WATCH THEM SEGREGATE

Analyzing patterns of economic segregation and STEM jobs in commuter zones.

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By

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Abstract

STEM workers have been touted as the economic drivers at local and federal level (Langdon, McKittrick, Beede, Khan, & Doms, 2011), and planners and policymakers often engineer policies for growth and economic development around their demand and supply. These individuals make 29 times more than their non-STEM counterparts (Langdon et al., 2011), and are consistently growing in numbers for the past 40 years (Watson, 2017). Therefore, it is essential to assess their impact on regional patterns. The thesis posits that STEM occupations drive patterns of economic segregation. To ascertain the validity of the phenomena, the study assesses the relationship between the concentration of individuals involved in STEM occupations and two measures of economic segregation; economic diversity and concentration of poverty. Upon analyzing the statistics at regional and census tract level for the five commuter zones, Seattle (WA), Portland (OR), Denver (CO), Albuquerque (NM) and Fort-Worth (TX), the study revealed mixed results. A secondary layer of spatial investigation was done to further explore the variability in the results.

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Chapter 1 - The Diverging Economy

1.1. Introduction

STEM occupations or jobs in Science, Technology, Engineering, and Management primarily employ non-manual skills, innovation, and scientific knowledge. As per U.S. Department of Commerce, STEM workers play a key role in the sustained growth of the U.S. economy. Projections in 2011 by the department suggested that 1 in 18 workers were employed in STEM occupations in 2010 (Langdon et al., 2011). The U.S. Bureau of Labor Statistics projected in 2001 that during the period 2010 to 2020, employment in STEM occupations will grow by 18.7%, compared to 14.3% for all occupations (Baccalaureate and Beyond Longitudinal Study (B&B), 2011). As per the latest update from the Department of Commerce, the industry in-fact grew 24 percent in the time period (Langdon, 2017). Individuals employed in such occupations earn considerably more than the median earnings for all occupations and The median earnings for STEM occupations were $74,380 in 2009 and $78,270 in 2012, a number that is twice the median earnings for all non-STEM workers during the same time period (Baccalaureate and Beyond Longitudinal Study (B&B), 2011). Looking at the considerable variation between the incomes of STEM and non-STEM workers, it can be asserted that STEM workers, with the choices they make based on their socio-economic status, propagate patterns of economic segregation.

Research Question

By examining the indices and the rate of change that captures economic segregation; diversity index and concentration of poverty, with the concentration of STEM workers, this research aims to determine the relationship between the two. Consistent/inconsistent patterns of concentrated poverty and diversity is statistically and spatially analyzed within the commuter zones across the United States. The results are drawn upon evaluating five case study commuter zones, Seattle (WA), Portland (OR), Denver (CO), Albuquerque (MN), and Fort-Worth (TX). In conclusion, it is determined whether *the* ***concentration of STEM occupations exacerbated economic segregation within commuter zones during 1980-2010.***

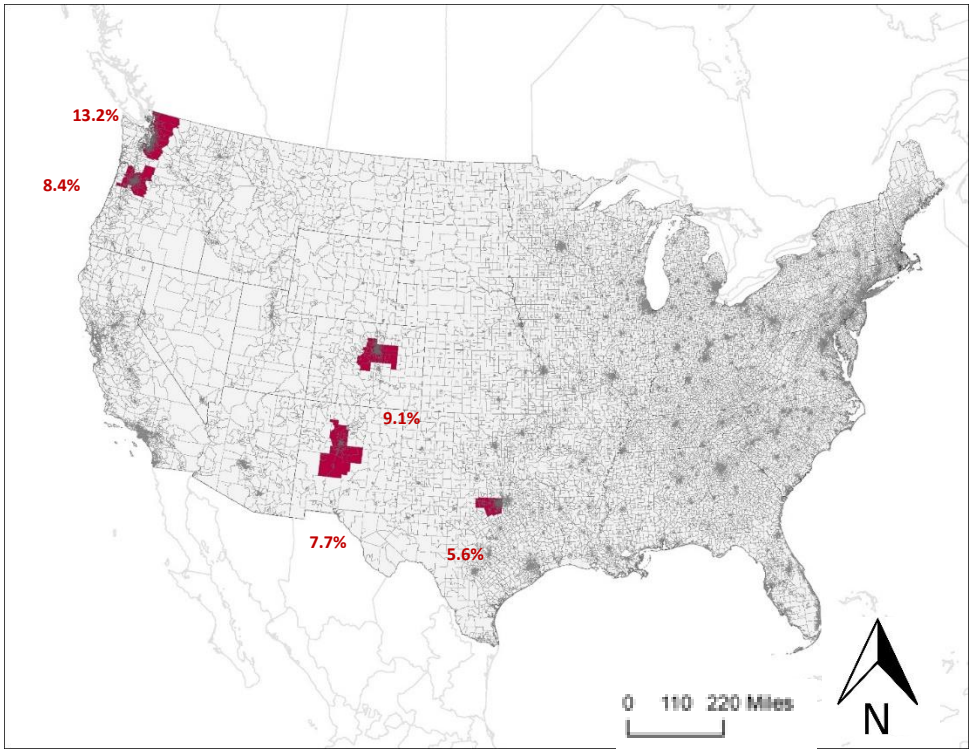


Figure 1- Commuter zones considered for case study, and the percentage of total workforce employed in STEM occupation. Data Source: Bloomberg (2015)

1.2. Background

In order to comprehend the association between STEM jobs to the economic segregation, it is essential to develop an understanding of what STEM occupations are. The acronym STEM refers to Science, Technology, Engineering, and Management. These occupations are used increasingly to emphasize on innovation, and the occupation which employ such workers are widely discussed and analyzed as they are considered economically viable. In policymaking, implication of the industry are widely discussed and strategies are employed in order to derive benefit from them. For example, Portland as a part of their economic development plan outlined in Comprehensive Plan Goals and Policies, adopted in 1994 and amended in 2011, has sought to establish a Science and Technology Quarter as the core of the region's biomedical, bioscience, and bioengineering industries and advance these industries.

In the studies reviewed, multiple definitions of STEM have been observed based on which the jobs are categorized. For this study, the Standard Occupational Classification (SOC) system, which is a federal standard, has been used. STEM occupations include jobs such as engineer, mathematical and computer scientist, natural scientist, health diagnosing occupation, and postsecondary teacher, ~~etc.~~ Computer occupations made up nearly 45 percent of STEM employment, and engineers made up an additional 19 percent (Watson, 2017). Mathematical science occupations and architects, surveyors, and cartographers combined made up less than 4 percent of STEM employment (Watson, 2017). Occupations which are listed as STEM-related such as dental hygienist and sales occupations are not included in the scope of this research.

The United States government has played its part in both creating demand and supply for such occupations. The Congress has acknowledged the vitality of these jobs and has been allocating budget to promote the progress of science and useful arts since 1945. The federal government had committed to provide funding to enhance the STEM labor supply and promote research, under President Roosevelt (Rothwell, 2013). This funding was delineated to "promote the progress of science and useful arts,". Such incentives have driven the demand for STEM jobs.

Witnessing the unmet demand for trained individuals in the STEM, in 2006, President George W. Bush launched the American Competitiveness initiative to improve STEM education. Likewise, President Obama conducted the "Educate to Innovate" campaign to boost STEM education. He also spearheaded initiatives designed to improve the quality of K-12 STEM education ("President Obama Launches 'Educate to Innovate' Campaign for Excellence in Science, Technology, Engineering & Math (Stem) Education," 2009).

With the growth of highly paid STEM occupation fostered by the innovation boom and the government, jurisdictions have developed economic development plans with focus on retention of such jobs in the region. These jobs assure greater financial benefits to the jurisdictions, which can be redirected to create better public amenities such as schools, hospitals, infrastructure systems, *etc.* Thus, growth in STEM economy is pursued as a city building strategy.

This competition for attracting businesses employing STEM workers is elucidated by the case wherein Amazon asked for a request for proposal from governments to decide the location for its second headquarters. In response, the company received 238 proposals. This number is particularly interesting given that Amazon specifically mentioned in their RFP that the city should

have a population of more than 1 Million, and there are only 10 cities in America that qualify based on this consideration.

Employment opportunities which may allow them to be placed in the "middle class" is one of the top priorities for the American household (Parilla, 2017). As emphasized by Amazon's example, the decisions that policymakers tend to make, are taken under the intense pressure to deliver more sustained and inclusive economic growth to their communities and meeting this demand. This vying for tech has polarized the geographies, a trend also observed in the commuter zones studied in this research. Four out of five commuter zones included in this case study have comprehensive plans that have explicit strategies to fuel economic growth based on the current STEM economy ("Seattle Economic Development Commission,",2014.;"Economic Development Plan Fort Worth,",2017,;"Denver Office of Economic Development," 2017; "Economic Prosperity and Affordable Strategy", 2012).

Redistributing benefits from these individuals are not the only motive of understanding the pattern of economic segregation that is caused by an increase in STEM occupations. Planning professionals need to safeguard these workers from the vulnerability of economic downturn as well. Workers in STEM occupation on an average experience lower unemployment rates than workers in any other field. This consistent low unemployment rate makes these occupations highly desirable. However, they are not completely immune to economic downturns. During the 2001 recession, the rate of unemployment for college-educated STEM workers increased than that of non-STEM workers (Watson, 2017). As per Moretti (2012), certain companies employing STEM individuals under thriving market conditions can generate five times as many indirect jobs as direct

jobs. Moretti in his research terms this as the multiplier effect. Given the economic benefits, it is of interest to plan cities and regions in order to support such occupations and redistributing the benefits can be a potential strategy for sustained economic development of the geography. Planners should thrive to disincentivize concentration of STEM occupations within a singular industry and a particular region to safeguard them from economic downturns or concentration of poverty.

To understand the relationship between STEM jobs and economic segregation, it is also essential to understand what the term economic segregation implies, how it is caused and what are its implications. Previous scholarship indicate that are economic segregation can be caused by numerous socio-economic constructs, of which, the most prominently discussed is income inequality (Reardon & Bischoff, 2011) .

Income inequality has been on the rise since 1970. According to the research conducted by Emmanuel Saez (Piketty & Saez, 2006), in 2015 households belonging to America's top 10 percent, earn more than nine times as much income as the bottom 90 percent. Moreover, the top 1 percent of America's households have more than doubled their share of the nation's income since the middle of the 20th century. On the other hand, during 1960-2011 the STEM labor force has grown at an average annual rate which is twice as much as the growth rate of the total workforce (Randall, Steele and Zimmer, 2014). Therefore, researchers can make a calculated assumption that the income generated by the STEM workers have added disproportionately to the growing economy and has contributed to the rising inequality.

In their research, Reardon and Bischoff focused on income inequality from 1970-2000 and concluded that inequality occurs mainly due to preferences of individuals based on their socio-economic status. Overall economic segregation as observed by Jargowsky (Jargowsky, 1996) has increased since the 1980s particularly for African Americans and Hispanics. He states that the phenomena is widespread affecting virtually every metropolitan area in the United States (Jargowsky, 1996, T. Watson, 2009). Economic segregation is a resultant of the choices that an individual household makes while determining their neighborhood. These choices are based on their socio-economic characterization of the community and often leads to concentration and isolation of households belonging to the different income classes.

