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# Segregation of Residents with Tertiary Education in Sweden from 1990 to 2012

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There has been a dramatic increase in the number of people with tertiary education in Sweden, partly due to the governmental policy of making higher education more geographically available. In this study, we analyze how educational expansion and the governmental policy of offering tertiary education outside of old academic centers affected segregation patterns in 2012 compared to 1990. We analyze the spatial distribution of those with tertiary education using neighborhoods based on  $k$ -nearest neighbors and measure the segregation of residents with tertiary education using a multiscalar method. Additionally, we compare local labor market regions that include old, new, or no institutions of higher education. The results show an overall higher share of tertiary-educated people age twenty-five to sixty-four in all parts of Sweden in 2012 and a decrease in the levels of population-weighted mean segregation at all geographical scales. Segregation was mostly introduced on the city or city district level (for larger cities) and regional level rather than the neighborhood level. Segregation also decreased in all three types of labor market regions. The segregation patterns remained similar between 2012 and 1990, however, and a higher share of the population lived in segregated areas in 2012 compared to that in 1990. **Key Words:** educational segregation, higher education, multiscalar segregation, segregation, tertiary education.

在瑞典，接受第三级教育的人数有了显著的增加，此一现象部分是由于政府让高等教育在地理上更为可及的政策所致。我们在本研究中，分析教育扩张和提供旧有学术中心之外的第三级教育之政府政策，如何影响2012年相较于1990年的隔离模式。我们运用根据K邻近算法的邻里来分析拥有第三级教育者的空间分布，并以多重尺度方法测量拥有第三级教育的居民的隔离情形。此外，我们比较包含新、旧、或未包含任何高等教育机构的在地劳动市场区域。研究结果显示，2012年在瑞典各地，年龄介乎二十五岁与六十四岁、接受第三级教育者的总体比例更高，且在所有地理尺度中，人口加权后的平均隔离皆有所减少。隔离最常在城市或（更大的城市中的）城市行政区层级与区域层级发生，而非邻里层级。在所有三类劳动市场区域中，隔离皆有所减少。但2012年和1990年的隔离模式却仍相似，且2012年较1990年而言有更高比例的人口生活于受隔离的区域之中。 **关键词：**教育隔离，高等教育，多重尺度隔离，隔离，第三级教育。

Dramático ha sido el incremento del número de gente con educación terciaria en Suecia, en parte debido a la política gubernamental por hacer la educación superior más accesible geográficamente. En este estudio analizamos el modo como la expansión educativa y la política del gobierno de ofertar educación terciaria fuera de los viejos centros académicos afectaron los patrones de segregación en 2012 en comparación con 1990. Analizamos la distribución espacial de quienes usan la educación terciaria disponible en el vecindario, con base en el  $k$ -vecino más cercano, y medimos la segregación de los residentes con educación terciaria usando un método multiescalar. Además, comparamos las regiones del mercado laboral local que incluyen instituciones de educación superior viejas, nuevas o ninguna. Los resultados muestran en general una porción más alta de gente educada en el nivel terciario, con edades de veinticinco a sesenta y cuatro años, en todas partes de Suecia en 2012, y una reducción en los niveles de segregación media ponderada de la población a todas las escalas geográficas. La segregación fue introducida principalmente a nivel de ciudad o de distrito urbano (para las ciudades más grandes), y a nivel regional, más que a nivel de vecindario. La segregación disminuyó también en todos los tres tipos de regiones de mercado laboral. Sin embargo, los patrones de segregación se mantuvieron similares entre 2012 y 1990; y una porción más alta de la población residía en áreas segregadas en 2012 en comparación con la distribución de 1990. **Palabras clave:** educación superior, educación terciaria, segregación, segregación educativa, segregación multiescalar.

The number of people worldwide with a tertiary education has dramatically increased since the mid-twentieth century (Altbach, Reisberg, and Rumbley 2009). In 1900, there were approximately two higher education students per 10,000 people worldwide, a number that increased to approximately 165 higher education students per 10,000 people in 2000 (Schofer and Meyer 2005). Moreover, in 2014, the number of higher education

students per 10,000 people worldwide increased to approximately 284 (UNESCO 2016).

This change has also been dramatic in Sweden, increasing from approximately 14,000 registered higher education students in 1945 (0.21 percent of the total population) to approximately 400,000 registered students in 2015 (4.06 percent of the total population; Statistics Sweden 1947, 2017a; Swedish Higher Education Authority 2017). The educational

expansion of higher education in Sweden has been aided by Sweden's long history of not having tuition fees for tertiary education and the availability of financial support and student loans (Swedish Higher Education Authority 2015).

At the beginning of the twentieth century, there were only two universities in Sweden: Uppsala and Lund University. There were also two private institutions of higher education, Stockholm högskola and Göteborg (Gothenburg) högskola, which became universities in 1960 and 1954, respectively. Additionally, the Royal Institute of Technology and Karolinska Institutet in Stockholm and Chalmers tekniska högskola (Chalmers University of Technology) in Gothenburg were established during the nineteenth century. In 1909, the Stockholm School of Economics opened, followed later by economic institutions of higher education in Umeå, Gothenburg, and Lund (Frängsmyr 2015).

The increase in the number of higher education studies was small but steady during the early twentieth century, but after World War II the number increased at a much faster pace. The large increase coincided with the development of the welfare state in Sweden, and higher education became available to a broader spectrum of the population. This change coincided with a conscious effort to make higher education available to social classes other than the upper class. A number of reformations involving primary and secondary schools made these changes possible, as did the availability of governmental stipends and student loans. During the 1960s, the increase in students led to a lack of lecture halls, teaching staff, and student housing. This issue was coupled with a controversial proposal for the reformation of higher education presented in 1968, which led to some unrest in the student population. Unlike student unrest in Paris and the United States, the Swedish equivalent did not lead to violent protests. Tensions culminated in 1968, when a number of students at Stockholm University "occupied" the Student Union Building (Frängsmyr 2015).

In 1977, the Swedish government restructured higher education and significantly increased the number of institutions of higher education (SFS 1977). Ten years later, in 1987, Sweden introduced policies to decentralize the nation's higher education institutions (Prop. 1986/87:127). Andersson, Quigley, and Wilhelmson (2004) described the motivations behind the 1987 decentralization policies in Sweden. They suggested that the rapid increase in higher education institutions was implemented to increase the educational level and the number of jobs in different regions. The education level motivations were as follows:

- Make undergraduate education more accessible in all parts of Sweden.

