the amount of theoretically constructible area in a municipality (see Table 13). Trying to capture the interaction between land scarcity and affluence of a municipality's population, we introduce an interaction term between the two. The dependent variables are settlement growth patterns, namely the change in land consumption per capita and workplaces (PCLU), the change in the extent of settlement area (SE), and the growth of the building volume density in residential areas (BD). Our models account for a spatial spillover effect of settlement growth in surrounding municipalities by employing spatial lag models. The analysis covers the two decades from 1990 to 2010, and includes 169 municipalities in the Canton of Zurich (all municipalities except for the two largest cities). We control for amenities such as access to the lake or accessibility by transportation means, and we also account for land prices, differences in income tax and initial level of per capita land consumption (PCLU) in the municipalities etc. (cf. Table 13).

The results show that in the Canton of Zurich, land scarcity per capita leads municipalities to digest growth by decreasing per capita land consumption (PCLU) and to contain the extent of the settlement area (SE). This strengthens the overall assumption and observation that densification of the present settlement area is aimed at by planners and investors, when land designated for construction is scarce. In that, the results are very similar to the findings of Broitman and Koomen (2015) for the Netherlands.

As for the second part of our research interest, we have found that – despite settlement growth patterns being significantly shaped by land scarcity in almost all the municipalities – land scarcity does not significantly drive changes in settlement patterns in the most affluent municipalities. The results show further that a decrease in per capita land consumption (PCLU) induced by land scarcity can be avoided by a relatively larger number of more than average affluent municipalities. However, a containment of extension of the settlement area (SE) can be avoided entirely by a small number of most affluent municipalities. The results for the growth of building density in residential areas (BD) between 2000 and 2010 support these observations: the less affluent the population of a municipality in 2000, the more land scarcity fosters BD. For the affluent municipalities, however, this relationship is negative but not significant.

While we found evidence that affluence can influence the outcome of settlement growth patterns, the identification of means or mechanisms that lead to such an outcome are outside the scope of our analysis. We interpret our results as evidence for a tendency existing in low-density neighbourhoods – equalling higher land consumption per capita – which are considered more attractive and are pricier. Affluent people, who have both the capacity to pay for the amenity of living in a low-density neighbourhood and equally the willingness to protect the neighbourhoods' status

quo, might act against further densification activity (Brueckner et al., 1999; Fischel, 2001). A study on land prices in the Canton of Zurich underpins these results: in some of the amenity rich municipalities (high sun exposure, bordering lake Zurich, close to the city of Zurich), the land prices for plots with a low maximum ratio of utilisation are higher than for those with a high maximum ratio of utilisation (ZKB, 2008), indicating that low-density is valued as an amenity. In support of that finding, Pleger (2017), in a study on voter's acceptance of land use policy measures in Switzerland, finds that homeowners are more opposed to spatial planning measures – usually in favour of densification – compared to people who rent. Our result suggest that this might reflect the fact that most affluent people are also homeowners.

Addressing potential problems of endogeneity, we used a Hausman endogeneity test finding the differences between the IV estimates and OLS estimates are not substantial and OLS estimates are consistent. However, concerns of correlated omitted variables and reverse causation or endogeneity can hardly be avoided (see e.g. Duranton and Puga, 2013). Thus, and although the results are plausible for our study area, in our interpretation we tried to be cautious in our causal interpretation of the derived correlations.

5.7. Conclusion

This study gives evidence that for municipalities with affluent inhabitants, land scarcity does not provide sufficient incentive to reduce land consumption and thus land use density. In Switzerland, private property is strongly protected under constitutional law, and expropriation of private land is almost non-existent. In this situation, it is usually the responsibility of the owners of private property to ascertain the best use of the land resources. In fact, they have the right but no obligation to construct on their land. Despite densification being advocated as salutary for society as a whole by urban planners and policy, land owners in affluent municipalities resist such pressure. Forecasts of continuing land scarcity and economic and population pressures in the Canton of Zurich underpin the expectations that the identified tendencies will continue. Furthermore, municipalities are normally interested in bolstering their tax revenue by attracting affluent inhabitants, thus they tend to give priority to economic and fiscal rather than ecological and social concerns (Knoepfel et al., 2012).

A continuation of such a development may raise several public policy concerns and lead to equity and efficiency implications. The first point is the quality of settlement patterns across the Canton of Zurich, e.g. if the affluent municipalities leave the pressure to densify to less affluent municipalities. In the worst case, this would result in a situation where poor people living in high-density areas "subsidise" the lifestyle choices of affluent people living in low density areas as described by Orfield (1999) in a study in the Twin Cities area in the U.S. A second concern, being very much related to the first one, is access to affordable housing. If there is a demand for low-density housing but housing prices are high in the affluent, amenity rich and low-density municipalities, the demand will most likely be directed towards land resources on the rural fringe, producing sprawl and diseconomies of scale in the provision of transport and in commuting time elsewhere (e.g. Ewing, 1997). Thirdly, such tendencies could aggravate social segregation. As Hilber (2015) observes, the presence of affluent homeowners will very likely generate positive externalities (fiscal externalities but also peer effects), resulting in better local public services, stronger social ties, and better maintained housing in the municipality they live in.

Our results show that depending on the affluence of a municipality's inhabitants, any policy related to restricting land for construction needs to be made cautiously so that individually favourable but socially dubious low density settlement patterns are not stimulated. Although there might not be a satisfactory solution for the identified problem,

we provide some suggestions. Firstly, within the current planning system and employing instruments already in use, planners could introduce a minimum ratio of utilisation, coupled with an obligation for timely development of new dwellings, otherwise taxes may be levied. Secondly, in affluent municipalities, the construction of low- or moderate-income housing should be supported to keep pace with the development of market-rate housing in order to contribute to a diversification of housing supply in terms of tenure and social mix to counteract social segregation which threatens social cohesion. Thirdly, architectural competitions could foster high quality densification to support new life styles other than the single-family home.

5.8. Appendix

We used the impacts command (Bivand and Piras, 2015) in the R package spdep to calculate the effects. Since impacts uses MCMC simulation, the coefficients for the total effect presented here are slightly different than for the coefficients in Table 17, though within the valid intervals.

Table 18: Average impacts of direct (local) and indirect (spill-over) effect of unit change in predictor variables

	PCLU90-10 (model 1)			***SE90-10 (model 2)***			***BD00-10 (model 3)***		
	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total
Land scarcity	-11.863***	-0.224	-12.087***	-0.155**	-0.058*	-0.213**	0.1767**	0.0224	0.1991**
Affluence	-1.338	-0.025	-1.363	0.057	0.021	0.078	-0.0447	-0.0057	-0.0504
Land scarcity * Affluence	2.628	0.050	2.677	-0.026	-0.009	-0.035	-0.0721	-0.0091	-0.0813
Level PCLU	-0.296***	-0.006	-0.302***	-0.002***	-0.001	-0.002***	0.0004	0.0000	0.0004
Level built-up area (SE)	-0.491	-0.009	-0.500	0.029***	0.011**	0.040***	-0.0018	-0.0002	-0.0021
Price of land (for construction)	-0.227	-0.004	-0.231	-0.001	0.000	-0.002	0.0044	0.0006	0.0049
Public expenses planning	-0.023	0.000	-0.023	0.000	0.000	0.000	-0.0005	-0.0001	-0.0006
Accessibility	0.101	0.002	0.103	-0.003	-0.001	-0.004	-0.0091	-0.0012	-0.0103
Commuters (out)	-0.458	-0.009	-0.467	-0.009	-0.003	-0.012	-0.0117	-0.0015	-0.0132
Commuters (in)	0.603**	0.011	0.615**	0.015***	0.005**	0.020***	0.0181**	0.0023	0.0204**
Tax rate	-0.129	-0.002	-0.132	0.008	0.003	0.011	-0.0057	-0.0007	-0.0064
Population growth ((x-x t-10)/xt-10)*100	-1.705***	-0.032	-1.737***	0.002	0.001	0.003	0.0341***	0.0043	0.0385***
One-person households	0.220	0.004	0.224	-0.034***	-0.013	-0.047**	-0.0370	-0.0047	-0.0417
Retired inhabitants	-0.287	-0.005	-0.293	0.003	0.001	0.004	0.0302	0.0038	0.0341
Theoretically constructible area	0.046	0.001	0.047	0.007***	0.002**	0.009***	0.0002	0.0000	0.0002
Share buildings pre 1919	0.462	0.009	0.047	-0.019***	-0.007**	-0.026***	-0.015	-0.002	-0.017
Share detached houses	0.305	0.006	0.310	-0.010*	-0.004	-0.014*	-0.0064	-0.0008	-0.0072
Share agriculture buildings/building volume	0.616	0.012	0.628	0.002	0.001	0.002	0.0133	0.0017	0.0150
Historical accessibility 1950	-0.001	0.000	-0.001	0.000	0.000	0.000	0.0000	0.0000	0.0000
Sun exposure in march	0.016	0.000	0.017	0.000	0.000	0.000	-0.0004	0.0000	-0.0004
Townscape protection	-5.777	-0.109	-5.886	0.143	0.053	0.197	0.1061	0.0134	0.1195
Cantonal border	4.807	0.091	4.898	-0.076	-0.028	-0.104	-0.1692	-0.0214	-0.1906
Border to Germany	46.326***	0.875	47.201***	0.508***	0.188	0.696**	0.4201	0.0532	0.4733
Border to lake Zurich	5.785	0.109	5.895	0.219	0.081	0.300	0.2127	0.0270	0.2397
Agglomeration Zurich	1.142	0.022	1.164	-0.109	-0.040	-0.149	-0.0776	-0.0098	-0.0874
Agglomeration Winterthur	16.550	0.313	16.863	0.371*	0.138	0.509*	-0.0172	-0.0022	-0.0194