The rising economic segregation has important consequences on social welfare. It determines ones' education level, peers, and social networks. In addition to this isolation, the conditions are exacerbated by out-migration of economically well-off African Americans living in economically weaker neighborhoods. This phenomenon takes away economic resources away which catalyzes concentration of poverty, and formation of ghettos (Wilson, 2012).

While segregation is factored by occupation, education, and income to a large extent, there are other factors that augment the effect such as size and density of a metropolitan (Yang & Jargowsky, 2006), level of education attainment (Jargowsky, 1996), concentration of workers in creative class (Florida, Mell, & er, 2015)and number of jurisdictions (Lens & Monkkonen, 2016). For different commuter zones, the above criteria vary and therefore affects the region with varied intensities. As a result of the rapid increase in wealth due to the new economic landscape coupled with geographical features, some metropolitans have become more prosperous than others,

resulting in divergent economies in towns that exist within proximity to one another (Moretti, 2012).

The parameters listed above contribute to the segregation of the five commuter zones studied with various intensities. The extent to which the households are distributed based on income will be determined by comparing the index of diversity (in this case the theil index) and concentration of low-income households and the analysis will be carried out for multiple level of geographies.

Economic segregation has social and economic consequences for a region. As mentioned before, people choose their neighborhoods based on their income levels which allows them the ability to afford a house in the area. There are secondary considerations in this decision such as proximity to schools, amenities, safety, and parks. The ability to afford a residential unit is largely determined by the household's income. Therefore, it is safe to say that income determines residential sorting to a large extent. Most of the researchers state that the neighborhood in which anyone chooses to situate a household is in determines their choices, however, it is evident that individuals who can afford a house in multiple neighborhoods owing to their high income determine the desirability of a certain neighborhood based on their choice, and individuals with low income who are not able to afford houses in that neighborhood are left with limited option and are forced to live in isolation. Thus, low-income level households were in fact never provided an opportunity to be selective about the socio-economic group they reside with. Determinations made by individuals with high income determine to a large extent the patterns of segregation.

These patterns accentuate the economic advantages of high-income households and exacerbate the economic disadvantage of low-income households. The mechanisms by which the economic

disadvantages are caused can be broken down into two categories; the neighborhood composition effect which determines the composition of a neighborhood based on attributes such as poverty rates, level of education, single parent household *etc.*, and spatial resource distribution which leads to unequal distribution of resources among the affluent and the poor (Reardon & Bischoff, 2011).

Coupled with non-ubiquitous distributions of public amenities, there is also non-ubiquitous investment in the shared public resources. Thus, economic segregation also leads to a difference in the level of service based in the income classes. A considerable body of scholarship corroborates this theory. Segregation has been shown to have the first-order impact on several neighborhoods characteristic outcomes such as schooling (Baum-Snow & Lutz, 2011), health (Acevedo-Garcia, Lochner, Osypuk, & Subramanian, 2003) and inter-generational mobility (Chetty, Hendren, & Katz, 2016).

Economic segregation also has important consequences on political participation of low-income neighborhoods. Residential segregation along economic lines, created by the housing, transportation, and urban redevelopment policies, set in motion a chain reaction of developments that have harmed the civic environment in poor neighborhoods while nurturing the civic environment in rich ones (Widestrom, 2015, p. 166).

To uncover the connection between the two phenomena this thesis employs a systematic approach first to understand the measures of segregation at the macro and micro level, and how the rates have changed from 1980-2010. The process iterated over five commuter zones allows

us to drive conclusions based on similar or dissimilar trends. Previous scholarship in this realm of is discussed in the next chapter, after which a methodology is designed and detailed.

Chapter 2: Methods of Exploration

2.1. Previous Scholarship

There has been a tremendous amount of research on the impacts of economic segregation and its implications. Moreover, the increase in STEM occupations and statistics related to its growth is periodically documented by the Department of Commerce. Despite this, the effect of the distribution of STEM workers on the sorting of households has yielded little research. The research method used in this study is rooted into previous scholarship that evaluate causes of economic segregation and understands the implications of the knowledge-based industries.

This study contributes to the literature on the causes of economic segregation within commuter zones in the United States. The earliest research exploring patterns of economic segregation and its implication was done by Park, which stated that “physical distances are indexes of social distance” (1926, p.18). This highlights that economic segregation is a construct of spatial parameter. In 1987, Wilson concluded in his study stating out-migration of the Black middle class has isolated poor Blacks in the inner city, with disturbing "concentration effects."

~~Following which~~, Jargowsky (1996) in his research observed a steady increase in economic segregation in U.S. metropolitan areas since 1980s despite the slow decline in racial segregation, highlighting the distinction between the two phenomena and how they cannot be used interchangeably. Most recently, Reardon and Bischoff (2016) find that economic segregation grew sharply in the 1980s, changed little in the 1990s, and then grew again in the early 2000s. The researchers attributed this to the rise in income inequality for the past four decades.

The role of factors other than income inequality that contribute ~~towards~~ economic segregation has been intensively analyzed by researchers such as Baum-Snow and Pavan (2013, 2016). The authors document a positive relationship between city size and an increase in the dispersion of earnings; they interpret this relation as evidence of a skill-biased change in agglomeration economies. In 2016, Diamond studied the geographical sorting of college graduates across U.S. cities between 1980 and 2010, whereas the current study focuses on the determinants of occupational sorting within cities.

Income segregation and its effect on neighborhood has been widely studied with respect that neighborhood effects play in social and economic outcomes, such as education, health, and intergenerational mobility. Education and segregation have a strong two-way link in the United States where public spending in schooling is very localized. For example, Baum-Snow and Lutz (2011) have analyzed the patterns of desegregation of local schools and found that school desegregation in large urban districts led to public enrollment declines for whites and increases for blacks, whereas, Chetty and Hendren (2016) used tax records in a quasi-experimental setting

to measure the strength of neighborhood effects on children and their ability to explain differences in inter-generational mobility across areas.

Although the effect of STEM workers has not been specifically investigated, the expansion of STEM economy, innovation economy or knowledge-based economy has been of interest to many researchers. Richard Florida in his book Rise of Creative Class (2002) posits that creative class has the ability in the 21st century to push a plow. Pandering to the creative class can help being financial aid to the city centers and contribute to its economy. Thus, the book stressed on the potential and implication of choices of one-third of the national workforce constituting the "Creative Class" – a group believed to bring economic growth to a region. In context of this research the creative class are STEM workers. Fifteen years hence, the author reflected on the "route to urban revival' he prescribed in his previous book, which leads to another work of insight- New Urban Crisis in 2017. In this book, he writes about the divergence in urban cities between the "creative class" and the "service class." In the literature, the author states that grouping of industry, economic activity, and talented and ambitious people in cities is the basic engine of innovation and economic growth. But, even as urban clustering drives growth, it carves deep divides into our cities and our society. As the affluent and advantaged return to cities, they colonize the best locations. Everyone else is then crammed into the remaining disadvantaged areas of the urban core or pushed farther out into the suburbs.

Another book that creatively dissects the impact of tech-industries on the economy is Enrico Moretti's book, The New Geography of Jobs (2012). In this, the author discusses the wide range of economic growth and prosperity across the U.S. regions and it connect with the typology of jobs

that the region offers. He states that innovation workers and companies create prosperity and the gains are mostly metropolitan in scale and are crucial in determining vitality of a region such as a commuter zone. He also states based on his research that innovators create demand for other occupations creating a multiplier effect and in a thriving economy, a single STEM worker can create as many as 5 jobs.

Empirical research on this topic also include work done by Florida and Mellander in 2015 wherein the authors conduct a comprehensive study of urban segregation in U.S. metro areas and link this increase to the emergence of the creative class and the expansion of jobs in the high-technology industry. A more recent study published by the Northwestern University and funded by the Ewing Marion Kauffman Foundation (Berkes, 2018) explores this nexus by basing their research on patent citations which stand as a proxy for local innovation and determine pattern of segregation as related to the knowledge-based economy.

2.2. Measures of Economic segregation

Building knowledge about the existing study that drive the knowledge-based industry and economic segregation is important however it is essential to understand ways with which the relationship can be measured. To do so, the following text will explore research on the metrics of economic segregation.

While there is a rich literature discussing measures of segregation among unordered categorial groups such as race and gender (Massey, 1978; Massey & Denton, 1988; Reardon & O'Sullivan, 2004), methods of measuring economic segregation is much less developed in comparison.

Massey and Denton (1988) conceived residential segregation as a multidimensional phenomenon and upon extensive literature review and cluster analysis to identify 20 different indices of segregation, they classified them into five key dimensions of segregation. These dimensions describe the evenness, the exposure, the concentration, the centralization and clustering of the demographic groups.

Moreover, these measures were developed to evaluate residential segregation. However, they can be applied to understand representation of economic groups within the area. Thus, for the purpose of this study, the measures of residential segregation are adapted to evaluate income diversity within an area. The research is built on the premise, more the diverse the geography being evaluated is, the less segregated it shall be.

Within the research, the measure of evenness is explored. The research evaluates the entropy of an area to measure the evenness. The measure was proposed originally by Theil (Theil 1972; Theil and Finizza, 1971). The entropy index (also referred in this research as Theil score, Theil index and diversity index) measures the (weighted) average deviation of each areal unit from the metropolitan area's "entropy" or racial and ethnic diversity, which is greatest when each group is equally represented in the metropolitan area. A large entropy index indicates greater economic segregation while a score of 0 determines a perfect distribution of socio-economic groups, whereas 1 implies complete segregation.

P- Population belonging to the concerned income group

The city's entropy is given by:

$E = (P)\log[1/P] + (1-P)\log[1/(1-P)]$

and a unit's entropy is analogous:

$E_i = (p_i)\log[1/p_i] + (1-p_i)\log[1/1-p_i)]$

The entropy index itself is the weighted average deviation of each unit's entropy from the city-wide entropy, expressed as a fraction of the city's total entropy:

$$H = \sum_{i=1}^{n} [t_i(E - E_i)/ET]$$

The Theil index is a measure of the redundancy of income (or other measure of wealth) in some individuals. Redundancy in some individuals implies scarcity in others. This method is able to satisfy the Pigou-Dalton property (inequality increases as a result of a regressive transfer). It is basic, easy to understand and can be calculated based on a matrix of household distribution with the help of an R package. Thus, it is used in this research as a metric.

Another measure of economic segregation explored in the research is the concentration of poverty, or the ratio between the lowest income class in the area to the total number of households in the area. This metric when calculated at a regional level enables the understanding the health of the economy by indicating how many households are poor, however upon performing a cluster analysis on the metric, and based on the spatial location and pattern of the low-income households, this metric has the potential to reveal the degree of segregation within a commuter zone.

The concentration of poverty within the city is given by:

$C = P_{very\text{-}low} / P$

The concentration of poverty within the unit is given by:

$C = P_{i\_very\text{-}low} / P_i$

In conclusion this research examines economic segregation based on two metric, a) by determining the entropy, or the weighted average deviation of each areal unit form the metropolitan area's diversity, and b) by determining the concentration of poverty within the census tracts. The metric does not provide inferences related to spatial patterns, therefore a secondary layer of analysis is done to explore the relationship spatially.