- Increase the attendance of students from areas that are geographically remote from the older institutions of higher education.
- Increase the accessibility among different social classes to higher education.
- Make it possible to obtain a higher education without moving out of the region.

According to Altbach, Reisberg, and Rumbley (2009), centers and peripheries have always existed in the academic world. In Sweden, academic centers correspond to what Chudnovskaya and Kolk (2017) called old institutions in Sweden; that is, the universities and some specialized institutions in Gothenburg, Uppsala, Stockholm, Lund, Umeå, and Linköping. Part of the policy agenda in Sweden has been to offer tertiary education outside of the old academic centers, making it possible for students to obtain a tertiary education without moving, or at least not moving far. These policies have led to an increase in tertiary education institutions and their geographical distribution (Chudnovskaya and Kolk 2017). Chudnovskaya and Kolk (2017) found, however, that although the new institutions in Sweden allowed young people to remain closer to home, old institutions maintained a strong influence on the schools students wanted to attend.

Different societal processes will affect, produce, and reproduce different spatial patterns of population distribution. The spatial distribution of the socioeconomic attributes of a population is affected by the underlying societal processes that produce them (Massey 1979). This spatial distribution is often skewed; the amount to which it is skewed can be measured using segregation measures. Spatial segregation measurements received attention with Duncan and Duncan's (1955) presentation of the dissimilarity index and the availability of U.S. census data (Wong 2016). An important innovation in measuring segregation was the ability to simultaneously measure neighborhoods at multiple geographical scales (Johnston et al. 2000; Fischer et al. 2004; Reardon et al. 2008). The inclusion of multiple geographical scales is important when measuring segregation, because segregation is highly scale dependent. For example, a neighborhood might be considered segregated when compared to the metropolitan area, but the city district that the neighborhood is included in might not be considered segregated compared to the metropolitan area. Therefore, instead of attempting to determine the optimal constant neighborhood size to use when measuring segregation, one can use variable neighborhood scales (Sampson 2012). See Hennerdal and Nielsen (2017) and Nielsen and Hennerdal (2017) for a comparison of different multiscale segregation measures and comparisons to nonmultiscale segregation measures.

One reason that segregation is important is the notion that one's neighborhood might affect one's socioeconomic outcome, the so-called neighborhood effect. Galster (2007) provided a number of possible mechanisms whereby neighborhoods might affect socioeconomic outcomes. An internal neighborhood effect is the process of a person in a neighborhood affecting one or more neighbor; for example, through socialization, whereby norms and behaviors might be affected by contact with neighbors; that is, a large proportion of the population in the neighborhood has a tertiary education, which might encourage others in the neighborhood to pursue higher studies. External neighborhood effects occur when regional structures affect a neighborhood's population; for example, when there is a lack of higher education institutions in a neighborhood or larger region, thus affecting the possibility and willingness of residents to obtain a higher education (Galster 2007).

Therefore, an example of internal and external neighborhood effects that might influence residents to obtain a tertiary education would be a neighborhood population that already had a significant share of people with a tertiary education, which "normalizes" the characteristic, and the presence of a higher education institution in the neighborhood or within commuting distance. An example of internal and external neighborhood effects that might dissuade people from pursuing a tertiary education would be a low share of the neighborhood population with a tertiary education and the absence of a higher education institution in the neighborhood or within commuting distance. The Swedish decentralization policy for higher education can thus be seen as a way to work with the external neighborhood effects, providing easier geographical access to institutions of higher education.

A specific theory that could help to explain the spatial distribution of people with a tertiary education is Florida's (2002) creative capital theory. The creative capital theory is based on the idea that regional economic growth is primarily driven by the innovations created by the so-called creative class. Therefore, the attraction and retention of the creative class is of importance. The creative class is defined as an economic class that creates economic value through creativity (Florida 2002). Hansen (2007) found that creative class and educational level correlates to 0.935 in Sweden, and Mellander (2009) determined that 25 percent of those with a creative occupation in 2001 in Sweden had a tertiary education but that 88 percent of those with a tertiary education had a creative occupation. Thus, the spatial distribution of residents with a tertiary education corresponds very well with the creative class (but does not comprise the entirety of the creative class). In this article, the creative capital theory is not of interest for its predictions about regional economic

growth, but it is useful for its ideas about what attracts the creative class to a region.

Because, according to Florida, the creative class is a driver for economic growth regions, the focus should be on attracting creative people rather than attracting companies. Florida (2005) found that "they were not slavishly following jobs to places. Instead, it appeared that highly educated individuals were drawn to places that were inclusive and diverse. ... These people prefer places that are innovative, diverse, and tolerant" (33–34).

The research field of migration patterns of labor has focused much attention on the question of whether job availability or amenities drive migration (Miguélez and Moreno 2014). A number of studies have been conducted in this field and have focused specifically on the migration patterns of the creative class, whose members are often referred to as knowledge workers, to assess the creative capital theory in terms of what attracts and retains people belonging to this group. Hansen and Niedomysl (2008) determined that in Sweden, in contrast to the creative capital theory, the difference in migration between the creative and noncreative classes is only marginal and that the primary driver for migration of the creative class is employment. Niedomysl and Hansen (2010) showed that for highly educated migrants in Sweden, jobs were more important than amenity-related factors compared to less educated migrants.

A number of studies and reports have investigated the differences in education expansion in higher education among different countries (Osborne 2003; Schofer and Meyer 2005; Altbach, Reisberg, and Rumbley 2009). Few studies, however, have assessed changes in the population distribution of residents with tertiary education inside individual countries due to expansion of higher education; that is, segregation of residents with tertiary education. Segregation literature has mostly focused on racial and ethnic segregation. One exception was a study by McVeigh et al. (2014), which investigated residential segregation based on education levels in the United States and the associated effects on political actions, focusing on Tea Party organizations.

In this study, we analyze the spatial distribution of those with tertiary education to measure the segregation of residents with tertiary education and determine how it changed over time between 1990 and 2012. Essentially, we seek to determine whether educational expansion and the governmental policy of offering tertiary education outside of the old academic centers (the external neighborhood effect) affected segregation patterns in 2012 compared to those in 1990. We use Chudnovskaya and Kolk's (2017) classification of old and new institutions of higher education and compare local labor market regions that include old, new, or no institutions of higher education.