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Chapter 6: synthesis and conclusions

In Switzerland, the built-up area is expanding (SFSO Swiss Federal Statistical Office and FDHA Federal Department of Home Affairs, 2014), and there are indications that this trend will continue. As elsewhere in Europe, however, extension of the built-up area is greater than would be expected on the basis of population growth alone (Alice et al., 2014; EEA European Environment Agency, 2006). The low density expansion of built-up areas – usually called urban sprawl – which has influenced the Swiss landscape over the course of the last decades (SFSO Swiss Federal Statistical Office, 2015), has increasingly induced ecological, social, and economic costs (EEA European Environment Agency and FOEN Federal Office for the Environment, 2016; Schwick et al., 2010). Much of the current debate on sprawl has seen public and policy makers rushing to address normative issues on sprawl without first having a good understanding of its mechanics. However, as with many social processes, a comprehensive understanding of the implications of urban sprawl can only come through the creation of both positive and normative knowledge (Burchfield et al., 2006a; Oueslati et al., 2014; Siedentop, 2005). This thesis contributes to expanding the knowledge base through quantitative analysis based on valid and reliable data. The main aim of this thesis was to identify, delineate and understand socio-economic determinants of urban growth in Switzerland.

Landscapes show how we have influenced our environment in the past, and further shaping is certain. One of the core principles of Swiss planning legislation is to orientate the activities of the public authorities towards a desired spatial development, considering the needs of people and the environment equally. Researched information is crucial to help decision-makers improve these planning policies and processes, and guide future policy decisions. To that end, the results of this thesis should lead to better judgments about allocating the resource land and contribute to more sustainable political decision-making related to land use and planning.

The analyses of this thesis come from different aspects: the focus of the first analysis derives from all Swiss municipalities and focuses on developments from 1980 to 2010; the second analysis sheds light on different preconditions – local tax and local accessibility, which trigger different urban development patterns, again for all Swiss municipalities but only from 2000 to 2010. The third analysis finally concentrates on the specific condition of land scarcity in a confined region (Canton of Zurich) and comprises two decades (1990-2010). In this way, the focus of the three analyses presented in this thesis moves from a coarser overview to a context specific examination.

In the next sections of this chapter, the main findings of the thesis are presented and put into perspective. Scientific urban growth analysis and the societal context of urban growth debates in Switzerland provide the general context. Finally, methodological issues are discussed and some recommendations for both future research and for improvements to Swiss planning practices are outlined.

6.1. Main findings

6.1.1. First Paper

The first paper (Chapter 3) of the present thesis is dedicated to a review of empirically assessed determinants of urban sprawl in the literature, and it contributes an empirical analysis of determinants of urban growth for Switzerland (cf.2.1.). The analysis differentiates between four different dependent variables depicting urban growth, namely the percentage of built-up area (PBA), dispersion of settlement (DIS), utilisation density (UD), and a combined so-called urban sprawl index (WUP) (cf. Chapter 2.4 for an overview over the variables, developed by Jaeger & Schwick, 2014). The study uses data for a period of 30 years (1980 to 2010). Employing four different dependent variables and thus distinguishing different dimensions of urban growth, the analysis contributes to a disentanglement of factors that drive urban development in general (PBA,UD,DIS) and factors that drive urban growth considered to be urban sprawl (WUP) in particular. Employing models that can depict spatial dependency in the data, the results confirm that spatial spillovers are a noticeable trait of urban growth.

The analysis shows that accessibility - determined by how well a municipality is connected to the traffic network infrastructure - seems to be the single most important enabling factor leading to urban growth and urban sprawl. For example, the hier.part diagrams that give the hierarchical partition variance for variables in a model (Grömping, 2006), and which are mentioned but not presented in the paper, show the dominance of the factor accessibility compared to population growth and tax revenue (as proxy for wealth). The results show that the more accessible a municipality is, the higher the percentage of the area of a municipality that will be taken up by built-up areas ten years later, measured by the value of PBA. Equally, the value for DIS will have grown, indicating that the built-up area will rather exhibit a dispersed form. Furthermore, the utilisation density (UD) will have increased, indicating that the number of people living and working within the built-up area has increased. And finally, resulting from a weighted combination of the three measurements mentioned, accessibility will also have driven up the urban sprawl index WUP. The positive influence of accessibility, and a thus well-developed transport system on urban growth is well established in the academic literature (Aguayo et al., 2007; Fröhlich, 2008). Herbert and Jefferson (1982) suggest that it is mainly communication networks and local accessibility that shape the form of urbanisation.

Furthermore, the analyses show that changes in social and demographic patterns influence spatial patterns, confirming preceding studies (Æro, 2006). For example, the higher the share of retired inhabitants in a municipality, the higher the level of built-up area (PBA), the lower the level of utilisation density (UD) and the higher the level of the sprawl index (WUP). The positive influence of retired inhabitants on the sprawl index (WUP) can be explained by the assumption that elderly people often use more living space per capita since they do not necessarily change housing when the family size is reduced (cf. chapter 7).

The results show a shift over time in how well the model fits the data regarding the utilisation density (UD). It does so particularly well for the last period of measurement (2000 – 2010) compared to the first period (1980-1990). This increasing explanatory power for UD over time could be due to better utilisation of existing buildings, that is an increasing number of people and jobs, at a constant (or slower) growing extension of settlement areas. The higher utilisation density (UD) for economic and medium centres gives evidence that this development takes place mostly in municipalities with high economic activity where the pressure on land is high.

6.1.2. Second Paper

Switzerland has a decentralised government which is reflected in the largely political autonomy of municipalities. This autonomy provides municipalities with the possibility to develop and apply local fiscal schemes to draw new habitants using attractive tax bases (Hilber and Schöni, 2016) which, in turn, influences settlement structure (Fang and Knox, 2015). The aim of the second analysis (Chapter 4) was to explore whether and how differences in local income tax between municipalities influence land consumption – measured as a percentage of built-up area and per capita uptake of built-up area. The analysis measures the dependent variables in 2010 while lagging the independent variables by 10 years, and covering all Swiss municipalities. The restricted time span is due to the availability of data on local tax. Furthermore, the analysis considers land consumption in rural areas different than in urban areas: urban municipalities – absorbing most of the population growth and providing most of the workplaces – have less land reserves and thus might be limited in their outward growth of settlement area while, generally, exhibiting higher land rent. Also, in order to better capture rural but accessible as well as urban but remote municipalities, the population weighted measurement of accessibility is employed and introduces as an interaction term between municipal tax and accessibility.

The theoretical background of the analysis is rooted in Tiebout's (1956) residential choice theory: differences in public goods and services – such as differences in taxes – are decisive factors in location choices of households. Taxes, in particular, are something that municipalities have a certain discretion over (FTA, 2016) and that can be used by the municipalities as an instrument to attract a certain class of newcomers in order to yield higher tax revenues (Fulton et al., 2001). Different population structures will then seemingly influence settlement structure. The analysis does not investigate the motivations of municipalities to set a particular – i.e. favourable – tax scheme. Rather, the focus lies on the connection between differences in the tax and in land-uptake over time.