2.3. Chosen case studies

It is crucial for cities to plan for the big picture especially in this time of accelerated climate change to provide for the population as well as conserve the natural resources. Three of the five case studies picked in this research have a strong history of regional planning. Seattle adopted its first regional plan in 2005 whereas the region of Denver adopted the Comprehensive plan-Blueprint Denver in 2002. These plans have been given five-star ratings by the American Planning Association. The region planning of Portland is unique as well. Portland has the first regional planning entity whose executives are elected representatives of the community. This entity determines plans and policies that the region of Portland is mandated to follow. Portland is also a unique case study as it is the first region in the United States to adopt the Urban Growth Boundary in the year 1967.

In contrast, Fort-Worth and Albuquerque do not have such strong regional planning devices that were enforced years ago. The regional planning efforts for these regions have been initiated in the past 10 years. Across the commuter zones, there is an emphasis on economic development derived from STEM industries and its workers. In their paper, the Cost of Segregation published in March 2017, Rolf Pendall, Gregory Acs, Mark Treskon, and Amy Khare analyzed 100 most populous commuting zones and documented its Generalized Neighborhood Sorting index (GNSI) and spatial proximity between black and white neighborhoods. Based on the analysis, Fort Worth at 43rd, Seattle was placed at 46th, Denver at 49th, Portland at 78th, and Albuquerque at 94th, thus representing various degrees of economic segregation. All the regions have higher than the national average of STEM workers contributing to their economy and therefore provide an opportunity to test this relationship in multiple socio-political climates.

2.4. The approach adopted for analysis

The data used to test these geographies is publicly available, anonymized and aggregated data, made available by the Bureau of Labor Statistics and Census Bureau. Data tables pertaining occupation of civilian of ages 16 and over, distribution of household income and median household income have been used.

While measuring the concentration of poverty, researchers employ federal poverty standard. This method has some flaws, primary of which is that it ignores the differences in cost of living across commuter zones, thus overlooking the regional context. The categories of income are determined by the household income dataset provided by the census bureau for the years 1980, 1990, 2000,

and 2010. These data tables contain 17 income groups for 1980 and 1990 and 16 for 2000 and 2010. Thus, we classify these income groups into the defined income classes. As the income groups are absolute in their dollar value, projections were calculated to split them when required. After that, the households were classified based on their income classes.

To begin the process, the 2000 commuter zone boundary was imposed on the census tract cartographic boundaries of 1980, 1990, 2000 and 2010 to identify census tracts that fall within the scope of the study. Thereafter, the collected data was joined with the cartographic boundaries. Upon analyzing the median household income within a commuter zone, the range was divided into 5 percentile range, which forms the basis for distribution of households is set.

Households earning less than 20 percentiles of the range of median household income were classified as 'very-low' income household, twenty to forty as 'low,' forty to sixty as the middle,' sixty to eighty as 'high' and more than eighty as 'very-high' income classes. These income classes were then used to calculate the two measures as described in the earlier section. The Theil index was determined using an open source software using R as a programming language.

To obtain the occupation data Standard Occupation Classification (SOC) is used. This classification is used by federal agencies to classify workers into occupational categories to collect, calculate or disseminating data. All workers are classified into one of 867 detailed occupations according to the occupational definition. The list of 2010, 2000, 1990 and 1980 is provided by the Bureau of Labor Statistics. BLS has also provided *crosswalks* between the multiple lists, which allow one to establish horizontal consistency among the lists.

Using the above list, final occupations is determined that are classified as STEM occupations. It was found that majority of the occupations were listed as *Professional Specialty Occupation.* The census bureau conducts individual level a category which can be found and is used by the census to collect statistics on employment.

To begin the commuter level analysis, the theil index and concentration of poverty were calculated for the entire region. The percentage of STEM workers was also determined. Thereafter the change in percentage of all the three metrices across the region and timeline was calculated. The calculated result is plotted as a bar chart in the next section.

Moving on, to test for the relationship at the census tract level, multiple regression analyses were conducted with the concentration of STEM jobs as the independent variable and concentration of poverty and theil index as the dependent variable. This was done to understand the nuances of the relationship as opposed to relying on one metric explained by a single metric overtime. The regression analysis was done to understand the extent to which stem jobs predict these two measures.

The STEM occupation data and the median income data is thereafter divided into 5 percentiles. For the STEM data, census tracts were identified which have the maximum number of STEM workers (top 20 percent based on percentile). These census tracts were characterized based on their location be it very-low income census tract, low-income census tract, *etc.* This distribution was used to conduct another set of analyses.

Together, the comparison of these statistics across the five commuter zones was synthesized into the analysis to create a relative understanding of spatial pattern delegated by STEM job across time and across the five case study regions. The findings and conclusions are based on the similar and dissimilar patterns that arise from this statistical and spatial analysis.

CHAPTER 3 – Findings

3.1 Regional level analysis

Commuter zones are large geographies and have been developed by USDA to delineate the economy better. The largest commuter zone discussed in this research is Seattle, which measures close to 100 miles if measured along the North-South axis. It includes parts of Mt. Baker Snoqualmie National Forest, Wenatchee National Forest and Mt. Rainer National Park. Given the geographic predicament, the clusters of households organically form at places which have feasible access to resources necessary for survival. While talking about a region, the focus here is specifically on towns and cities with a large concentration of households (> 10,000).

The first result being discussed is the regional level statistics of the Theil index, the concentration of poverty concerning the total observed population of STEM workers in the region. The statistics observed are summarized in Figure 02.

Commuter Zone	1980			1990			2000			2010		
	Theil diversity index	Concentration of poverty	The ratio of STEM workers	Theil diversity index	Concentration of poverty	The ratio of STEM workers	Theil diversity index	Concentration of poverty	The ratio of STEM workers	Theil diversity index	Concentration of poverty	The ratio of STEM workers
Seattle	0.3739	0.3264	0.18	0.4054	0.358	0.2	0.346	0.3873	0.23	0.31	0.35	0.25
Portland	0.3283	0.3412	0.15	0.2793	0.358	0.18	0.4585	0.4163	0.21	0.42	0.4	0.23
Denver	0.3421	0.3107	0.17	0.2938	0.2163	0.21	0.3072	0.3152	0.23	0.26	0.33	0.23
Fort Worth	0.3415	0.0811	0.14	0.3751	0.3241	0.18	0.3679	0.3051	0.19	0.35	0.31	0.19
Albuquerque	0.3081	0.121	0.21	0.3756	0.3163	0.23	0.4005	0.3102	0.23	0.34	0.37	0.24

Figure 2: Table indicating overall Theil index, Concentration of poverty and Ration of STEM workers as compared to all individuals employed in the region.

The figure is explained with the help of charts (Figure 03 a., b., and c.), which illustrates the percentage change in the indices across the three-time period.

The first chart shows the changes occurring in the time period 1980-1990.

In this decade the first two years were defined by the recession, wherein more than 12 million Americans faced joblessness. Steel and other heavy industries, particularly in the Midwestern Rust Belt struggled with competition faced from Japan and Germany, and the nation was experiencing large-scale deindustrialization.

Given the background of economic flux in the country, Denver shows positive statistics. The diversity index decreased by 14 percent and concentration of poverty decreased by 30 percent. During this time, many individuals left the city of Denver to find jobs elsewhere, however considering the overall region of Denver and the commuter zone around it, one witnessed growth

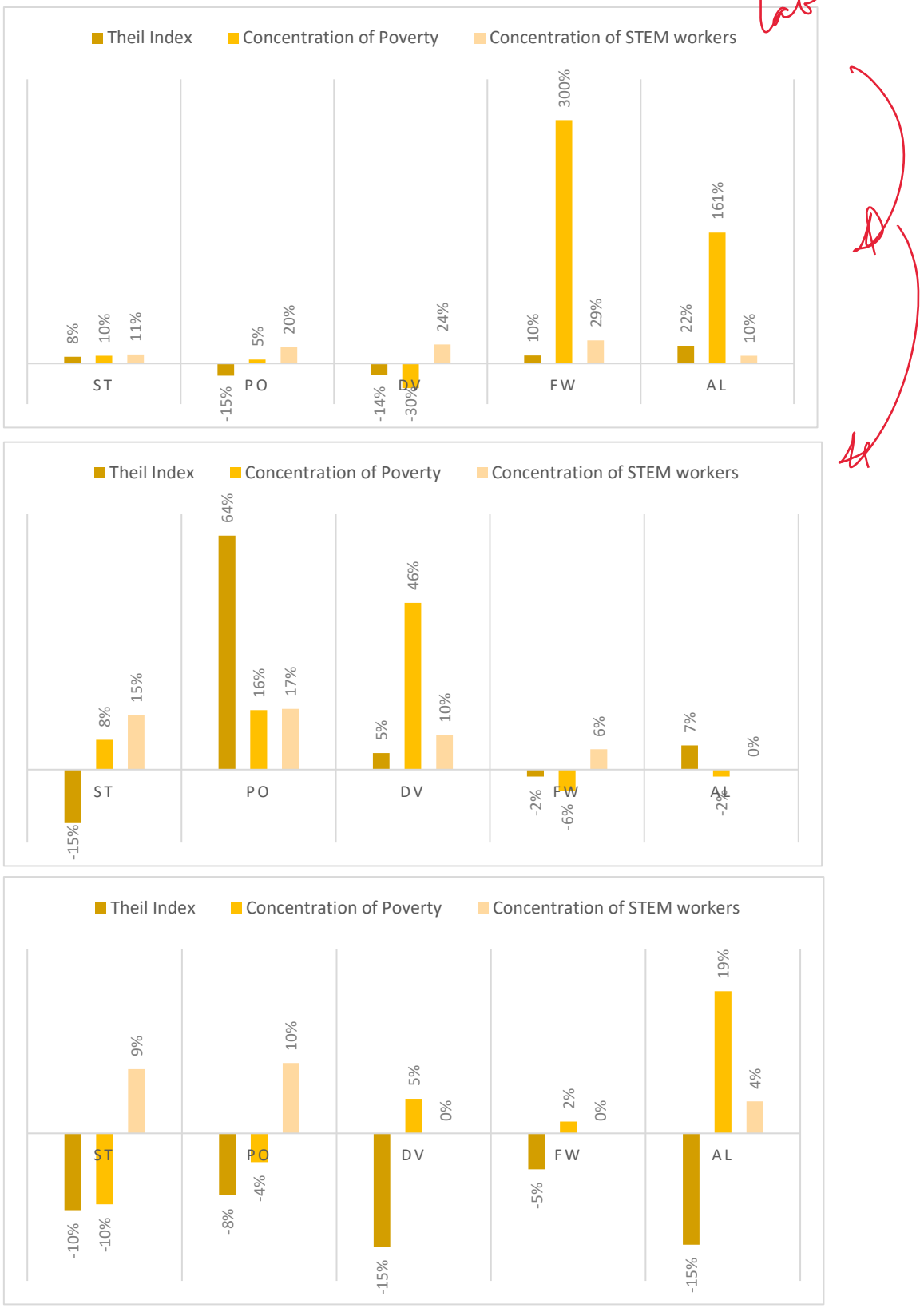


Figure 3 Percentage in the parameters; Theil index, concentration of poverty and STEM workers: a. Time period 1980-1990, b. 1990-2000, c. 2000-2010

decrease in diversity index respectively, however, both the regions seem to control the growth of concentration of poverty. The number of STEM workers also increased in both the regions. Lastly, it is interesting to note that during this time, in Fort Worth and Albuquerque (comparatively smaller commuter zones), the number of STEM workers increased 30 and 10 percent, and the diversity index also increased by 10 and 22 percent. However, the concentration of poverty increased at a remarkable rate. Fort Worth is also a part of larger economy comprising of Dallas and Arlington. For further research, including the census tracts in the other cities might be of interest. This will give a more holistic picture of Fort Worth's regional standing. Currently, it seems that during the time-period it was disproportionately affected by the increase of very-low-income households. Albuquerque, despite being a region of its own shows a tremendous increase in the concentration of poverty. This could be factored by lack of economic diversity in the region at the time. Upon observing the statistics for all the regions across the five commuter zones, it can be concluded that the concentration of poverty increased with the increase in STEM jobs. It can be argued that the technology market was growing. However the disbursement of the financial benefits during this time is inequitable especially in smaller commuter zones. The larger commuter zones with its diversity of economic activities were able to hold well against the economic challenges of this time period.