**Table 1** Share of populated grid cells with 400 persons or less and share of the population that live in populated grid cells with 400 persons or less

	1990	2012
Populated grid cells with 400 persons or less, age 25–64 years	0.997	0.964
Share of the population age 25–64 years that lives in populated grid cells with 400 persons or less	0.915	0.852

Sweden is of interest not only because of its large educational expansion but also because of the governmental policy to counteract any geographical inequality of access to tertiary education, which can be evaluated. Furthermore, as previously mentioned, those with a tertiary education in Sweden correspond highly with the creative class, implying that one can study the attractive qualities of a place in the context of creative capital theory.

## Methods and Data

Measuring spatial segregation using methods such as the dissimilarity index and many of the other commonly used segregation measurements fails to capture the spatiality because the borders between areal units are preserved as absolute barriers and the distances between areal units are not considered (Wong 2016).

We use the method proposed by Hennerdal and Nielsen (2017) to measure the residential segregation of how evenly or unevenly spatially distributed residents with a tertiary education are in relation to residents without a tertiary education. Hennerdal and Nielsen's segregation measure was developed to address the modifiable areal unit problem (MAUP), including the part of the MAUP related to the area of reference (ref-MAUP). The MAUP arises when analyzing spatially aggregated data because the result of such an analysis is compromised due to its dependency on the areal delineation. The ref-MAUP relates to a common situation where the analysis is based on comparisons between values for areal units and the corresponding value for an area of reference (e.g., the area of reference might be a metropolitan area or an entire country). In such cases, the result is once again compromised, because it is dependent on the delineation of the area of reference. As a consequence, it is not possible to make meaningful segregation comparisons between different study areas if one uses methods suffering from either the MAUP or ref-MAUP. By using the approach suggested by Hennerdal and Nielsen (2017), it is possible to control the aggregation and make both the areal units and the area of reference scalable.

Hennerdal and Nielsen (2017) made the areal unit and the area of reference scalable by aggregating the  $k$ -nearest neighbors of each populated grid cell. This approach uses a stepwise increase in individuals around a location until a predefined number

of individuals ( $k$ ) is reached. In this manner, the  $k$ -nearest neighbors of a location are defined, and those individuals constitute the selection used for aggregation. The software EquiPop (Östh 2014) was used to calculate the  $k$ -nearest neighbors for each location.

In addition to  $k$ -nearest neighbors, other multi-scalar approaches include *distance bands* and *nested spatial units*. The benefit of distance bands is that circular areal units used for aggregation become scalable by changing the radius. Reardon et al. (2008) used this approach to measure racial segregation at different scales in metropolitan areas of the United States. Nested spatial units enable movement between scales by aggregating smaller areal units into areal units representing another geographic scale. An example of using this approach is the study by Jones et al. (2015), which investigated segregation in London.

The data used in this study reflect whether a person between twenty-five and sixty-four years of age has a tertiary education. This information is based on Statistics Sweden's LISA database (Statistics Sweden 2016). The geographic location of each individual's residence was aggregated by Statistics Sweden into grids of 250 m for residents living in urban areas and 1,000 m for residents living in nonurban areas due to privacy concerns. The definition of urban areas is based on the 2010 classification by Statistics Sweden. The basis for the classification is that an urban area is an area where at least 200 residents live in a contiguous space without disruptions and distances of less than 200 m between residents (Statistics Sweden 2011).

To analyze the segregation of residents with a tertiary education, the location quotient ( $q$ ) was calculated for each populated grid cell. Thus, the share of persons with a tertiary education among the  $k$ -nearest neighbors was divided by the share of persons with a tertiary education among the individuals in a larger area of reference constituted by the  $K$ -nearest neighbors.

The segregation index ( $s_i$ ) of each populated grid cell  $i$  is then calculated as  $s_i = 1 - q$  if  $q < 1$  or  $s_i = 1 - (1/q)$  if  $q > 1$  (Nielsen and Hennerdal 2017). If the difference between the shares among the  $k$ -nearest neighbors is not statistically significantly different ( $p < 0.01$ ) than the share among the  $K$ -nearest neighbors, then  $s_i = 0$ . The segregation measure ranges from 0 to 1. A segregation value of 0 means that the share among the  $k$ -nearest neighbors is not different, or the difference is not statistically



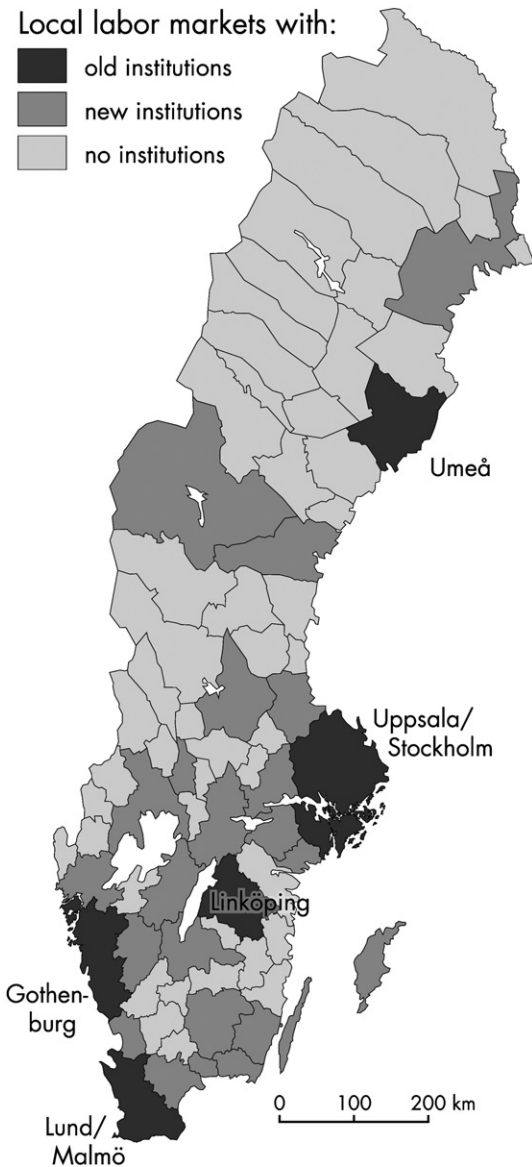
significant, from the share among the larger population consisting of the  $K$ -nearest neighbors; that is, no segregation. A segregation value of 0.5 means

that the difference in share is double or half, a segregation value of 0.75 means that the shares vary by a factor of four or a quarter, and 1 reflects an infinite difference. For a more comprehensive description of the method, see Hennerdal and Nielsen (2017). When visualizing the segregation using maps, we distinguish between segregation due to higher and lower shares compared to that of the reference area.