The results give evidence that tax variation between municipalities influence land consumption in two ways. Either, it leads to a densification, that is a reduction of per capita land uptake with a reduction of growth of the settlement area, or it leads to a growth in per capita land uptake. The first effect is more visible in urban, accessible municipality while the second effect is more visible in rural, remote municipalities. Municipalities that are rural in structure but fairly accessible from the populous centres, follow the trend of the urban areas and tend to densify their settlement structure. It seems that sprawling urban structures are more frequent among remoter municipalities with favourable tax schemes. In such cases, the benefits of disaggregated governance and local autonomy may be diminished by higher fiscal and environmental costs that are caused by urban sprawl. This can occur in spite of a disciplining effect on local public finances (Feld and Kirchgässner, 2001), due to asymmetric urban development among municipalities.

6.1.3. Third Paper

The Swiss planning system allocates a scarce resource – land for urban development. To better grasp the influence of scarcity on land development, the third analysis (chapter 5) investigates the impact of land scarcity on urban growth, differentiated into the growth of per capita land consumption (PCLU), the growth of spatial extent of settlement areas (SE), and the growth of building density in residential areas (BD). The analysis is confined to the Canton of Zurich, as data depicting the amount of designated built-up area per municipality is only available for that jurisdiction. The models are set up as cross-sectional, measuring a twenty years' time span (1990 to 2010) and control for spatial correlation in the data, including the identification of direct and indirect spatial effects.

Not surprisingly, the results show that land scarcity hinders both a further extension of per capita land uptake and of the settlement area, and fosters the density in building areas. This means that in municipalities with larger areas left for construction, densification dynamics could be undermined by the tendency to grow outwards rather than inwards and upwards. In that, the results are similar to a study carried out for the entire area of the Netherlands, where the authors find evidence that the higher the share of land assigned to residential expansion in a region, the lower the share of densification (Broitman and Koomen, 2015).

A second aim of the research was to integrate the fact that settlement structure can be considered as an amenity (Strong and Walsh, 2008), and that different settlement structures are valued differently by people. For example a study by Irwin (2002) showed that the value paid for a view over open countryside increased with the probability that the countryside in question would not be built on in the future. In particular, the third analysis investigated whether the influence of land scarcity on urban growth is different, according to how affluent the inhabitants of a municipality are. The assumption was that affluent people, who have both the capacity to pay for the amenity of living in a low-density neighbourhood and equally the willingness to protect the neighbourhoods' status quo, might act against further densification activity (Brueckner et al., 1999; Fischel, 2001). The results give evidence that for municipalities with affluent inhabitants, land scarcity does not provide sufficient incentive to reduce land consumption, to limit the growth of the settlement area or densify within the residential areas. Such a diametrical development of urban growth related to the affluence of residents could raise several public policy concerns and, if unsolved, lead to equity and efficiency implications concerning both urban and social development.

6.2. General Conclusions

This thesis considers (recent) urban development in Switzerland – often regarded as unsustainable and referred to as urban sprawl – and explains how that development can be linked to socio-demographic factors. Moreover, it illustrates how land consuming spatial development belongs to broader national shifts such as rising affluence, improving accessibility, structural changes with ongoing shrinking of agriculture, and social and demographical changes such as the increasing share of elderly people and equally increasing share of one-person households. But the thesis also makes the case that a better understanding of how certain processes function helps explain how these general trends play out spatially.

In this context, the three following topics will be discussed. Accessibility which plays an important role, on the one hand as a determinant of urban growth, on the other hand because the level of accessibility moderates e.g. how municipal differences in tax shape land uptake. Second, whether population growth results in a land consuming spatial pattern which seems to be context dependent. Finally, the local effect of scarcity of land for construction is dealt with; promoting densification of urban areas in the light of growing demand, yet scarcity of offer, might have unwanted regional consequences.

First, improving accessibility in Switzerland is a task of both the regions and municipalities but also of the national administration (Frohlich et al., 2005). According to the population weighted accessibility variable used in the analysis (Tschopp and Fröhlich, 2006), the cities, followed by the agglomerations, have the highest rates of accessibility. Furthermore, the accessibility of municipalities located in agglomerations has been improved over the timespan considered in the analyses, which has increased the number of municipalities from which easy access to the nearest city is provided. In the analyses carried out in this thesis, accessibility is a prime determinant of changes in urban structure. However, the analyses also show evidence that when the accessibility in a municipality is very high – e.g.

the main cities – , a “saturation effect” can take place where an increase in accessibility will no longer have a large influence on urban structure, such as growth of per capita land consumption (see Chapter 4). The presence of a certain “saturation effect” was noted as early as 2008, in a study on accessibility and the willingness to commute in Switzerland, Fröhlich (2008): at a certain point, further improvement of the accessibility has a decreasing impact on the willingness to commute. Similar results are shown by Tschopp (2007) in a study on the correlation between accessibility change and population change. Tschopp finds that the positive correlation between these variables is lessening over time. As Axhausen (2008) confirms, these saturation effects are most pronounced in those parts of the country which started with relatively high levels of accessibility.

In order to curtail undesired future settlement developments, the consideration of the current level of accessibility could help to find indications of which regions are prone to which form of urbanisation (Wissen Hayek et al., 2011). The implication would be that accessibility, as an instrument of spatial planning but also as a factor influencing spatial planning, must be considered as much more powerful in certain regions as is probably the case today, and less powerful in others (cf. 6.4. practical implications). Hence, once again, coordination of planning and transportation systems remains particularly important for influencing spatial development.

Second, between 1980 until the end of 2016, the Swiss population grew from around 6.4 to 8.4 million inhabitants. The population growth rate is 1.2% for the period 2011–2015, which makes Switzerland one of the few growing regions in Europe (World Bank, 2016). Furthermore, forecasts predict a further population growth of around 1 to 2.5 million until 2045 (SFSO Swiss Federal Statistical Office, 2016a). Against this background, population growth and its influence on settlement structure has been the subject of public and political discussion. In 2014, for example, the two popular initiatives “against mass immigration” and “ecopop” were submitted to the voters, both aimed at the reduction of population growth due to immigration. Whereas the first initiative “against mass immigration” was accepted by a tight majority, the second one, called “ecopop” (cap on immigration), was rejected. Among others, both initiatives used the argument of urban sprawl as a consequence of population growth.

How is population growth linked to urban growth and urban sprawl in the literature? For a long time, the relationship seemed to be established that population growth is indeed a main driver of urban growth (Brueckner, 2000c). Similarly other studies, mainly in the U.S. context, confirmed a positive relationship as shown by McGrath (2005) Paulsen (2012) Spivey (2008) or Wassmer (2008). However, several other authors empirically confirmed observations that in certain areas urban growth (measured as expansion of urban areas) had been at a higher rate than their population growth warranted. Burchfield et al. (2006) suggest that cities with a historically high population growth sprawl less, but that sprawl is promoted the greater the uncertainty regarding the future population growth is. Catalán et al. (2008) find that between 1993 and 2000, the Barcelona Metropolitan Region urban growth (developed area) was six times larger than its population growth. Mann (2009) established a negative relationship between the number of inhabitants and the residential building area (m^2) in Switzerland.

Although the popular assumption is that sprawl is driven by an increasing number of households the results of this thesis give evidence that the relationship between population growth and urban growth in the Swiss context is more complex and depends on the regional context and the time span considered. A very plausible example of how a growing population can lead to a denser urban structure – and thus the opposite of sprawl - are cities like Geneva, Zurich or Bale after 2000. On the other hand, in so-called shrinking cities (Martinez-Fernandez et al., 2012), the loss in population and working places leads to lower utilisation of the present built-up area. Since housing and infrastructure are rarely dismantled, a negative population growth results in an urban structure considered as sprawl. Further complicating the relationship between population growth and urban settlement structure is the fact

that construction and allocation of housing space can trigger population growth, as explained in more detail in Chapter 3, and thus reverse the causality. Furthermore, demands on space are changing not only because of demand for space for living but also e.g., for sports, leisure and health activities (ARE and ETHZ, 2008).

In this light, it seems important to think about the dynamics of population growth and urban growth not as a linear process that leads to higher land uptake and urban sprawl. The insights of this thesis raise the proposition that sprawl is occurring not only because more people need a place to live but also because of where and how people choose to live, which is linked to accessibility and their income. In this regard, Cheshire et al. (2014) stress that what really is increasing the demand for houses, is not the number of households but rising income. The results of this thesis rather support one dimension of this statement namely that affluent municipalities – in terms of affluence of their inhabitants – favour land consumption and thus urban sprawl.