The 90s were the age of the internet marked by the World Wide Web and rapid growth in STEM occupations across the United States. Internet became the new frontier for businesses which spurred dramatic shifts in the existing economic landscape and had an equally dramatic effect on regional patterns, especially for the larger commuter zones. The time period 1990-2000 reveal a

reversal of trends wherein the concentration of poverty increased dramatically for larger commuter zones.

There was an increase in diversity index for Portland and Denver implying that they became more segregated but not for Seattle. The trends in Seattle wherein the region appears to have become more diverse, but the concentration of poverty has still increased, suggests that the commuter zone of Seattle suffered from a checkerboard problem during this time. The number of STEM workers grew by 10-20 percent in the three larger regions.

For the smaller economies such as Fort Worth and Albuquerque, a marginal decrease in concentration of poverty is witnessed. This indicates that the regions did not allow the trend of increase in the concentration of poverty from the previous decade to continue during the 90s. The number of STEM jobs did not increase remarkably for the smaller regions during this period. However the economic benefits reaped during this time seem to be distributed more equitably in the smaller commuter zones, than in the larger ones.

The last figure (Figure 3c.) describes the changes that occurred in 2000-2010. The economic boom continued over the first decade of the 21st century, and so did the number of STEM occupations for three of the five regions. Denver and Fort-Worth did not see an increase in the number of individuals performing STEM operations. Despite a downturn between 2006 and 2009 and the dot-com bust, the concentration of poverty was controlled for most of the region except Albuquerque (which does not have economic diversity).

The positive news from this era is the theil index statistics, which seem to have reduced for all the case study regions. This indicates that the regions at the time became less economically segregated. The trends suggest that during this period the fiscal benefits were distributed somewhat evenly, as more and more individuals were employed within STEM jobs. There is no distinction that can be made here based on the size of the commuter zone as similar trends can be viewed across the different commuter zones, the outlier being Albuquerque.

Out of the eighteen cases observed, there are five cases wherein an increase in all three parameters are observed. Six cases represent an inverse relationship between the theil index and concentration of poverty and five cases represent an inverse relationship between theil index and STEM workers. Eight cases observe an inverse relationship between the concentration of poverty and STEM workers. A low diversity index and high concentration of poverty as observed in many of these cases indicate towards the 'checkerboard problem' and is a mark of diverging economy wherein there are high concentrations of households with median incomes that are *very-low* or *very-high*.

Observing the parameters and their relationship with one another, it can be concluded that there are no apparent trendlines. The percentage change in STEM jobs does not relate to the percentage change in theil index or concentration of poverty at a regional level. It also reveals that regions of smaller sizes or with limited economic mix respond in an antagonistic manner to the national level economic phenomena when compared to regions which are vast and are economically diverse.

3.2 Census tract level analysis

The regional level analysis provided a comprehensive overview and understanding of the economic conditions and regional trends vis-à-vis parameters of segregation. The percentage change of the three metrics across the timeline were inconsistent and thus, did not reveal any patterns. To confirm the findings of the first set of analyses, and confidently whether the concentration of STEM workers exacerbates economic segregation or not, the study delves deeper

		Theil index		Concentration of poverty	
		R squared	Intercept	R squared	Intercept
Seattle	1980	2%	0.3%	9%	-0.7%
	1990	0%	-0.1%	11%	-0.7%
	2000	0%	0.0%	18%	-0.8%
	2010	3%	0.2%	12%	-0.5%
Portland	1980	7%	0.6%	5%	-0.5%
	1990	0%	-0.1%	14%	-0.7%
	2000	5%	0.3%	12%	-0.6%
	2010	0%	0.0%	10%	-0.5%
Denver	1980	21%	1.0%	33%	-0.6%
	1990	4%	-4.0%	44%	-2.0%
	2000	2%	0.3%	36%	-0.9%
	2010	5%	0.5%	27%	-1.0%
Fort Worth	1980	21%	1.0%	33%	-0.6%
	1990	4%	-0.4%	44%	-1.6%
	2000	2%	0.3%	37%	-1.4%
	2010	5%	0.5%	27%	-1.0%
Albuquerque	1980	20%	1.0%	12%	-4.0%
	1990	12%	0.7%	28%	-1.0%
	2000	23%	1.0%	26%	-1.0%
	2010	2%	0.2%	12%	-0.5%

***

*

Figure 4. R squared statistics and intercepts for equations determining theil index and concentration of poverty based on independent variable – concentrations of STEM workers at a census tract level

into the relationship between the STEM occupations and the selected measures by conducting series of regression analyses. The results of these analyses are discussed in this section.

The regression analysis is used as an instrument here to quantify the relationship between the parameters of economic segregation in consideration; the theil index and the concentration of Poverty, which is designated as the dependent variable, and the number of STEM occupations, designated as the independent variables, also referred to as a covariate. This was done by comparing observations associated with each of the census tracts for the four years (1980, 1990, 2000 and 2010). The need of quantifying the relationship between a dependent variable and a set of independent variables is to calculate the contribution of each independent variable to the value of the dependent variable. The models described in this study predicts the relationship between both the pairs theil index and STEM occupations and concentration of poverty and STEM occupation. The results are statistically significant. A statistically significant regression model of the parameters concerning the STEM occupations indicates that concentration of STEM workers in census tracts do exacerbate economic segregation. However, the value of the intercept and the robustness of the model (figure 4) indicates that there is a small increase/decrease in the measure with large increase of the concentration of STEM workers.

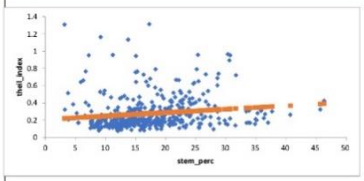
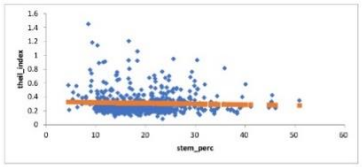
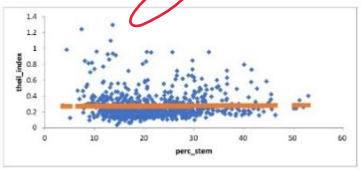
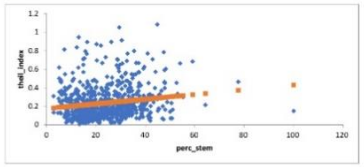
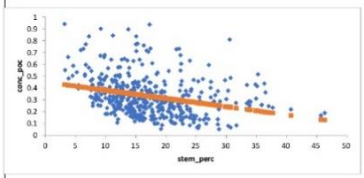
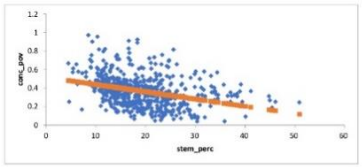
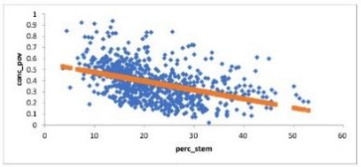
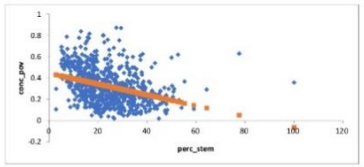
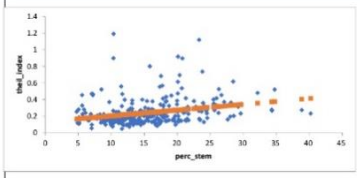
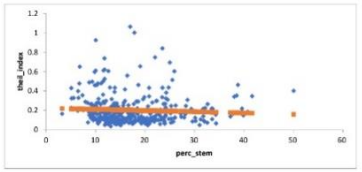
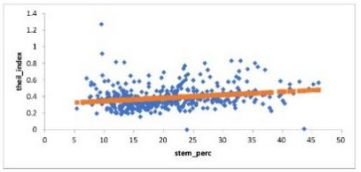
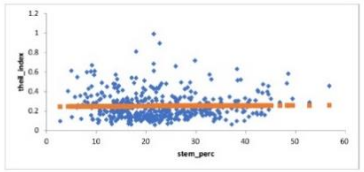
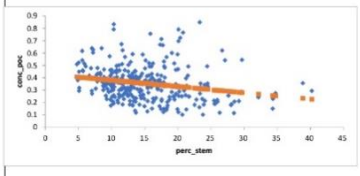
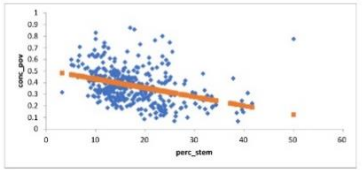
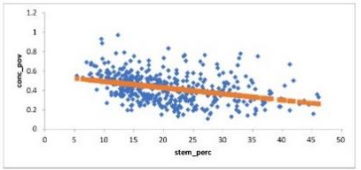
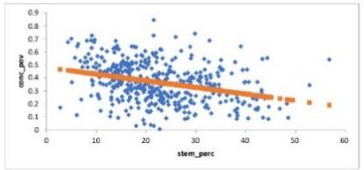
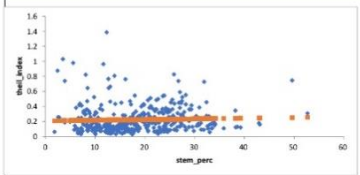
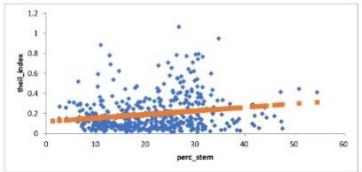
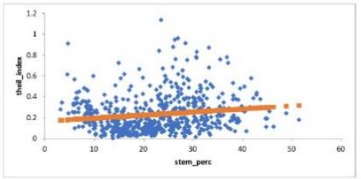
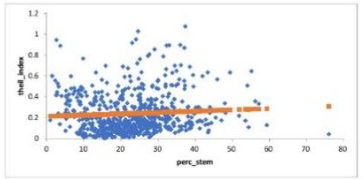
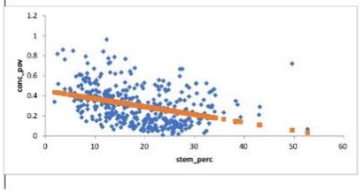
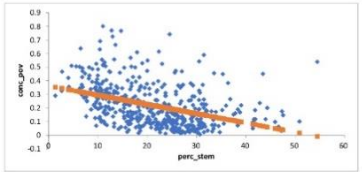
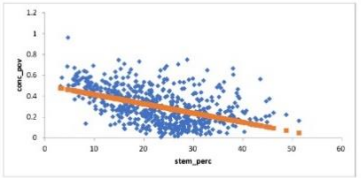
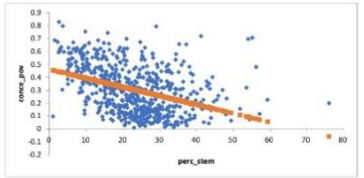
The table in figure 4 summarizes R squared statistics and the slope for both Theil index and Concentration of Poverty. It is observed that the values for theil index have low R squared statistics. This indicates that the variability of theil index around the data line is high and the measure is not well explained by the independent variable (ratio of STEM workers to the total employed individuals). The linear regression plots for this data is visualized in Figure 5.