The residence of every person in the same 250- or 1,000-m grid cell was allocated to the same point in the center of the grid cell. This allocation limits how small a  $k$  value can be when calculating shares among the  $k$ -nearest neighbors. If the  $k$  value is smaller than the number of individuals who reside in each grid cell, the number of neighbors will be larger than  $k$  in practice and could result in misleading results. Therefore, the smallest  $k$  value in this study is 400, because more than 95 percent of all populated grid cells in both 1990 and 2012 had populations (age twenty-five to sixty-four) that were less than 400 and more than 85 percent of the population (age twenty-five to sixty-four) lived in a grid cell with 400 people or less (see Table 1).

Based on a multiscale approach, multiple values can be used for the  $k$  and  $K$  values. Starting from 400, we use quadrupling up to 409,600 to study all possible combinations of  $k$  and  $K$ , where  $K > k$ . The multiscale approach is preferable when studying segregation because a location might be segregated on one scale but not on another. In addition, a multiscale approach is preferable because a segregation trend might vary at different geographical scales.

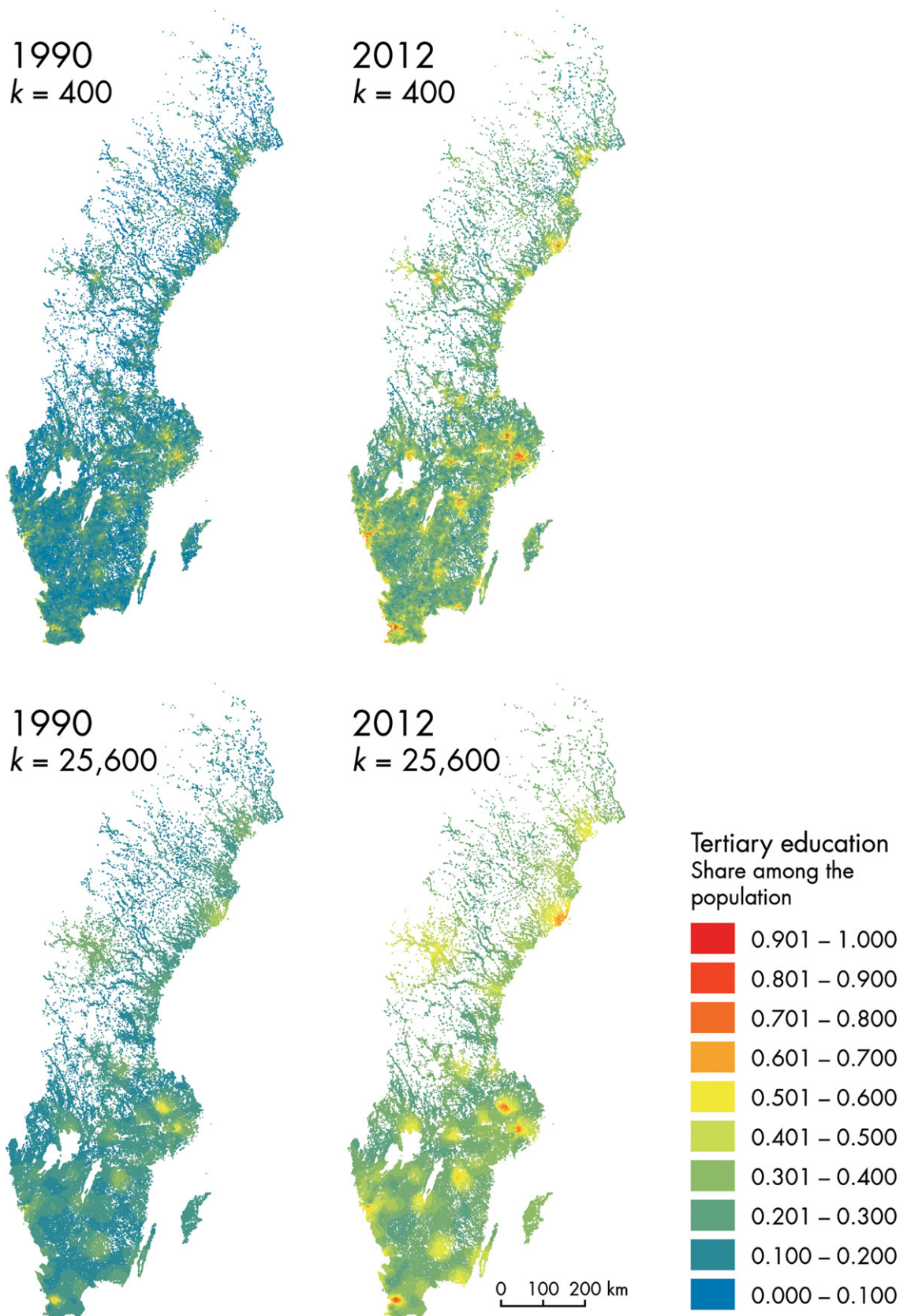
To calculate the segregation index of an area (or a set of populated grid cells), a population-weighted mean is calculated. To determine whether the spatial patterns are different in different parts of Sweden with or without old or new institutions of higher education, local labor markets have been categorized based on the occurrence of old, new, and no institutions of higher education. Local labor markets are an aggregation of municipalities provided by Statistics Sweden based on commuting for work. Local labor markets are suitable for this study because municipalities would be too small and counties would be too large. The delineation of the local labor market regions used in this study is the revised version released in 2008 by Statistics Sweden. The