Finally, the thesis also considers the fact that people have preferences for certain urban structures – namely low density - and that the means to pursue these preferences influences spatial urban structure. As explained in much more detail in Chapter 5, people will pay through the housing market for nicer neighbourhoods endowed with amenities. As the supply of housing is limited in these neighbourhoods, access to a better neighbourhood can be capitalised in land and housing prices (see e.g. Hilber, 2015). In addition, any planning policy – intended to steer urban growth into a more sustainable, compact form – shortens the supply of land for construction, which - in attractive neighbourhoods - seemingly increases the value of low density urban structure. Furthermore, municipalities may actively set a low maximum coefficient of utilisation ("Ausnützungsziffer") to attract better-off taxpayers who can afford a less-intensive use of land (Hilber and Schöni, 2016; ZKB, 2008). This thesis (see especially so Chapter 5), provides evidence that densification – which is promoted by planners as sustainable growth but is not appreciated by large parts of society – could be avoided by affluent households. In the worst case, this condition can create a certain tendency where the success of affluent municipalities or regions in reducing future growth within its own boundaries merely shifts that growth to somewhere else, e.g. to the urban fringes. In other words, if growth is unwanted, then local growth-limiting policies could become a 'beggar-thy-neighbour' strategy, shifting the possibly harmful implications of urban growth somewhere else, most probably without regard to its consequences there.

As the authors of the final report of the NFP 54 program sustainable development of the built environment already concluded in 2011, high-income, mobile households profited more from the urban development of the recent years, leading to improvement in the quality of the area they live in. Families and low-income households are driven out of the inner cities, and in general, socio-demographic challenges (such as gentrification) are underestimated (SNSF, 2011). In this regard, it seems important to focus on forms of densification that are socially acceptable and attractive for households (cf. 2.2.3).

Even as the evidence base improves, urban planning remains challenging. The results of the thesis provide evidence for helping address some of the challenges but they certainly do not provide all the answers necessary.

6.3. Methodological aspects and future research directions

A methodological issue - endogeneity - as well as two fundamental questions, a) the discrepancy between preferences for and resentments against sprawl, and b) the cost of sprawl, warrant discussion in order to guide future research efforts.

First, any analysis of urban growth and urban structures is complicated by an endogeneity problem because urban growth and urban structure can be the cause and the consequence of factors such as population growth or accessibility (see e.g. Duranton and Puga, 2013). In the analyses of this thesis, the problem is tackled by a) time lagging the independent variables (Papers I, II and III, Chapter 3, 4, 5) and b) by employing in addition a two-stage estimation (Paper II, Chapter 4). However, endogeneity and the unclear direction of causality can be tackled separately and explicitly with methods such as instrumental variable regression or spatial and temporal lag specification based on e.g. network theories. Based on the insights of this thesis and related subprojects of SPROIL (NFP 68, www.nfp68.ch), a next step could be a more integrated model approach, including socio-economic but also political as well as topographic and geographic explanatory factors. Such a model could aim at explaining urban growth and urban sprawl with a unit of analysis at a very low level (below a hectare), embracing multilevel techniques and explicitly tackling various endogeneity problems from the beginning. However, a different, probably promising approach could also be to compare regions. The results of this thesis can help for the identification of appropriate case study regions that allow a comparative examination of some of the suspicions produced in this project by applying more qualitative methods to trace back causal processes. Such a study area could include a comparison between a region or municipality where the rate of accessibility experienced an exceptional change in the last decades, with a control region. One such study is a report commissioned by the Federal Office for Spatial Development (FOSD) which evaluates the impacts of the Lötschberg Basistunel (a 34 km long tunnel under the Alps, connecting the northern and southern part of Switzerland) on the regions concerned, four years after the opening of this tunnel. In this report, the increase in accessibility on the settlement growth in the region of Brig-Visp-Naters is estimated to be only marginal (Ernst Basler + Partner, 2012). However, evaluating the impact on the region again in some years' time could reveal information on (reversed) causality between accessibility, population growth, and urban growth.

Second, the current state of urban growth in Switzerland is characterised by a discrepancy between people's preferences and tastes for housing that foster land consumption, and a simultaneously growing resentment against current urban growth considered to be sprawl. Hence, a central question to be better investigated is why households continue to reveal preferences that foster such sprawling development despite the aversion to sprawl? In short, Swiss citizens place high value on the natural environment of their country, while at the same time triggering urban development. Being aware of this contradiction is important when interpreting the current sprawl of urban development as the fulfilment of resident's preferences (Downs, 1999), while compact and dense urban structures, that are promoted by planners, cause resistance among the residents (Evans and Unsworth, 2008; Geoghegan, 2002). It is agreed, for example, that there is consumer demand for single family low density housing (Moura et al., 2015) and that this preference changes with household size and level of income. While the effect of such demands has negative externalities, these cannot be adequately addressed if the underlying factors that produce them are ignored. In such a case it is hard to formulate policies to make people not foster sprawl. Furthermore, there is a lack of understanding how consumer demand is altered by governmental interventions that facilitate or even guide the sprawl-relevant choices of households, e.g. by public subsidies such as the deductions to income tax through home ownership. More generally, and as Glaeser states in the preamble of a book on urban policies by Cheshire, Nathan and Overman (2014), it is impossible to implement wise policies without anticipating how those policies will alter human behaviour.

Third, while it is agreed that sprawling urban development causes many direct and indirect societal and environmental harm (cf. introduction), little empirical work has been undertaken to evaluate the effective cost and benefits of decentralised urban growth. Expanding municipalities, for example, have to deal with potential loss of

agricultural land, a dissection of local ecosystems, or the diminishment of aesthetic benefits (Brown et al., 2005; Coisnon et al., 2013; Crane, 2008; Lopez and Hynes, 2006; Wissen Hayek et al., 2011). Furthermore, as Carruthers and Ulfarsson (2003) or Hortas-Rico and Solé-Ollé (2010) point out, urban sprawl increases the level of expenditure, as it may raise the provision costs of certain local public goods and requires greater investment in extending basic infrastructures for new urban development located on the urban fringe. In Switzerland, e.g. Pflieger and colleagues (2011) demonstrated that the annual costs of water provision per capita in the agglomeration of Lausanne costs 2.5 to 3.5 times more in less densely populated areas than in dense areas. These differences mainly result from economies of scale related to maintenance costs. A report for the attention of the Federal Office for Spatial Development (FOSD) comes to similar conclusions that outward urban growth – in contrast to inward growth, that is densification – causes multiple costs for infrastructure (Ecoplan, 2000a). Despite those few examples, much of the disagreement on the costs of sprawl is probably due to the lack of empirical evidence. Chin (2002), e.g. does not only express doubts about the lack of empirical work and consistency in methods of measurements of costs of urban sprawl, but further clarifies that an understanding of the impact of urban sprawl would be aided by making greater distinction between the types of sprawl, similar to the different dependent variables used throughout this thesis. This would certainly contribute to a comparison of alternative urban forms with each other. Ewing (1997) points out the difficulties in measuring costs; while it is established that negative impacts of urban sprawl exist, it is hard to tie them directly to sprawl as causal factors. This is because many of the costs are the costs of modern urban living, regardless of urban form. Despite those difficulties, models that take into account the costs of urban growth are warranted and such analysis should also add to inform future policy recommendations.

6.4. Practical implications

This doctoral thesis has focused on the evaluation of socio-economic determinants of urban growth, in order to contribute to the question of how to better steer urban growth to make it more sustainable. Therefore, practical recommendations addressed to planning policy makers and decision-makers are summarised in the next paragraph. Three subjects, all having a certain relevance in Switzerland at the moment, are discussed: the upgrade of public infrastructure, agglomeration programs, and compensation payments and redistribution mechanisms between municipalities.

In 2014, the Swiss voters approved a long-term strategy to finance and upgrade rail infrastructure (FABI). Part of the strategy is a development programme including e.g. half-hourly train services from Zurich to Lugano, or the expansion of S-Bahn services around Bern, Basel and Geneva. In the light of the forthcoming improvement of transport infrastructure, and thus accessibility, it appears crucial to simultaneously clarify and tackle the impacts on urban development in the regions and municipalities concerned by such improvements. As the results of the analyses indicate, in municipalities that are highly accessible, yet not fully urbanised (e.g. in terms of a lower percentage of built-up area in comparison to central cities or a higher share of construction land), an unintended impact of increasing accessibility will likely result in an unwanted growth of urban settlement structure, namely a land consuming, sprawling development. Thus, it is particularly in those areas where incentives and prescriptions for higher density should be implemented. As the expert on planning Gaëlle Pinson concludes in an extensive report on Spatial planning in Switzerland in 2008 (ARE and ETHZ, 2008), spatial consequences of sector policies – such as transport infrastructure policies – usually have more impact on space than spatial policies per se. Thus, for example in the case of FABI, it would be important to involve urban planners and actors concerned with the issue early enough in the planning process to enable prudent planning. This recommendation is strongly backed by the results of this thesis which highlight the importance of accessibility as a determinant of urban growth and changes in urban

settlement structures. In addition to strengthening the connection between spatial planning and infrastructure policies, spatial planning should also be more closely associated with other space-related policies, such as housing policies or mortgage lending policies.