Theil index generally has a slightly positive or no correlation with the concentration of STEM jobs in a census tract. This indicates that the diversity of households belonging to various socio-economic background within census tracts decrease with an increase in the concentration of STEM occupations. Based on the trends it can be concluded that the chosen parameters are a better indicator in cases of Fort-Worth and Albuquerque which have smaller economies and high concentration of workers involved in knowledge-based industries. For larger economies such as Seattle, Denver, and Portland, more information is required to generate a model that can predict economic segregation at a commuter zone level. Although the trends are consistent with the initial assumption, the results cannot be considered due to extremely low values of R squares.

On the other hand, STEM occupations provide better estimates of variability of the concentration of poverty, than the theil index. These results have high significance as well. In general, the concentration of poverty is inversely related to an increase in STEM occupations. One can interpret a census tract within which large cohort of people is employed in STEM occupations, the level of concentration of 'very low' income household belonging to the bottom 20 percentile of households based on the median income decrease. Based on the statistics observed for every 10 percent increase in STEM occupations, one can observe 0.07 – 0.4 percent increase in the concentration of poverty. The numbers for the intercept are low, representing only a marginal change in concentration of poverty based on STEM occupations. Nevertheless, it can be stated that the concentration of STEM jobs impact concentration of poverty more than the diversity of a commuter zone.

In the literature reviewed studies stated multiple factors of economic segregation at a regional level including education, income, and employment. Individuals belonging to the STEM sector is a measure of employment, and therefore only partially explain the patterns of segregation. The literature also confirms that STEM occupations have higher incomes and high level of education. An increase in a number of STEM workers must mean an increase of educated individuals and increase in high-income households, however as witnessed in the research, this is not the case, especially at a regional level.

can there be smoothed version
legibility?

	1980	1990	2000	2010
SEATTLE COMMUTER ZONE				
HOW WELL CONCENTRATION OF STEM OCCUPAITONS PREDICT SEGREGATION -				
HOW WELL CONCENTRATION OF STEM OCCUPAITONS PREDICT CONCENTRATION OF POVERTY -				
PORTLAND COMMUTER ZONE	1980	1990	2000	2010
HOW WELL CONCENTRATION OF STEM OCCUPAITONS PREDICT SEGREGATION -				
HOW WELL CONCENTRATION OF STEM OCCUPAITONS PREDICT CONCENTRATION OF POVERTY -				
DENVER COMMUTER ZONE	1980	1990	2000	2010
HOW WELL CONCENTRATION OF STEM OCCUPAITONS PREDICT SEGREGATION -				
HOW WELL CONCENTRATION OF STEM OCCUPAITONS PREDICT CONCENTRATION OF POVERTY -				

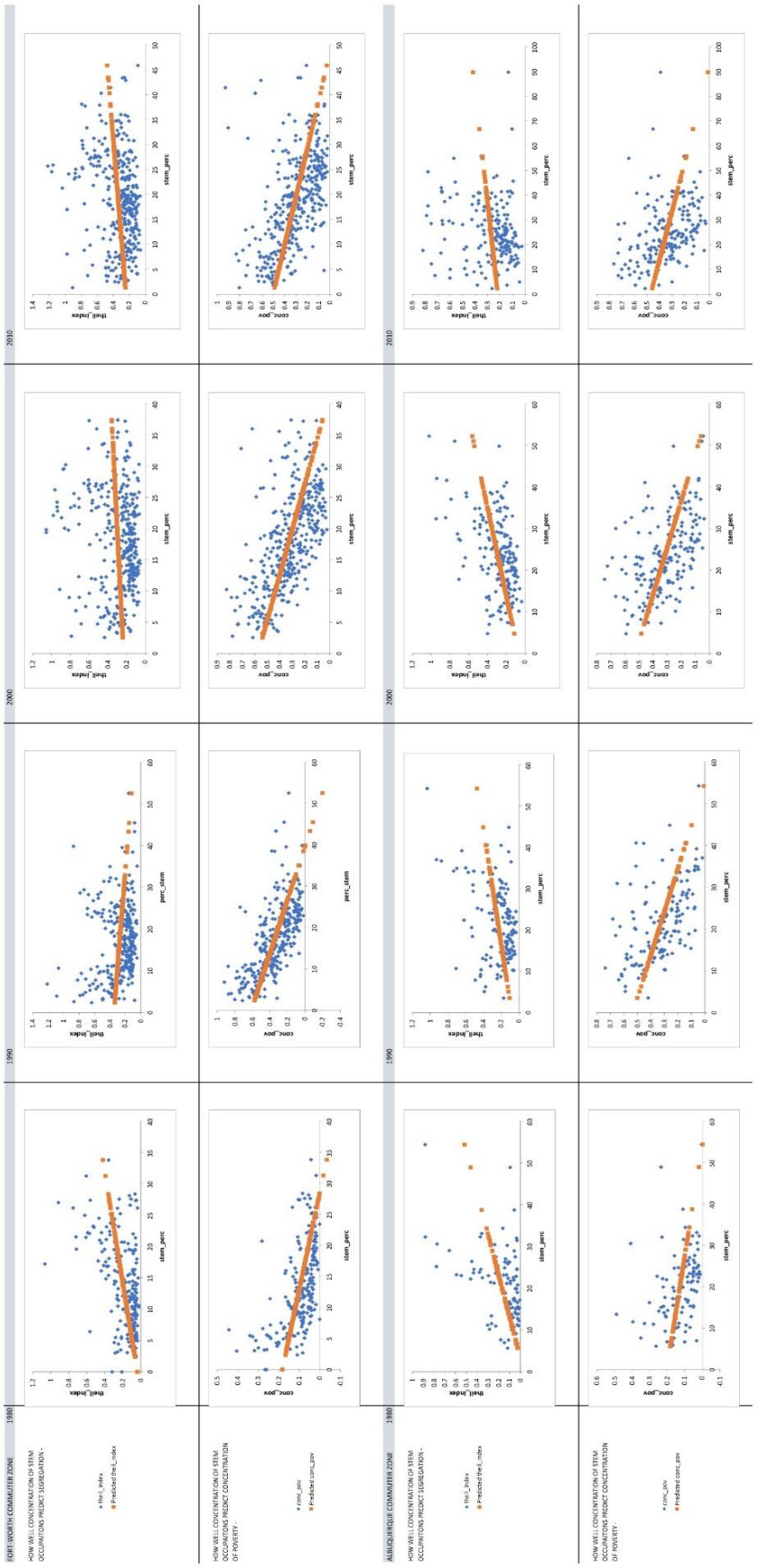


Figure 6: Statistical models are indicating a relationship between a. Theil score b. The concentration of poverty parameter and individuals involved in STEM occupations.

3.3 Exploring spatial relationships between case study commuter zones

The last section discussed the robustness of the relationship of concentration of STEM workers and concentration of poverty and theil index. Upon analysis, it is evident that between the two, the concentration of poverty is a better explained by the concentration of STEM workers and hence a better indicator of economic segregation caused by them. Given the robust, in this section, visual analysis is conducted between the two measures. Clusters of census tracts with a high concentration of poverty indicate high economic segregation. These events are mapped along the census tracts with a high concentration of STEM workers (top 20 percentile). Moreover, a comparative analysis is done for the percentage change of such census tracts vis-à-vis different classes of income, very-low, low, middle, high and very high.

Figure 7: Location map- Seattle commuter zone and important commercial centers.

3.3.1. Seattle (Tacoma-Bellevue)

The regional scale pattern for Seattle is illustrated in Figure 7 and Figure 8. Figure 8 shows that across the timeline, the areas with high concentration of STEM occupations include city centers of Everett, the county seat for Snohomish County, situated north of Seattle,

North Bend (King's County) situated in the east and Tacoma (Pierce County) in the South. The western edge of the city is lined with Elliot Bay.

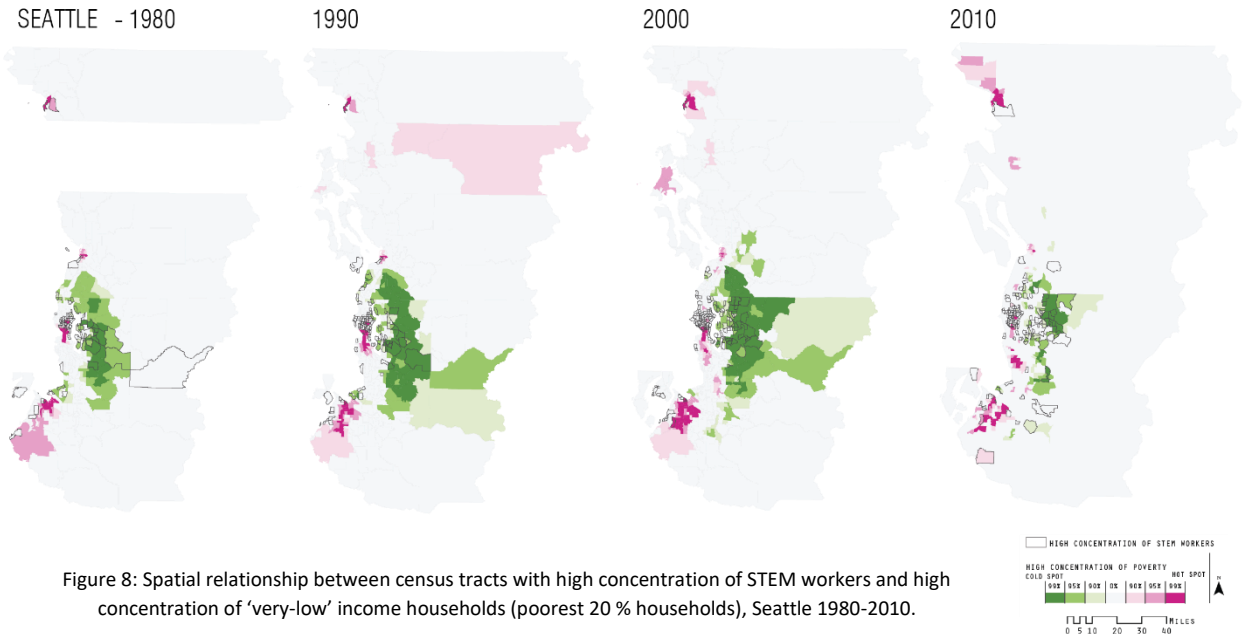
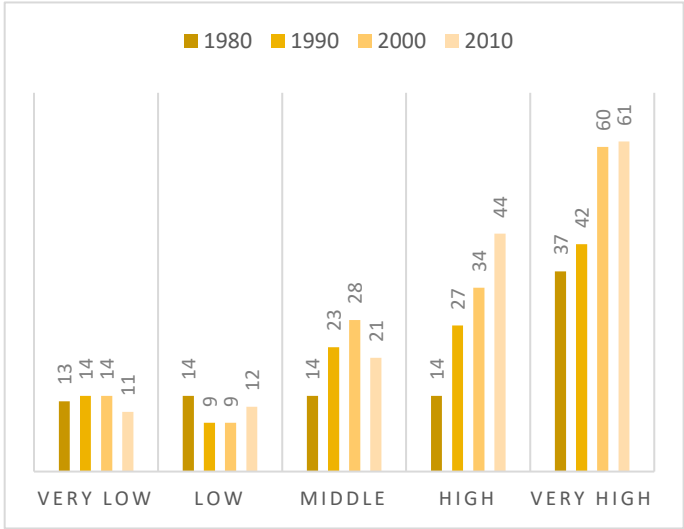


Figure 8: Spatial relationship between census tracts with high concentration of STEM workers and high concentration of 'very-low' income households (poorest 20 % households), Seattle 1980-2010.