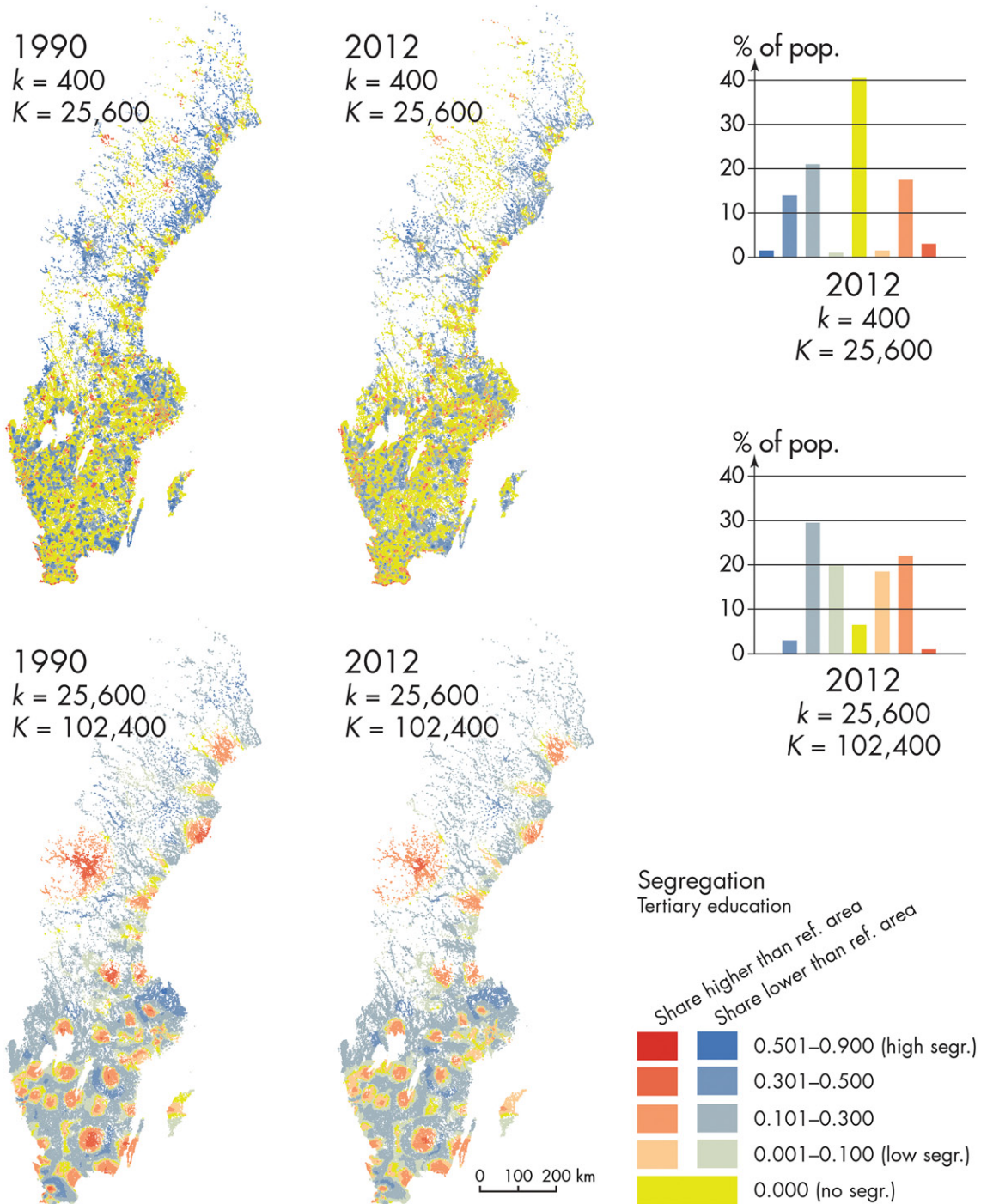
**Figure 1** Local labor markets in Sweden with old, new, and no institutions of higher education in 2012.

**Table 2** Share of the population age twenty-five to sixty-four with a tertiary education

	1990	2012	Increase (%)
Share of the population age twenty-five to sixty-four years old	0.51	0.51	0
Share of persons age twenty-five to sixty-four with tertiary education	0.23	0.40	74
Share of women age twenty-five to sixty-four with tertiary education	0.23	0.45	96
Share of men age twenty-five to sixty-four with tertiary education	0.22	0.35	59
Share of persons age twenty-five to sixty-four with tertiary education in urban areas	0.24	0.42	75
Share of persons age twenty-five to sixty-four with tertiary education in nonurban areas	0.15	0.30	100
Share of persons age twenty-five to sixty-four with tertiary education in local labor markets with old institutions	0.27	0.46	70
Share of persons age twenty-five to sixty-four with tertiary education in local labor markets with new institutions	0.20	0.35	75
Share of persons age twenty-five to sixty-four with tertiary education in local labor markets with no institutions	0.15	0.28	87



**Figure 2** Share among the population age twenty-five to sixty-four with tertiary education among the nearest 400 and 25,600 neighbors in 1990 and 2012.