Traditionally, cities and city-regions have not had any special role within the vertical federal Swiss system (federation, cantons, municipalities), and metropolitan regions or agglomerations had rarely any competence in spatial planning (Kübler, 2003). However, since 2007 attempts to implement planning cooperation exist with the so-called agglomeration programs. The programs enable agglomerations to draft their own transportation and urban development programs and to avail themselves of federal programs for funding transportation-related infrastructure projects. The outcome of this thesis clearly supports the strengthening of spatially connected greater administrative entities, such as regions or agglomerations. For example, in all of the analyses, the importance of spatial interdependence between the municipalities was a major factor; urban growth and urban structures in one municipality are not independent of changes of factors in neighbouring municipalities. In the Canton of Zurich, for instance, increasing land scarcity in one municipality will also hinder the outward growth of built-up areas in the surrounding municipalities (cf. chapter 5). Furthermore, the outcome of this thesis supports the strengthening of functionally defined administrative entities, in particular regions that are equally accessible from the centres whether the mode is fast or slow. Analysis II (cf. chapter 4), for example, gives evidence that whether low local taxes fosters or hinder the level of land consumption in a municipality depends also on the degree of accessibility (public and private transportation). Thinking about municipalities in functional terms (such as dividing them into accessibility classes) could be an approach to better anticipate how future spatial development will evolve. This would also mean that in regions like Lausanne, Zurich or Bale and their agglomerations, spatial planning must function differently from spatial planning in remote areas like certain valleys of Ticino or Grison, the central cities and the rural alpine regions being the two extreme ends of the scale. As a last remark regarding the agglomeration programs, and in the light of the considerable leverage of accessibility on spatial development as described above, it seems also important that the agglomeration programs are not merely programs to improve infrastructure but are used as actual instruments to steer sustainable settlement development.

Last but not least, a key principle of spatial planning – if not the most important - is to balance interests. The task of policy makers and planners is to establish a qualitative balance between built-up space and undeveloped areas. There is, for example, a major acceptance of landscape conservation, nature conservation and agricultural areas. However, and in contrast to that acceptance, there is also the ongoing trend of land consumption by individuals. As a means for planners to establish a balance between built-up- and undeveloped areas, densification seems inevitable, and, as such, is an important pillar of the future spatial development in Switzerland (cf. 2.2.3). Yet, when implementing densification any planning policies should take into account people's preferences of where and how to live (see 2.2.3.). For example, Conedera et al. (2015) stress the importance of proximity of urban green spaces and advocate for more such spaces especially in residential areas that lack private or gardens shared with others. However, even with carefully planned densification efforts, there will be winners and losers from planning policies. Important seems to be that gains for the winners should outweigh losses for the losers, as stated by Cheshire, Nathan and Overman (2014). Further, as seen especially in the third analysis (chapter5), the spatial distribution of these gains and losses is complex and plays out across the urban system in ways that are far more nuanced than would be suggested if we focussed only on what is happening to a single municipality. One - already ongoing - process that will help to balance out certain spatial developments is the fusion of local authorities. Furthermore, with regard to the strength of planning at the municipal level, it would be important for the cantons and the federal state to also highlight in their communication strategies the collective impact of actions of municipalities. Finally, in Switzerland, fiscal equalisation

mechanisms have a strong tradition. Since 2013, the Swiss cantons are obliged to levy a surplus value tax on gains resulting from local zoning decisions ("Mehrwertabschöpfung"). By federal law, the money has to be used to either compensate owners of private property for revoked or modified building rights or to "promote sustainable urban growth", in other words, to promote a form of densification that is socially acceptable. One way for the cantons to use this money could be investing it in such a way as to balance benefits and costs of land consumption for the inhabitants. Such additional redistribution would have be earmarked for land use planning and urban development projects (i.e. establishment of green spaces, public meeting points). This would help to increase incentives for better designed densification, by supporting planning and implementation capacities as well as revoking building zones — and hence withdrawing certain land from the urbanisation process.

6.5. References

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Appendix

Chapter 7: Gründe für die Zersiedelung der Schweiz: Die sozioökonomischen Treiber der Siedlungsentwicklung 1980-2010

Abstract

Die Siedlungsfläche der Schweiz nimmt laufend zu, wenngleich das immer knappere Gut Boden nicht vermehrbar ist. Deshalb muss die haushälterische Nutzung von Boden ein Grundpfeiler nachhaltiger Raumentwicklung sein und der entsprechende Verfassungsauftrag (Art. 75) eingelöst werden. Der vorliegende Beitrag befasst sich mit den sozio-ökonomischen Treibern der Raumentwicklung in der Schweiz.

7.1. Einleitung

Dieser Beitrag ist wie folgt aufgebaut: zunächst wird erläutert, inwiefern die Siedlungsentwicklung der Schweiz nicht nachhaltig ist, dem folgt ein Überblick über aktuelle Debatten zur Raumentwicklung. In einem nächsten Teil wird die historische Siedlungsentwicklung in der Schweiz kurz beleuchtet, dies mit einem speziellen Fokus auf die Zersiedelung. In einem dritten Teil werden dann Ergebnisse einer Studie präsentiert, in der wir sozio-ökonomische Treiber von Siedlungsentwicklung identifiziert und analysiert haben. Der Beitrag endet mit einem Fazit. Wir hoffen, mit den hier präsentierten Ergebnissen Anstösse für die weitere Debatte rund um die Raumplanung in der Schweiz geben zu können.

7.1.1. Mangelnde Nachhaltigkeit der Siedlungsentwicklung

Die Schweiz erlebt seit Jahrzehnten eine rasante Siedlungsentwicklung. Hat die Bevölkerung zwischen 1985 und 2009 um 17.5% zugenommen, verzeichnen die Siedlungsflächen in der gleichen Zeit eine Zunahme um 23.4% und der Anteil Siedlungsfläche an der Gesamtfläche der Schweiz ist im gleichen Zeitraum von 6.0% auf 7.5% gestiegen (BFS 2013b). Diese Diskrepanz zwischen Bevölkerung- und Siedlungswachstum läuft dem 2002 formulierten Nachhaltigkeitsziel des Bundesrates, den Verbrauch an Siedlungsfläche pro Einwohner bei 400 Quadratmetern pro Kopf zu stabilisieren, entgegen. Mit den neusten Auswertungen der Arealstatistik ergibt sich sogar eine Flächenzuwachs von 400.9 m^2/Kopf (1992/1997) auf 406.9 m2/Kopf (2004/2009) (BFS 2013b).

Die mangelnde Nachhaltigkeit der Siedlungsentwicklung hat die Debatte um die Wirksamkeit der Raumplanung neu entfacht: dies zeigt das Beklagen von Landschaftsverschandelung, von verdichtetem Bauen oder dem Umfang der

Erschliessung durch private und öffentliche Infrastruktur und einhergehend auch die Sorge um den Verlust von Naturlandschaften und damit der Biodiversität. Forderungen nach einem schonenden Umgang mit der unbebauten Landschaft stossen bei der Stimmbevölkerung inzwischen auf Wohlwollen, wie das Ja zur nationalen Zweitwohnungsinitiative 2012 oder auch zur Teilrevision des Raumplanungsgesetztes von 2013 zeigen. Letztere wurde mit 63% Zustimmung angenommen und zielt durch die Förderung einer kompakten Siedlungsentwicklung, die Verkleinerung der zu grossen Bauzonen und der Nutzung von brachliegendem Bauland noch stärker auf eine haushälterische Nutzung des Bodens ab.

7.1.2. Aktuelle und kommende Debatten der Raumentwicklung in der Schweiz

Weniger im Fokus der Öffentlichkeit als die Siedlungsfläche stand bisher die Betrachtung der Landschaft als Ökosystem und die Rolle des Bodens als Produktionsfaktor für die Land- und Forstwirtschaft. Dieses Thema ist insofern stark mit der Siedlungsdebatte verknüpft, als zwischen 1985 und 2009 54,5% der aufgegebenen Landwirtschaftsflächen zu Siedlungflächen umgenutzt wurden, die übrigen 45.5% wurden zu bestockten und unproduktiven Flächen, und umgekehrt rund 90% der neuen Siedlungsflächen im gleichen Zeitraum auf vormaligen Landwirtschafsflächen entstanden (BFS 2013b). Spätestens seit der Lancierung der Initiative für die Ernährungssicherheit (2016), welche das Thema von schützenswertem Landwirtschaftsland auf nationaler Ebene aufgreift, wird aber auch die Diskussion um Umnutzung von Landwirtschaftsfläche breiter geführt.