Seattle was a heavily industrialized city until 1980. It has served as the headquarters of Boeing, a company manufacturing airplane from 1916 until the 1970s. With the decline in demand for industrial goods post-Vietnam war, the city saw a massive decline in the economy. Seattle had an intense economy before the 1980s which had witnessed booms and busts. Therefore the commuter zone already exhibited an economically segregated pattern.

During 1980 to 1990, Seattle commuter zone's fortune was closely associated with the growth of Microsoft. Its first product BASIC came out in 1976 and was incorporated in Albuquerque, and by 1978 the sales exceeded one million. They moved to Seattle Commuter zone (in Bellevue) in 1979. BY 1985, the sales were recorded over $140 million. Unlike Boeing which contributed to the economy only by employing individuals, Microsoft initiated a realm of entrepreneurs which



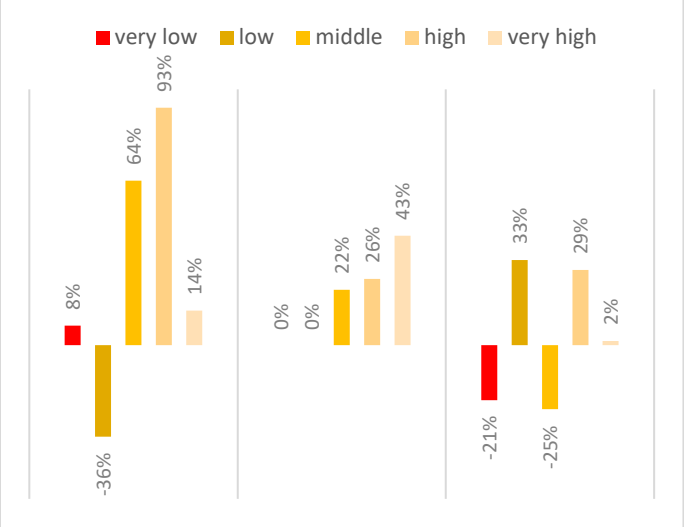


Figure 9a. Distribution of census tracts with high concentration of STEM workers across the five economic classes, very-low income, low income, middle income, high income and very-high income group for the commuter zone Seattle. 9b. percentage change in across the three time periods 1980-90, 1990-00, and 2000-10.

supported the technology created by Microsoft. This transformed the city; however, the locations of concentrated poverty did not change.

In 1980, the clusters of high-income census tracts were concentrated in and around Bellevue, which has been historically a rich suburb of Seattle, whereas the poverty was concentrated in the city centers of Seattle, Everett, and Tacoma. It is evident from the figure that individuals with STEM occupations did not choose to locate in areas with high concentration of poverty.

Although the census tracts with concentrated poverty are spread out along the region, ~~It is interesting to note that~~ there are only few that coincide with the clusters of very-low-income households. In the year 1990, the number of census tracts having a high concentration of STEM workers increased but not in the areas with high concentration of poor households. This pattern continues to appear in 2000 and 2010. Tacoma and Everett which were previously had a low concentration of poor households saw an increase in the number of STEM workers, benefitting

from the regional economy. In Seattle, the census tracts which previously housed them witness a decline in poverty levels and there are no clusters of concentrated poverty in and around Bellevue which has had a high concentration of STEM workers. In fact, Bellevue is in the 99 percent cold spot as per the figure 8.

This increase or decrease in number is better understood by figure 9 wherein the distribution of a number of census tracts across the five income groups being studied in the context of this research is visualized. In the year 1980, 13 census tracts with a high concentration of STEM workers also had large concentrations of very low-income households. Low, middle and high-income households also consisted of 14 census tracts each. A large proportion of census tracts with high concentration of workers, 37 census tracts, also had high incomes. In the year 1990, the number of census tracts with a high concentration of STEM workers saw a ~~negative growth~~ in the low-income census tracts and a slight increase in very-low-income census tracts as compared to the middle, high and very high income census tracts. In the next decade, the number of census tracts with STEM workers in low and very low-income groups did not increase. In the time period 2000-2010, a negative growth is witnessed for very-low-income census tracts (21%) however, there was an increase in the concentration of STEM workers in low income census tracts. Overall the number of census tracts with high income groups have increased dramatically over the years, with STEM workers choosing to locate themselves in high and very high income groups.

3.2.2. Portland (Vancouver-Hillsboro)

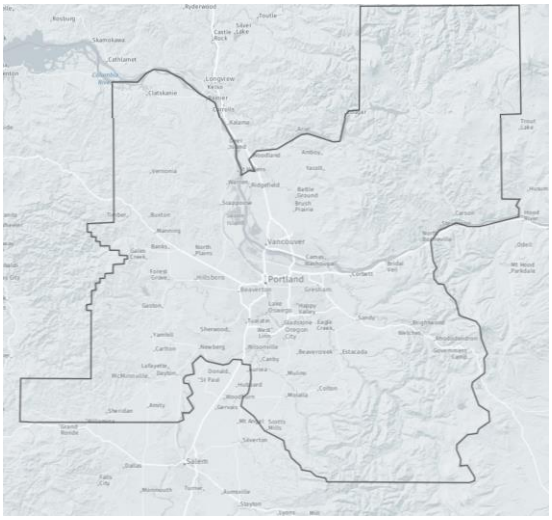


Figure 10: Location map- Portland commuter zone and important commercial centers.

While Seattle's STEM workers occupied areas with high concentration of poverty and transformed them into areas with a low concentration of poverty, in Portland, an increase in the number of such census tracts was observed in areas with a concentration of very-low and low-income census tracts. This pattern, however, occurs only to the south-west of the border of Portland and Washington. Areas in the commuter zones

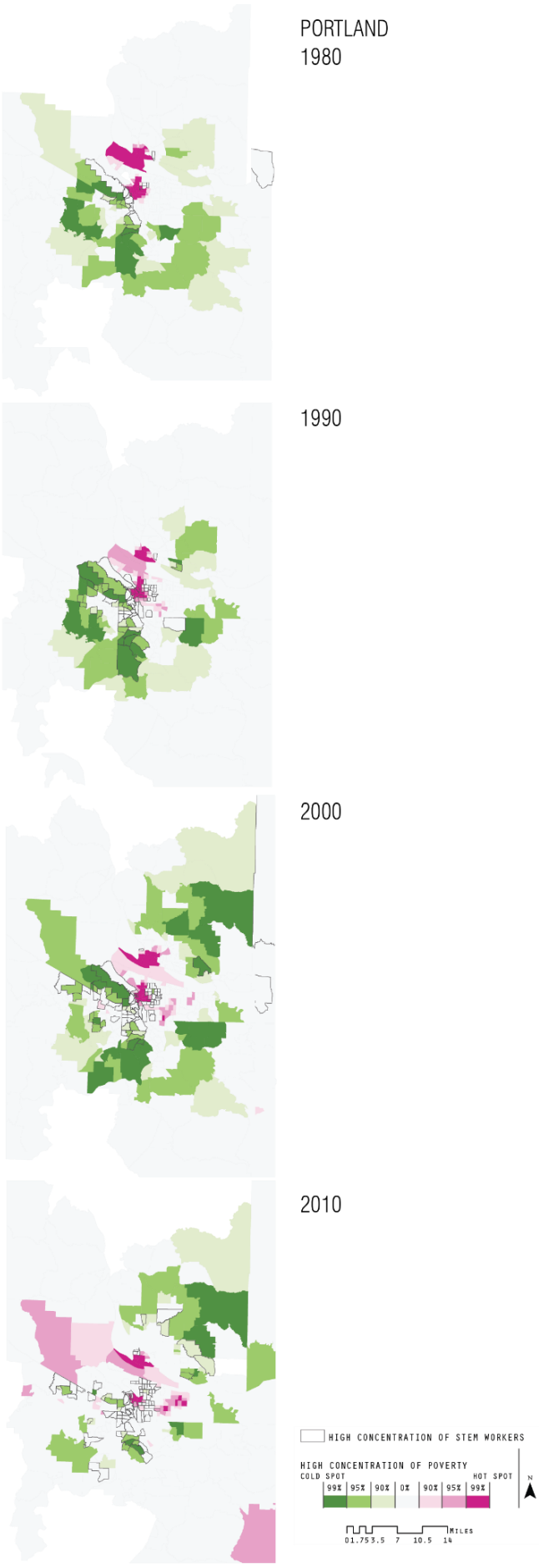
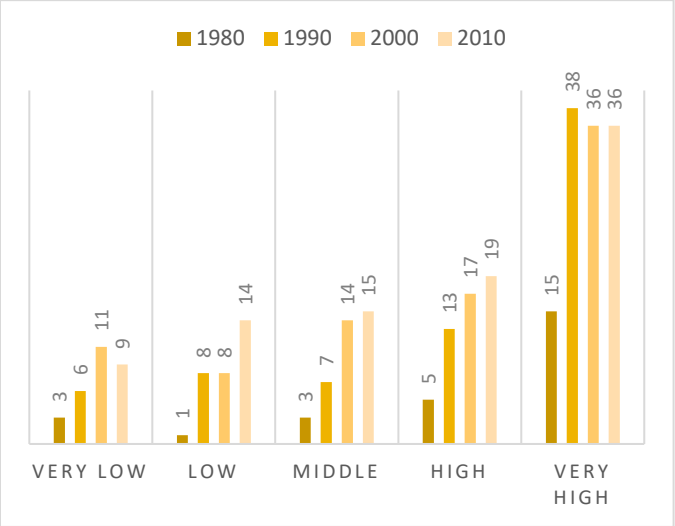


Figure 11: Spatial relationship between census tracts with high concentration of STEM workers and high concentration of 'very-low' income households (poorest 20 % households), Portland 1980-2010.