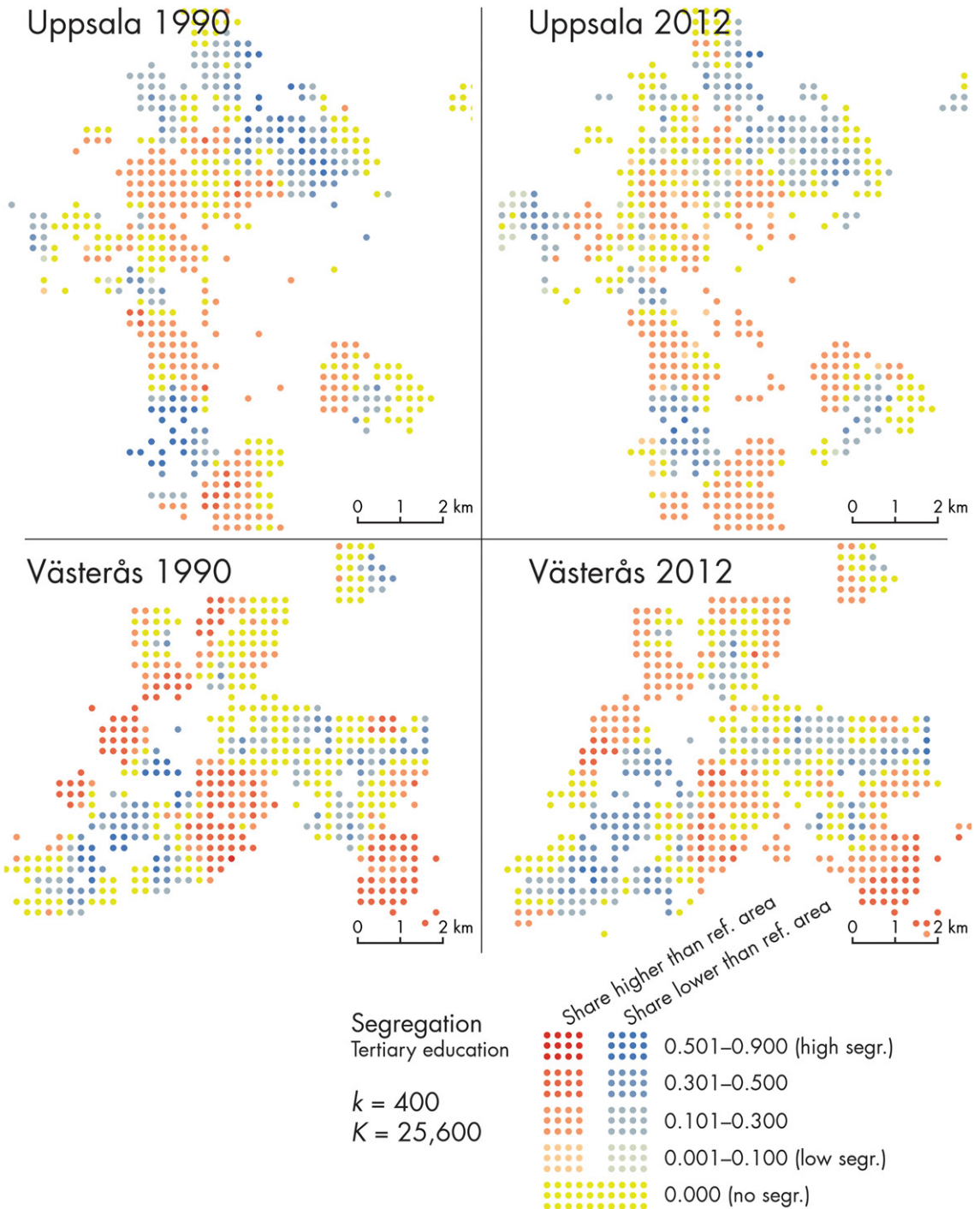


**Figure 3** Segregation for the population age twenty-five to sixty-four with a tertiary education in relation to those without among the nearest 400 neighbors compared to the nearest 25,600 neighbors and among the nearest 25,600 neighbors compared to the nearest 102,400 neighbors in 1990 and 2012.

local labor markets are categorized into old institutions, new institutions, and no institutions and are shown on a map in Figure 1. The *old institutions* include all local labor markets that house any of

Chudnovskaya and Kolk's (2017) classification of old higher education institutions in Sweden. The *new institutions* are all local labor markets that house any of the higher education institutions on the 2012 list





**Figure 4** Segregation for the population age twenty-five to sixty-four with a tertiary education in relation to those without among the nearest 400 neighbors compared to the nearest 25,600 neighbors in the cities of Uppsala and Västerås in 1990 and 2012.

published by the Swedish Higher Education Authority (2013), except for local labor markets with old institutions. The category *no institutions* includes all local labor markets with no higher education

institutions in 2012. In the year 2012, 55 percent of the population age twenty-five to sixty-four was living in local labor markets with old institutions, 32 percent in labor markets with new institutions, and

13 percent in labor markets with no institutions. See the Appendix for a list of the local labor market regions that were classified into the different categories.

**Results**

Table 2 shows that the share of the total Swedish population age twenty-five to sixty-four was the same in both 1990 and 2012 (0.51). The share of the population age twenty-five to sixty-four with a tertiary education increased from 0.23 to 0.40 between 1990 and 2012. This increase was much higher for women than for men (96 percent increase compared to 59 percent), and the share of women with a tertiary education was 0.1 higher than that for men in 2012 (Statistics Sweden 2017b). Additionally, the geographical differences in the share of the

population are quite large. The highest share can be observed in urban areas and in the local labor markets with old academic institutions. The lowest share is associated with nonurban areas and local labor markets with no institutions of higher education. The biggest increase was in nonurban areas and in local labor markets with no institutions. Over time, the geographical differences have decreased when looking at urban areas, nonurban areas, and the three different categories of labor markets.

Figure 2 shows the share of the population age twenty-five to sixty-four with a tertiary education in 1990 and 2012 for the nearest 400 and 25,600 neighbors of each populated grid cell in Sweden. The dramatic increase in the twenty-two-year span is visible throughout Sweden, with seemingly all populated locations exhibiting increases in the share of people with tertiary education. The highest shares of tertiary education are associated with labor markets that include old institutions of higher education (see Figure 1).

Figure 3 presents the levels of segregation for individuals with a tertiary education in relation to those without for the population age twenty-five to sixty-four. Two different combinations of  $k$  and  $K$ ,  $\{k = 400; K = 25,600\}$  and  $\{k = 25,600; K = 102,400\}$ , are shown. The combination  $\{k = 400; K = 25,600\}$  shows the segregation between the nearest 400 neighbors (age twenty-five to sixty-four) compared to the nearest 25,600 neighbors in both 1990 and 2012. The color scale shows whether there is no segregation (yellow) or segregation characterized by either a high (red) or low (blue) share of residents with a tertiary education. Thus, the red areas have a significantly higher share of people with a tertiary education than the surrounding areas, and the blue areas have a significantly lower share of people with a tertiary education than the surrounding areas.

**Table 3** Share of populated grid cells that had the same type of segregation in both 1990 and 2012

$k$	$K$	Urban locations	Nonurban locations
400	1,600	0.68	0.73
400	6,400	0.67	0.70
400	25,600	0.68	0.72
400	102,400	0.72	0.75
400	409,600	0.74	0.78
1,600	6,400	0.66	0.67
1,600	25,600	0.72	0.76
1,600	102,400	0.77	0.83
1,600	409,600	0.81	0.87
6,400	25,600	0.75	0.78
6,400	102,400	0.82	0.86
6,400	409,600	0.84	0.88
25,600	102,400	0.87	0.87
25,600	409,600	0.88	0.91
102,400	409,600	0.85	0.88

Note: Includes only locations populated by individuals age twenty-five to sixty-four in both 1990 and 2012.

**Table 4** Share of the population that lived in the three different segregation types in 1990 and 2012

$k$	$K$	1990			2012		
		Lower than ref. area	No seg.	Higher than ref. area	Lower than ref. area	No seg.	Higher than ref. area
400	1,600	0.173	0.681	0.146	0.168	0.676	0.156
400	6,400	0.277	0.534	0.190	0.272	0.531	0.197
400	25,600	0.360	0.422	0.218	0.372	0.406	0.222
400	102,400	0.408	0.349	0.243	0.437	0.306	0.257
400	409,600	0.455	0.297	0.247	0.485	0.242	0.273
1,600	6,400	0.348	0.415	0.237	0.348	0.418	0.234
1,600	25,600	0.454	0.275	0.271	0.455	0.275	0.270
1,600	102,400	0.492	0.221	0.288	0.513	0.190	0.297
1,600	409,600	0.540	0.176	0.284	0.557	0.134	0.309
6,400	25,600	0.474	0.192	0.334	0.483	0.198	0.319
6,400	102,400	0.520	0.133	0.347	0.525	0.128	0.347
6,400	409,600	0.566	0.112	0.322	0.586	0.076	0.338
25,600	102,400	0.536	0.069	0.395	0.526	0.063	0.411
25,600	409,600	0.590	0.049	0.360	0.576	0.052	0.372
102,400	409,600	0.545	0.046	0.409	0.537	0.030	0.433

Note: Lower than ref. area is characterized by a significantly lower share of the population with a tertiary education compared to those in surrounding areas. No seg. is characterized by no significantly higher or lower share of the population with a tertiary education compared to surrounding areas. Higher than ref. area is characterized by a significantly higher share of the population with a tertiary education than the surrounding areas.