Nebst ökologischen und ästhetischen Wirkungen gibt es auch direkte ökonomische Implikationen des Siedlungswachstums: Beispielsweise die anfallenden Kosten für den Bau und Unterhalt von Strassen, Wasserversorgung, Stromnetz und Abfallentsorgung, der höhere Energieverbrauch pro Kopf und der Anteil ungedeckter Kosten im öffentlichen Verkehr, die bis heute weitgehend von der Allgemeinheit getragen werden müssen. So schätzt eine umfassende Studie von 2015 für die USA , dass die dortige zersiedelte Bauweise der U.S. Wirtschaft gut 1000 Milliarden pro Jahr kosten (Litman 2015). Für Kanada wird in einer Studie von 2013 zumindest von mehrstelligen Milliardenbeträgen ausgegangen (Thompson 2013).

In der Schweiz, deren Siedlungsstruktur zweifelsohne nicht mit jener Nordamerikas vergleichbar ist, fehlen solche generellen Kostenschätzungen weitgehend; gleichwohl gibt es empirische Analysen, welche den Zusammenhang zwischen Siedlungsentwicklung und Infrastrukturkosten aufzeigen. So zum Beispiel eine Studie im Auftrag des ARE von 2000, welche die kostensteigernde Wirkung einer dezentralen Siedlungsstruktur bestätigt (Ecoplan 2000; siehe auch Pflieger & Ecoffey 2011).

7.1.3. Beitrag aus der aktuellen Forschung

Vor diesem Hintergrund stellen sich im Umgang mit Boden und Raum verschiedene Fragen: Wie soll die Schweiz in den kommenden Jahrzehnten aussehen? Wie organisieren wir unser Zusammenleben und wie die Verkehrs- und Pendlerströme? Wer setzt welche Prioritäten? Die Grundsatzfragen werden auf verschiedenen Ebenen verhandelt. Bund, Kantone, Regionen, Städte und Gemeinden entwickeln Vorstellungen und Strategien zur Entwicklung ihres Raums, aber auch von privater und politischer Seite werden substanzielle Diskussionsbeiträge erbracht. So ist der vorliegende Beitrag ein Resultat der laufenden Forschung aus einem Modul des Projekts ‚Sproil'

(Siedlungsentwicklung steuern – Bodenverbrauch verringern), welches durch das NFP 68[7] zum Thema Ressource Boden finanziert wurde. (Weilenmann et al., 2017)

Unter Berücksichtigung aller 2495 Gemeinden in der Schweiz (Gemeindestand 1.1.2012) haben wir Daten für die Perioden von 1980 bis 2010 ausgewertet. Die Auswertungen basieren auf einem sogenannten räumlichen Regressionsmodell, welches es erlaubt, für jede Gemeinde die Entwicklung der Siedlungsstruktur in den je umliegenden Gemeinden als einen zusätzlichen Erklärungsfaktor zu berücksichtigen. Detailliertere Ergebnisse sind in der Publikation von Weilenmann et al. (2016) zu finden.

7.1.4. Siedlungsentwicklung messen und Zersiedelung quantifizieren

In der Raumplanungsdebatte wird häufig der unscharfe Begriff Zersiedelung verwendet, um ein ungeregeltes, schnelles und scheinbar unstrukturiertes Wachstum von Siedlungsfläche in der Landschaft zu beschreiben. Dazu kommen jedoch historisch gewachsene Siedlungsflächen wie Streusiedlungen, Weiler und Aussenwachten. Zersiedelung zu quantifizieren, also mess- und somit auch vergleichbar zu machen, ist damit ähnlich schwer wie Zersiedelung qualitativ zu definieren.

In dieser Studie verwenden wir eine Messgrösse, die gewichtete Zersiedelung, welche im Rahmen des NFP Programms 54 von Jaeger et al. entwickelt wurde und heute auch vom BAFU und ARE verwendet werden (Jaeger et al. 2008, 2010; Schwick et al. 2011). Jaeger et al. (2008, 2010) beschreiben Zersiedelung als eine gewichtete Funktion von Ausnützungsdichte, Flächeninanspruchnahme und Dispersion von Siedlungsfläche (siehe Box I) und integrieren damit unterschiedliche Aspekte von Siedlungswachstum in einer Messgrösse. Figure 11 zeigt die historische Entwicklung der drei Messgrössen und des daraus resultierenden Wertes für die gewichtete Zersiedelung in der Schweiz.

BOX I: Zersiedelung quantitativ gemessen nach Jaeger et al. (2010)

Die gewichtete Zersiedelung wird gemessen als eine gewichtete Kombination von

a) Anteil überbauter Fläche[a], die Flächeninanspruchnahme
b) Dispersion der Gebäude innerhalb der Fläche
c) Ausnützungsdichte (Arbeitsplätze und Wohnungen) der überbauten Fläche

Der Wert der gewichteten Zersiedelung ist umso höher…

a)… je mehr Fläche überbaut ist
b)… je weiter gestreut die Gebäude in der Landschaft liegen
c)… je geringer deren Ausnützungsdichte ist

[a] als grundsätzlich überbaubar eingestufte Fläche der Gemeinden (abzüglich Gewässer, Wald, steile Gebiete etc.).

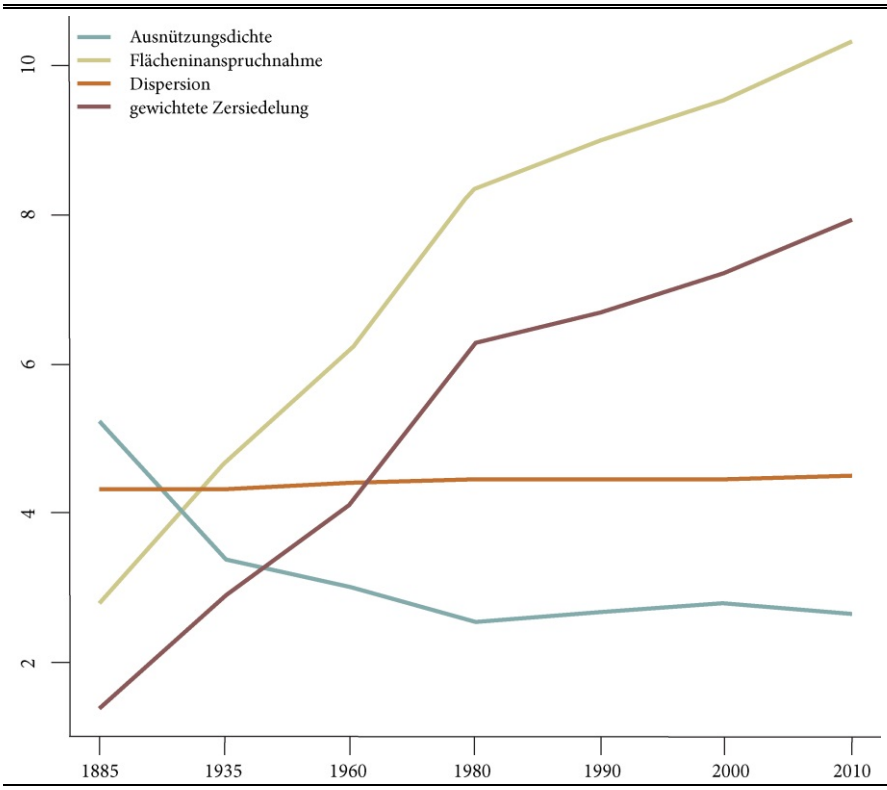
7.1.5. Historische Betrachtung der Siedlungsentwicklung

Die historische Betrachtung der vier Messgrössen der Siedlungsentwicklung (Ausnützungsdichte, Flächeninanspruchnahme, Dispersion und der resultierende Wert der gewichteten Zersiedelung) (Figure 11), zeigt

[7] In den Nationalen Forschungsprogrammen (NFP) werden Forschungsprojekte durchgeführt, die einen Beitrag zur Lösung wichtiger Gegenwartsprobleme leisten. Die Themen sind jeweils vom Bundesrat ausgewählt.

einerseits eine bis in die 1980 Jahre fast lineare Zunahme der überbauten Fläche, die erst 1980, mit dem Inkrafttreten des Raumplanungsgesetztes sichtbar gebremst wird, aber dennoch weiter ansteigt. Wie die fast parallele Entwicklung der gewichteten Zersiedelung erkennen lässt, sind diese beiden Grössen stark miteinander korreliert.