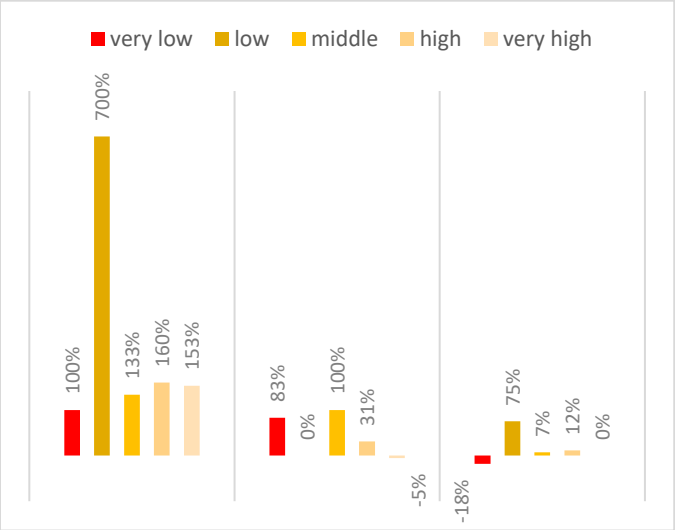


Figure 12a. Distribution of census tracts with high concentration of STEM workers across the five economic classes, very-low income, low income, middle income, high income and very-high income group for the commuter zone Portland. 12b. percentage change in across the three time periods 1980-90, 1990-00, and 2000-10.

which belong to the state of Washington consistently did not witness any clustering of low-income households, or census tracts with a high concentration of STEM workers, across the timeline.

Portland has long been Oregon's dominant economic center. The city's importance stems largely from its location. Situated on the confluence of Columbia and Willamette River, Portland is a major port in the Pacific North-West. During the post-war years, Portland maintained a strong commercial base and diversified its economy considerably (Price et al., 1987). This diversity allowed Portland to remain unfazed during economic downturn experienced by the rest of America in the 1970s and 1980s. This pattern is evidenced by the figures.

In 1986, the major STEM employers situated in Portland were Tektronix, Intel, Boeing of Portland, Floating Point System, and Electro-Scientific Industries.

As per the Fig. 11, in 1980 STEM workers situated themselves in the city centers of Beaverton, extending up to Hillsboro. Apart from these select census tracts, the concentration of poverty in the nearby census tracts observed is high, especially along the river banks. In 1190, the number of census tracts with a high concentration of STEM workers increased, in and around the city centers, especially around the south-west side of the river. It is observed that some census tracts with a high concentration of poverty are included in the clusters, regardless of which the census tracts with STEM workers are able to maintain a mix of households wherein there is a high number of high-income and very high-income households.

In 2000 the number of census tracts with a high number of STEM employees increased. The pattern of the growth is observed moving westwards towards Hillsboro which houses Intel's largest campus. This movement can also be explained by the MAX light rail which connects Portland, Beaverton, and Hillsboro. The census tracts with a high number of individuals employed in the STEM are still showing resilience to poor households. However, the physical proximity is reduced. Ironically, the commuter zone is becoming more ubiquitous in the distribution of income.

The patterns observed in 2010 convey that the concentration of poor households has yet increased. There is also a dramatic decrease in concentration of poverty across the border in Washington. This can be explained by new light rail lines of MAX commuter rail opening which connects downtown Portland and Vancouver Washington.

Looking at the figures 12a and 12b, we can observe that a large number of STEM workers chose to locate themselves in the census tracts with a concentration of very-low households and low households. The middle, high and very-high-income census tracts attracted far fewer STEM

workers than the formerly discussed income groups. Overall, in Portland also, the number of STEM workers remained high in very-high-income groups.

These trends project a reading in resonance with the expectation from a diverse economy such as the one observed in the Portland commuter zone. The reason might be the plethora of STEM occupation opportunities were provided courtesy the variability in industry observed. These occupations do not necessarily ask for higher education and therefore is within reach of individuals in low-income census tracts. Another reason for this trend could be the adoption of a regional boundary limiting the expansion of the city by Portland and its surrounding cities, called the Urban Growth Boundary. Adopted in 1977, this Boundary created an increased value of real estate in and around the city centers which can be afforded only by high-income households. Therefore, STEM workers might have chosen to live in a more affordable location, given they cannot sprawl out of the boundary.

Vancouver however, does not fall within this boundary and is a part of another state. In a way, it is the 'dirty little secret' of Portland and has a neutralizing effect on the economic forces that play a role in the part of the commuter zone which is within Oregon. The consistent increase in wealth observed in Vancouver, Washington, could be the growth boundary, however, since the area does not have a high concentration of STEM workers, it is clear that they choose to locate themselves in areas closer to the Portland- Hillsboro corridor active with tech opportunities.

3.3.3. Denver (Aurora-Lakewood)

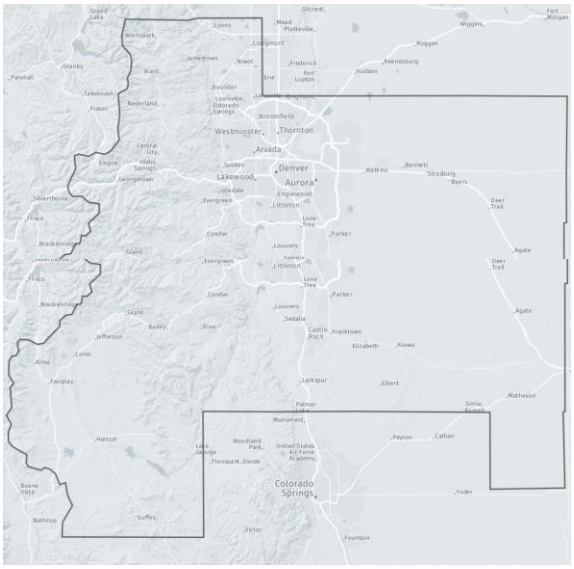


Figure 13: Location map- Denver commuter zone and important commercial centers.

When the transcontinental railroad bypassed Denver for cities like Cheyenne, Wyoming, efforts of business and civic leaders like John Evans helped to pass a bond to connect the 106-mile railroad from to Denver. This at the time was viewed as a risky investment at the time has paid off tremendously in the long run, as it was the key factor in the transformation of the city into one of the most thriving economies of the USA. Due to its strategic location, Denver has facilitated the

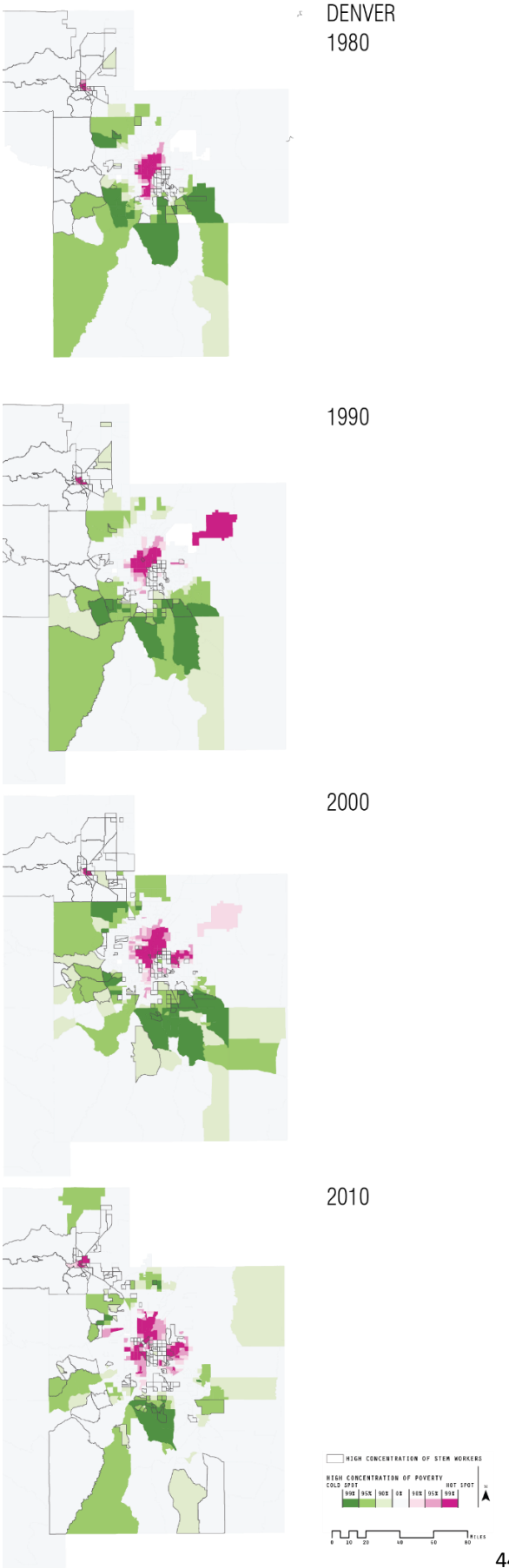


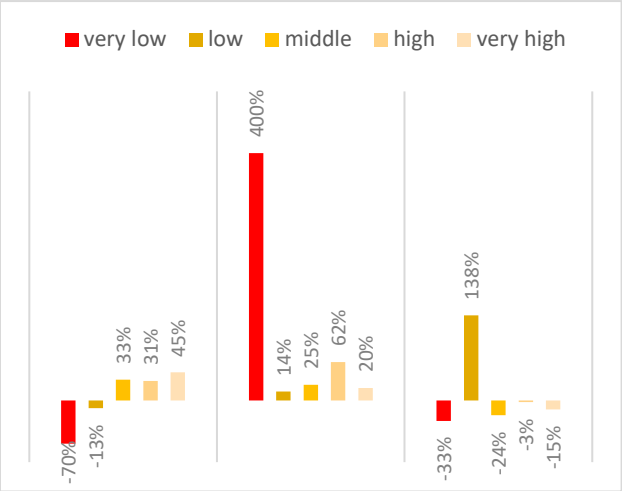
Figure 14: Spatial relationship between census tracts with high concentration of STEM workers and high concentration of 'very-low' income households (poorest 20 % households), Denver 1980-2010.

movement across the breadth of the country for over 150 years. As a center of confluence, the region saw a growing manufacturing industry and became a telecom hub during the early 20th century.

Denver saw a boom attributed to 'tech' industries before the other case study commuter zones considered in this study. Post-War George Wallace engineering firm which provided engineering expertise to the US Naval forces had his establishment in Denver. He moved the establishment later to a suburban office park in the south-east of Denver, around which a cluster of tech industries thrive soliciting expertise in data, telecom, aviation, *etc.* This made Denver extremely an attractive destination for migrants and also contribute to a massive over speculation of the success of the city, which inflated real estate rates.

Due to the above factors, during the economic distressed experienced by the country in the 1980s, Denver's economy fell precipitously, rendering a large population in the poverty level. This increase in the urban poor is evidence form concentration of poor income households mapped during 1980 (Fig 14). During the time the workers involved in STEM occupations remained close to the south of Denver, where George Wallace had established the Denver Technology Center decades before.