**Table 5** Population-weighted segregation values for different areas

<i>k</i>	<i>K</i>	Sweden		Old inst.		New inst.		No inst.	
		1990	2012	1990	2012	1990	2012	1990	2012
400	<i>1,600</i>	0.08	0.06	0.07	0.05	0.09	0.06	0.09	0.06
400	6,400	0.15	0.10	0.14	0.09	0.16	0.12	0.15	0.11
400	25,600	0.20	0.15	0.20	0.14	0.22	0.17	0.19	0.14
400	102,400	0.25	0.20	0.26	0.19	0.25	0.21	0.24	0.21
400	409,600	0.28	0.24	0.30	0.24	0.26	0.22	0.27	0.24
<i>1,600</i>	<i>6,400</i>	0.11	0.08	0.11	0.07	0.13	0.09	0.12	0.08
1,600	25,600	0.19	0.14	0.18	0.13	0.20	0.15	0.18	0.14
1,600	102,400	0.24	0.19	0.24	0.18	0.23	0.20	0.23	0.20
1,600	409,600	0.27	0.23	0.29	0.24	0.24	0.21	0.26	0.23
<i>6,400</i>	<i>25,600</i>	0.14	0.10	0.13	0.09	0.14	0.11	0.14	0.10
6,400	102,400	0.21	0.16	0.22	0.15	0.20	0.17	0.19	0.17
6,400	409,600	0.24	0.21	0.27	0.22	0.21	0.18	0.21	0.20
<i>25,600</i>	<i>102,400</i>	0.16	0.13	0.16	0.11	0.17	0.15	0.14	0.14
25,600	409,600	0.21	0.18	0.25	0.20	0.18	0.16	0.18	0.17
<i>102,400</i>	<i>409,600</i>	0.13	0.12	0.17	0.15	0.09	0.08	0.09	0.08

Note: The values in italics consist of *k* and its smallest associated *K*, which is the quadruple number of *k*.

Overall, Figure 3 shows that although there has been a dramatic increase in the share of the population with a tertiary education between 1990 and 2012, the patterns of segregation are generally the same. The  $\{k=400; K=25,600\}$  combination in Figure 3 exhibits more areas with no segregation compared to the  $\{k=25,600; K=102,400\}$  combination. The diagrams in Figure 3 show that 41 percent of the population age twenty-five to sixty-four in 2012 lived in areas that had no segregation for the  $\{k=400; K=25,600\}$  combination, and the corresponding number is 6 percent for the  $\{k=25,600; K=102,400\}$  combination. Although the share of people living in areas with no segregation for the  $\{k=400; K=25,600\}$  combination was approximately seven times higher than that for the  $\{k=25,600; K=102,400\}$  combination, the population-weighted mean segregation was higher for the  $\{k=400; K=25,600\}$  combination because higher segregation values can be obtained from smaller *k* values, given that the probability of differing more from the *K*-nearest neighbors increases. Thus, more high values for the  $\{k=400; K=25,600\}$  combination can be observed in Figure 3.

Overall, a smaller share of the population lives in areas with segregation characterized by a high share of tertiary-educated residents than the share of the population that lives in areas with segregation characterized by a low share of tertiary-educated people for both combinations of *k* and *K*.

Figure 4 shows the  $\{k=400; K=25,600\}$  combination in 1990 and 2012 for the cities of Uppsala and Västerås. Uppsala University was founded in 1477; thus, Uppsala city is part of those labor markets with old institutions. The higher education institution in Västerås was established as part of the 1977 higher education restructuring and is thus part of those labor markets with new institutions. The populations of Uppsala and Västerås were 109,497 and 98,233, respectively, in 1990 and 140,454 and 101,877 in 2010 (Statistics Sweden 2018). Figure 4

shows that both cities have distinct segregated and nonsegregated areas and that the patterns are stable over time.

Table 3 presents the share of populated grid cells with the same type of segregation in both 1990 and 2012 for all *k* and *K* combinations. The three segregation types include segregation characterized by a significantly lower share of people with a tertiary education compared to that in the surrounding areas, no segregation, and segregation characterized by a significantly higher share of people with a tertiary education compared to that in the surrounding areas. Only the locations that were populated in both years are included in Table 3. The locations are displayed as urban locations (250-m grid cells) and nonurban locations (1,000-m grid cells). The results in Table 3 suggest that the overall pattern remained the same over time; that is, most populated grid cells exhibited the same type of segregation in both years.

Table 4 shows the segregation type for the population in 1990 and 2012. The share of the population living in locations that are not segregated based on a specific *k* and *K* combination generally decreased over time (eleven out of fifteen). In other words, a higher share of the population lived in segregated areas in 2012 compared to that in 1990. Of those people who lived in segregated areas, more lived in locations with a significantly lower share of individuals with a tertiary education rather than in locations with a significantly higher share of individuals with a tertiary education. Thus, overall, the underlying patterns are the same but more individuals live in segregated areas and the segregation is more often characterized by a significantly lower share of the population with a tertiary education.