Figure 11: Entwicklung der vier Messgrössen von Siedlungsentwicklung in der Schweiz, 1885 bis 2010



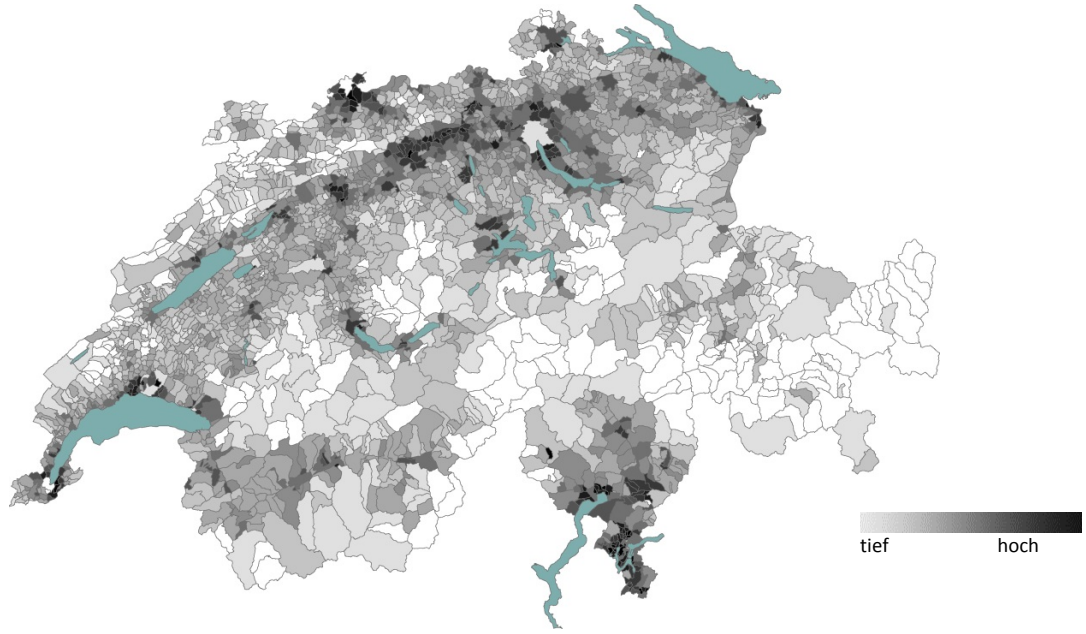
Quelle: Jaeger & Schwick, 2014, Abbildung: Eigene Darstellung

Die Ausnützungsdichte wies 1885 den höchsten Wert auf und nahm bis in die 1980 Jahre konstant ab, dann aber bis 2000 leicht zu. Dies reflektiert die Tatsache, dass früher die Siedlungen viel dichter gebaut und effizienter genutzt waren. Die Dispersion der Gebäude in der Landschaft ist die konstanteste Variable und scheint sich seit Ende des 19. Jh. wenig verändert zu haben, dabei ist ein leichter Aufwärtstrend auszumachen.

7.1.6. Wie zersiedelt ist die Schweiz?

Um sich ein Bild der aktuellen Situation auf Gemeindeebene machen zu können, sind in Figure 12 die Werte der gewichteten Zersiedelung für 2010 (die aktuellsten verfügbaren Daten) abgebildet: je dunkler eine Gemeinde, desto höher ihr Grad an Zersiedelung. Die Karte zeigt, dass nicht nur die mittelländischen Agglomerationen um die grossen und einzelne mittlere Städte, sondern auch der Süden und der Südwesten der Schweiz stark zersiedelt sind. Auffallend ist jedoch der tiefe Wert der Kernstädte (Zürich, Genf, Basel, Lausanne, Bern), was auf die starke Verdichtung und damit eine hohe Ausnützungsdichte zurückzuführen ist. Hohe Ausnützungsdichten in Städten spiegeln sich in der Bevölkerungsdichte wider: In den schweizerischen Agglomerationen (gemäss Statistik leben dort 75 Prozent der Bevölkerung) liegt die Bevölkerungsdichte bei 614 Einwohner/km^2, im urbanen Kanton Basel-Stadt sind es z.B. 5236 Einwohnern/km^2.

Figure 12: Zersiedlungsindex 2010 für alle Schweizer Gemeinden



Quelle: Jaeger & Schwick, 2014, Abbildung: Eigene Darstellung

7.1.7. Sozio-ökonomische Treiber der Zersiedelung

Gestützt auf theoretische Überlegungen sowie Verfügbarkeit geeigneter Daten (seit 1970 gemeindespezifisch erhoben) berücksichtigen wir in unserer Regressionsanalyse die folgenden Variablen um die Zersiedelung zu erklären: Bevölkerungswachstum, Bundessteuerertrag pro Kopf (als Annäherung an Reichtum), Erreichbarkeit (öffentlicher Verkehr & Individualverkehr) der Gemeinde, Zu- und Wegpendlerquote, Anteil Wohneigentümer (nicht differenziert nach Stockwerkeigentümer/Einfamilienhausbesitzer), Anteil über 65-Jähriger pro Gemeinde, Anteil Einzelhaushalte pro Gemeinde, Angestellte des 1. und 3. Sektors sowie Veränderung der Angestellten des 1. Sektors in den letzten 10 Jahren. Weiter identifizieren wir ländliche und Agglomerationsgemeinden, Kantonszugehörigkeit, Metropolregionen und Raumplanungsregionen sowie einige Besonderheiten wie die Zentrumsfunktionen einer Gemeinde (Schuler et al. 2005).

7.1.8. Demographisches und ökonomisches Wachstum sowie ändernde Ansprüche

Wir können mit unseren Variablen nicht alle Messgrössen der Siedlungsentwicklung (Ausnützungsdichte, Flächeninanspruchnahme, Dispersion und gewichtete Zersiedelung) mit gleich gutem Ergebnis erklären. Gleichwohl: Die Erhöhung der Ausnützungsdichte wird durch das Modell über die drei Dekaden (1980-2010) zunehmend besser erklärt, nämlich 65% der Varianz 1980 und 75% der Varianz 2010, bei der Flächeninanspruchnahme und der gewichteten Zersiedelung sind es jeweils über 75% der Varianz über alle Dekaden. Allerdings können bei der Dispersion nur rund 30% der Varianz über den gesamten Zeitraum der Messungen hinweg erklärt werden. Diesen letzten schlechteren Wert erklären wir damit, dass die Dispersion der Gebäude in der Landschaft v.a. durch Topographie und andere natürliche Gegebenheiten bestimmt sein dürfte, welche wir im Modell nicht berücksichtigen, da wir uns auf sozio-ökonomische Variablen konzentrieren. Die steigende Flächeninanspruchnahme und Ausnützungsdichte der Fläche in den letzten Jahrzehnten sind dagegen auf ein Wachstum demographischer und vor allem ökonomischer Art zurückzuführen, welche unser Modell abbildet.

Unsere Ergebnisse zeigen auch, dass Bevölkerungswachstum alleine die Zersiedelung und den damit verbundenen Bodenverbrauch bis ins Jahr 2000 nur sehr unvollständig erklärt. Andere, mit dem Bevölkerungswachstum allerdings in Verbindung stehende Entwicklungen haben die Zersiedelung stärker beeinflusst, wie z.B. der Anstieg Personen über 65 Jahre. Auf diesen Zusammenhang gehen wir im übernächsten Unterkapitel noch genauer ein. Ermöglicht durch das stetig steigende Wohlstandsniveau kommen weitere Faktoren dazu. So ist die Zahl der Haushalte, im Vergleich zum Bevölkerungswachstum, überproportional gestiegen. Ebenfalls haben sich individuelle Ansprüche bezüglich Grösse der Wohnfläche und der Art des Wohnens - wir leben in immer grösseren Wohnungen und beanspruchen dazu pro Kopf mehr Wohnfläche - geändert. Eindeutig in unseren Ergebnissen ist schliesslich auch, dass wohlhabendere Bevölkerungskreise – gemessen an der Steuerbelastung pro Kopf - mehr Fläche in Anspruch nehmen.

7.1.9. Erschliessung ist zentral

Weiter zeigt die statistische Analyse, dass insbesondere die Erschliessung die Zersiedelung und damit den Bodenverbrauch voranzutreiben scheint. So ist der Zusammenhang zwischen Erreichbarkeit und Siedlungswachstums für alle drei Dekaden positiv: je erreichbarer eine Gemeinde vor 10 Jahren war, desto höher sind heute die Werte der vier Messgrössen der Siedlungsentwicklung. Dies heisst: gute Erschliessung verstärkt die Flächenausdehnung und die Zersiedelung und dies oft stärker als andere Faktoren wie Bevölkerungswachstum oder Einkommen. Es kann aber auch festgestellt werden, dass die Verdichtung primär in den besser erschlossenen regionalen Zentren erfolgt und erst mit einer zeitlichen Verschiebung die weitere Peripherie erreicht tendenziell also zuerst eine Flächenausdehnung und dann eine Verdichtung zu beobachten ist.

In unserer Analyse für die gesamte Schweiz unterscheiden wir nicht nach Art der Erschliessung (öV, pV), da die Ergebnisse für beide Erschliessungsarten sehr ähnlich ausfallen. In einem Regionen spezifischeren Model, welches zum Beispiel mehr auf die Unterschiede zwischen urbanen Gebieten, Agglomerationen und peripheren Regionen eingehen würde, wären Unterschiede wahrscheinlich ersichtlicher.

7.1.10. Ältere Leute belegen mehr Fläche

Unsere Auswertungen zeigen, dass mit dem Anteil Bewohner im Alter über 65 Jahre, der Flächenverbrauch, aber auch der Wert der gewichteten Zersiedelung pro Gemeinde steigt, während die Ausnützungsdichte sinkt.

Diese Ergebnisse sind schon für die Jahre 1980 und 1990 erkennbar und der Einflusses verstärkt sich sogar noch für die Periode 2000 bis 2010. Um die Resultate zu differenzieren, lohnt sich eine etwas genauere Betrachtung der räumlichen Verteilung von Personen über 65 pro Gemeinde: Für das Jahr 2010 fällt auf, dass der Anteil Personen über 65 Jahre in den Agglomerationen relativ tief ist (unter 15%), in den Kernstätten mit zwischen 15% und 20% höher und vor allem in den Alpengebieten mit über 20% hoch. Interessant ist ebenfalls die Entwicklung in den letzten Dekaden. So hat etwa der Anteil Personen über 65 Jahre in den Kernstädten zwischen 1980 und 2010 abgenommen. Insgesamt angestiegen ist hingegen der Anteil dieser Alterskategorie in den Agglomerationen. Die Agglomerationsgemeinden in denen der Anstieg über 10% lag, befinden sich auffallender Weise in den Kantonen Zürich, Basel und Bern um die Kernstädte verteilt. Dies ist möglicherweise auch die Folge der stetig steigenden Mietpreise in den Kernstädten wo die Bevölkerung aufgrund der Dynamik des Mietwohnungsmarktes und geringerer Eigenheimquote dem Druck steigender Immobilienpreise stärker ausgesetzt ist: der durchschnittliche Mietpreis in

den Zentren von 2000 bis 2014 um über 23% gestiegen, in den suburbanen Gemeinden aber nur um rund 21 % (BFS 2014).

Die Gemeinden mit dem höchsten Zuwachs an Personen über 65 Jahre sind aber in abgelegenen Tälern des Tessins und Graubündens zu finden, was mit der Abwanderung von jüngeren Leuten zu erklären ist. Eine GWR Analyse (geographically weighted regression), welche wir durchgeführt haben und die räumlich[8] spezifischere Ergebnisse liefert, zeigt dass der positive Zusammenhang zwischen dem Anteil an älteren Leuten und der gewichtete Zersiedelung vor allem in den Agglomerationen des Mittellandes, insbesondere auch um die Kernstädte (mit Ausnahme von Basel) überhaupt statistisch signifikant ist.

Auch wenn unsere Studie nicht spezifisch die Wohnsituation im Alter untersucht, sollten wir die Folgerung, dass ältere Leute die Zersiedelung fördern, in einem grösseren Kontext interpretieren. Wir vermuten, dass unsere Ergebnisse nicht damit zusammenhängen, dass ältere Leute mehr Fläche verbauen, vielmehr gehen wir davon aus, dass ältere Leute auch dann in ihren Wohnungen und Häuser bleiben, wenn sich die familiäre Situation geändert hat. So zum Beispiel, wenn die Kinder aus dem Haus ausziehen oder die Partnerin/der Partner in ein Pflegeheim muss oder verstirbt. Dann wird aus der ehemalig gut genutzten Wohnung ein Einpersonenhaushalt mit, im Vergleich zur früheren Situation, sehr hohen Flächenverbrauch pro Person. So ist der Anteil Einzelpersonenhaushalte ist mit über 45% in der Altersklasse 65+ höher als in allen anderen Altersklassen (BFS, 2013).

7.2. Fazit

Im Wissen darum, dass unsere Modelle nur einen begrenzten Teil der Wirklichkeit abbilden können und wir viele Themen, die direkt und indirekt mit der Siedlungsentwicklung zusammenhängen auslassen wie zum Beispiel die Raumplanungspolitik in den einzelnen Gemeinden, die Entwicklung von Hypothekarzinsen, Mieten und den Einfluss der Bauwirtschaft, möchten wir abschliessend einige Schlussfolgerungen für eine nachhaltige Siedlungsentwicklung ziehen.

Der Ausbaustandart von Verkehrsinfrastruktur und die damit einhergehende Erreichbarkeit stehen in einem komplexen Zusammenhang mit der Siedlungsentwicklung. Gute Erreichbarkeit ermöglicht eine Trennung verschiedener Nutzungen über längere Distanzen; so können Wohn- und Arbeitsort überhaupt erst räumlich getrennt werden. Gute Erreichbarkeit wirkt sich aber zum Beispiel auch über Wertsteigerung von Immobilien und Boden (siehe z.B. Ibeas et al. 2012) auf die Siedlungsentwicklung aus. Gleichzeitig stellt sich insbesondere beim Zusammenspiel zwischen Erreichbarkeit und Siedlungsentwicklung die Frage nach Ursache – Wirkung. Auch wenn unsere Studie diese Komplexität nicht vollständig abbilden kann, so gibt sie doch einen starken Hinweis darauf, dass eine bessere Erschliessung mittelfristig die Zersiedelung begünstigt. Dass die Raumplanung die Siedlungsentwicklung zunehmend mit der Verkehrsentwicklung koordiniert, ist demnach im Sinne der Ergebnisse unserer Studie.

[8] Die Ergebnisse der GWR Analyse sind räumlich spezifischer da für einzelne Gemeinden separate Regressionen geschätzt werden. Die statistische Unsicherheit ist jedoch so viel grösser, dass wir die Ergebnisse dieser Analyse nur ergänzend erwähnen aber nicht präsentieren.

Zersiedelung ist zu einem erheblichen Teil auch eine Folge des Lebensstils und viele Massnahmen daher wohl eher Symptombekämpfung. Einschneidende Massnahmen werden daher den Lebensstil betreffen und sind wohl eher unpopulär. Es braucht vermutlich auch noch mehr "weiche" Massnahmen wie Vorbilder und Informationskampagnen betreffend Wohnformen, Verkehrsverhalten usw. So könnte zum Beispiel auch die Debatte um altersgerechtes Wohnen stärker mit der Siedlungsfrage allgemein verknüpft werden.

Als letztes erwähnt seien hier die Ergebnisse des räumlichen Models, welche zeigen, dass die Zersiedelung stark von Entwicklungen in der grösseren nachbarschaftlichen Umgebung geprägt ist, und es daher angezeigt ist, in einem regionalen, nachbarschaftlichen Rahmen zu denken und zu handeln. Entsprechend werden zum Beispiel isolierte raumplanerische Massnahmen einzelner Gemeinden nicht unabhängig der Situation und den Entwicklungen in anderen Gemeinden einer Region wirken. Eine starke regionale Koordination in der Siedlungsplanung ist für eine nachhaltige Siedlungsentwicklung unabdingbar.

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Curriculum vitae

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Academic Education

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2015:	SNSF media-training for researcher, MAZ Lucerne
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2013:	Inferential Statistics, ECPR Summer School, Ljubljana (Slovenia)

Publications (outside PhD thesis)

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29th european regional science association Summer School (paper presented)	(Milano, Italy)3-10 July 2016
Forum für Wissen WSL "von der Siedlungsentwicklung zur Landschaftsgestaltung" (research presented)	(Birmensdorf) 1 December 2015
1st Swiss Real Estate Research Congress SRERC (paper presented)	(Zurich) 20 October 2015
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