Table 5 shows the population-weighted mean segregation values for all of Sweden and the three different categorizations of labor market regions for all combinations of *k* and *K* in 1990 and 2012. When the *k* value is constant, the higher the *K* value is, the higher the segregation mean. This means that

<i>k</i>	<i>K</i>	Sweden	Old inst.	New inst.	No inst.
400	1600	-0.03	-0.02	-0.02	-0.03
400	6400	-0.04	-0.04	-0.04	-0.05
400	25,600	-0.05	-0.06	-0.05	-0.05
400	102,400	-0.05	-0.07	-0.04	-0.03
400	409,600	-0.05	-0.06	-0.04	-0.03
1600	6400	-0.04	-0.03	-0.03	-0.03
1600	25,600	-0.05	-0.05	-0.04	-0.05
1600	102,400	-0.05	-0.07	-0.03	-0.03
1600	409,600	-0.04	-0.06	-0.03	-0.02
6400	25,600	-0.04	-0.04	-0.03	-0.04
6400	102,400	-0.04	-0.06	-0.03	-0.02
6400	409,600	-0.04	-0.05	-0.03	-0.02
25,600	102,400	-0.03	-0.05	-0.02	-0.01
25,600	409,600	-0.03	-0.04	-0.02	-0.01
102,400	409,600	-0.01	-0.02	-0.01	-0.01

**Figure 5** Difference in population-weighted segregation values between 1990 and 2012. Segregation was measured among the population age twenty-five to sixty-four with a tertiary education in relation to those without among the nearest *k* neighbors compared to the nearest *K* neighbors.

one should not only look at the highest value in Table 5 to determine the scale at which segregation is introduced, because the values are partly a product of how big the difference is between *k* and *K*. It is, however, possible to identify the degree to which segregation occurs on different scales by only comparing reference areas that have the same size relationship to each *k* value. In this study, this is done by comparing different combinations of *k* and *K*, consisting of *k* and its smallest associated *K*, which is the quadruple number of *k*. These combinations are in italics in Table 5. For the whole of Sweden and the labor markets with new and no institutions, the highest values column-wise for these combinations are in the *{k = 25,600; K = 102,400}* combination. For the labor markets with old institutions, which houses the three metropolitan areas in Sweden, the corresponding combination is *{k = 102,400; K = 409,600}*. This then shows that segregation is mostly introduced on the city level, city district level (for larger cities), and regional level rather than the neighborhood level.

Figure 5 shows the change in segregation that is presented in Table 5. All combinations of *k* and *K* values decreased for all categories. Old institutions decreased the most for *k* and *K* values that included *K = 102,400* and *K = 409,600*, and the other *k* and *K* value combinations exhibited similar decreases among the different categories.

**Conclusions**

Sweden has experienced a dramatic increase in the share of the population with a tertiary education. This change was due to a number of factors. The

burgeoning welfare state in Sweden emphasized education and established an infrastructure that led to a dramatic increase in the number of students in the 1960s and 1970s. The 1977 education reform expanded higher education options, and the 1987 decentralization reform made higher education more widely available in Sweden.

In this study, we analyzed the spatial distribution of those with tertiary education in 1990 and 2012 to evaluate the geographical effect of these higher education reforms. The study shows that Sweden’s governmental policy for expanding the proportion of the population with a tertiary education has been successful, with an overall higher share of tertiary-educated people age twenty-five to sixty-four in all parts of Sweden at the end of the study period.

In addition, the study shows that the level of segregation of people with a tertiary education has uniformly decreased at all geographical scales. Additionally, segregation has decreased in all three categories of labor market regions: labor market regions with old, new, and no institutions of higher education.

Although the share of people with a tertiary education has increased and the level of segregation has decreased, the spatial distribution remains mostly the same. In other words, most of the areas that had relatively low or high shares of tertiary educated people in 1990 were characterized by the same type of segregation in 2012. In addition, the study showed that segregation is mostly introduced on the city level, city district level (for larger cities), and regional level rather than the neighborhood level. This then points toward external neighborhood effects being one of the main underlying reasons for tertiary segregation; for example, a lack of higher



education institutions in the region affecting the possibility and willingness of residents to obtain a higher education. Of course, this does not mean that segregation at the neighborhood level, influenced by residential sorting and internal neighborhood effects in the form of neighborhood norms connected to tertiary education, is not present.

On one level, one could argue that the results are consistent with the creative capital theory, because the highest concentrations of people with a tertiary education are located in the three metropolitan areas: Stockholm, Gothenburg, and Malmö. These metropolitan areas correspond to Florida's conclusions about what attracts the creative class (see, e.g., Wimark 2014). In accordance with the creative capital theory, however, one might expect a higher increase in those areas that included metropolitan areas (the old institutions labor market regions) compared to the other areas. Instead, there was a large increase in all regions, with the greatest increase occurring in nonurban regions. Therefore, something else is driving the spatial distribution. Massey (1979) argued that the spatial distribution of the socioeconomic attributes of a population is an effect of the overall economic system. Following this claim, the spatial distribution of people with a tertiary education in Sweden seems to have changed in response to an overall economic system that relies increasingly more on a highly educated workforce.

Overall, the governmental push in Sweden for increased access to higher education seems to have been successful in providing more people with a higher education and decreasing the level of tertiary education segregation. The segregation patterns from 1990 remain in 2012, though, and a higher share of the population lived in segregated areas in 2012 compared to that in 1990. Therefore, future research should explore the reasons for the underlying spatial patterns and possible neighborhood effects (internal and external). Potential fields of interest might include tertiary education segregation in relation to neighborhood effects on education and career, student achievement in primary and secondary schools, and political polarization (following McVeigh et al. 2014). ■

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## Appendix

Local labor markets with old institutions: Göteborg, Linköping, Malmö–Lund, Stockholm–Solna, and Umeå.

Local labor markets with new institutions: Borås, Eskilstuna, Falun–Borlänge, Filipstad, Gotland, Gävle, Halmstad, Jönköping, Kalmar, Karlshamn–Olofström, Karlskrona, Karlstad, Kristianstad–Hässleholm, Luleå, Nyköping–Oxelösund, Skövde, Sundsvall, Trollhättan–Vänersborg, Västerås, Växjö, Örebro, and Östersund.

Local labor markets with no institutions: Arjeplog, Arvidsjaur, Arvika, Avesta, Bengtsfors–Dals, Ed,

Bollnäs–Ovanåker, Dorotea, Fagersta, Gislaved, Gällivare, Hagfors, Haparanda, Hudiksvall, Hällefors, Härjedalen, Jokkmokk, Karlskoga, Kiruna, Kramfors, Lidköping–Götene, Ljungby, Ljusdal, Ludvika, Lycksele, Malung, Mora, Norrköping, Oskarshamn, Skellefteå, Sollefteå, Sorsele, Storuman, Strömstad, Strömsund, Söderhamn, Torsby, Tranås, Vansbro, Vetlanda, Vilhelmina, Vimmerby, Värnamo, Västervik, Årjäng, Åsele, Älmhult, Örnsköldsvik, and Överkalix.