In the 90s, there were strategic attempts made by the administration to revive the city, such as low rentals for office space, to make the rates competitive and attracting more businesses. These exercises in economic planning paid off when by many industries revived in Denver. Today



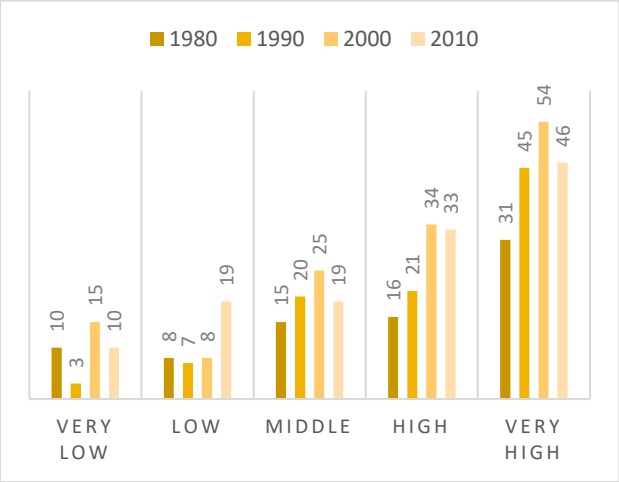


Figure 15a. Distribution of census tracts with high concentration of STEM workers across the five economic classes, very-low income, low income, middle income, high income and very-high income group for the commuter zone Denver. 15b. percentage change in across the three time periods 1980-90, 1990-00, and 2000-10.

Denver's economy has strong industries across sectors such as Aerospace, Aviation, Bioscience, Telecom, Energy, Health and IT employing a large number of STEM workers ("Denver's Changing Economy," 2016).

Given the context, in the 1990s the area observed expansion in some census tracts which have a high concentration of STEM workers. However, the concentration of poverty seems to increase around the urban core, rendering the commuter zone largely suburbanized. Census tracts with the lowest concentration of STEM workers had a high concentration of poverty.

In the map of 2000, it is observed that the number of individuals in STEM jobs increased in LoDo (Lower Downtown), which was once a thriving tech hub under George Wallace. The wealth in Denver seems to be more ubiquitously distributed. Having witnessed extreme economic woes in the past four decades, Denver at this time had adopted a comprehensive plan- 'DenverBlueprint', for the region in the year 2000 (Helicopter Planning, 2000), in a commitment to grow the economy equitably and control the

urban growth pattern. In 2010, with clustering of STEM occupation around the city center, the concentration of poverty gripping the city center seems to be alleviated.

Looking at the statistics in figure 15a and 15b, it is evident that the high number of STEM workers consistently chose to live in high and very-high-income census tracts, but there was a tremendous increase in the number for very-low-income census tracts in the time-period 1990-2000. During this time, we observed in our first set of findings that the concentration of poverty increased dramatically. It can be inferred that STEM workers choosing to live in the low-income census tracts was a factor of the regional economic conditions.

3.3.4. Fort-worth (Dallas-Arlington)

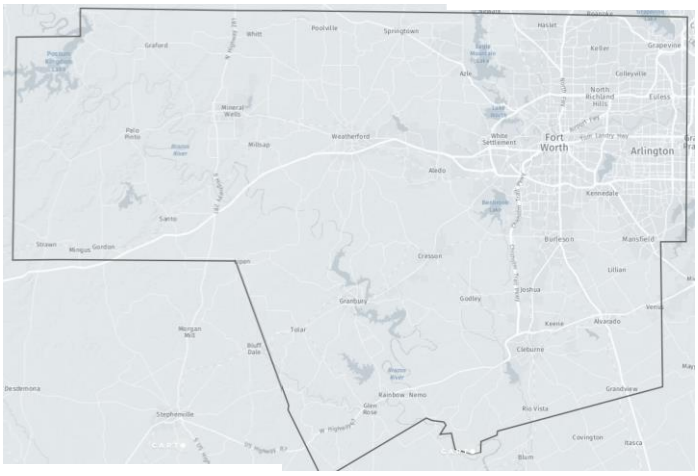


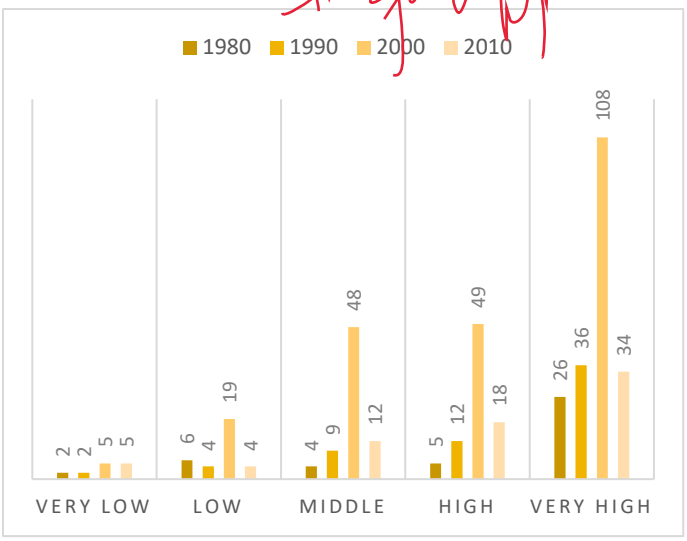
Figure 16: Location map- Fort-Worth commuter zone and important commercial centers.

Fort Worth is a city created by war. With the discovery of oil in Texas, refineries and pipeline companies such as Sinclair Refining Company, Texaco, and Humble Oil and Refining (Exxon Company) converged on Fort Worth, which also developed into a center for oil stock exchanges. The region thrived as an economy during the world-wars.

Figure 17: Spatial relationship between census tracts with high concentration of STEM workers and high concentration of 'very-low' income households (poorest 20 % households), Fort-Worth 1980-2010.

With the outbreak of World War II, the aviation industry came to Fort-Worth. The opening of Dallas/Fort-Worth International Airport in 1974 ushered in a new era of aviation history. At the time it was built, the airport was the largest in the world. The aviation/aerospace industry remains an important factor in Fort Worth's economy today.

Fort Worth enjoys the benefits of being a center in the aviation industry and its proximity to Dallas, the largest inland metropolitan in the USA. It also profits from the thick labor force contributed by several reputed university communities primary of which are, Texas Christian University, Texas Wesleyan, University of North Texas Health Science Center and Texas A & M University School of Law. The primary employers for STEM workers in the area are Bell Helicopter, Lockheed Martin, American Airlines, and XTO Energy ("Economic Development Plan," 2017).



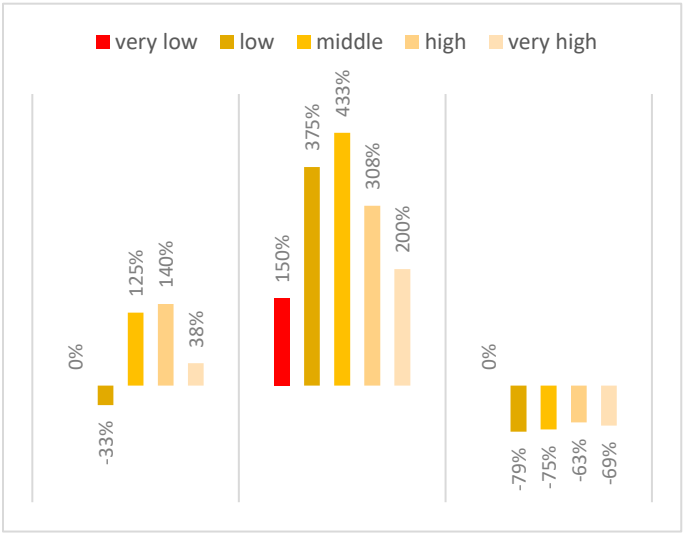


Figure 18a. Distribution of census tracts with high concentration of STEM workers across the five economic classes, very-low income, low income, middle income, high income and very-high income group for the commuter zone Fort Worth. 18b. percentage change in across the three time periods 1980-90, 1990-00, and 2000-10.

Fort Worth has been long dependent on Dallas for its growth, but it is growing fast as an independent economy. The effects of this change are captured in the maps, in figure 17.

The north-east part of the region consistently has a low concentration of poor households consistently throughout the timeline observed. This area is also closest to the city of Dallas. As one moves towards the South-West, the concentration of poverty increases.

In Fort Worth, the low-income census tracts are clustered in the city centers for all the years, and the high-income census tracts and concentration of STEM workers is suburbanized.

During 1990-2000, all the income groups saw an influx of STEM workers. During this time period, it was observed in the first set of findings that the concentration of poor reduced in the commuter zone. This trend was reversed in the years 2000-2010, with all income groups being hit somewhat equally, which means there was a brain-drain from Fort Worth during this time. The concentration

of poverty in the region increased by 2 percent and the region became more diverse during this time.

With dramatic change in population of individuals working in STEM fields and the observed leapfrogging of nodes with high concentration of poor and simultaneous suburbanization of STEM workers indicates that there is a massive tendency of sprawl in the region of Fort Worth, the sprawl in the region is expected to continue, if the growth is not directed by careful policy-making and there is a danger of substantial disinvestment over large area

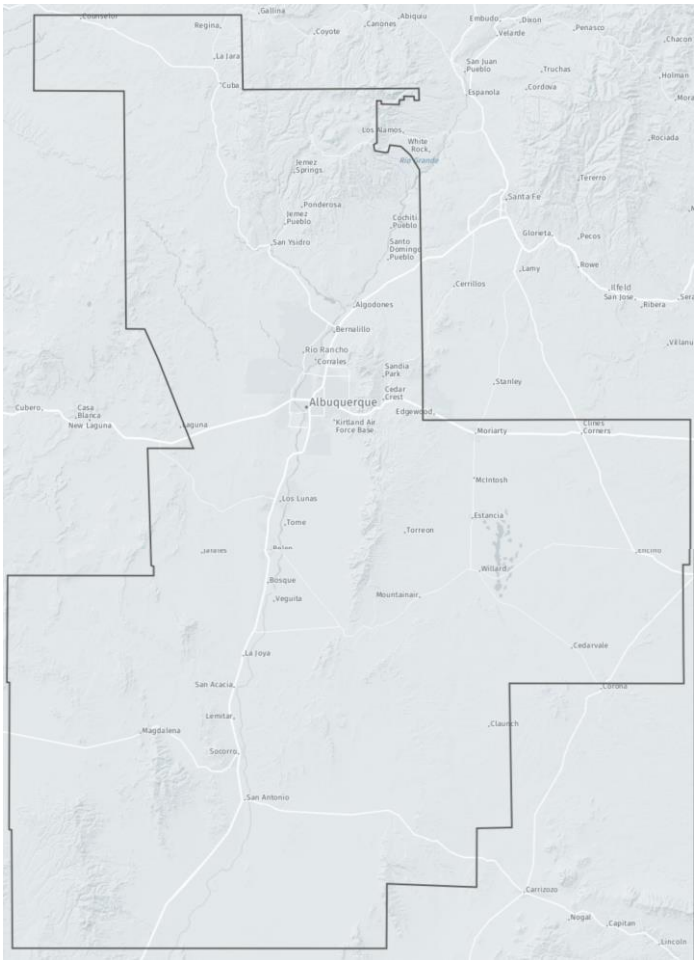
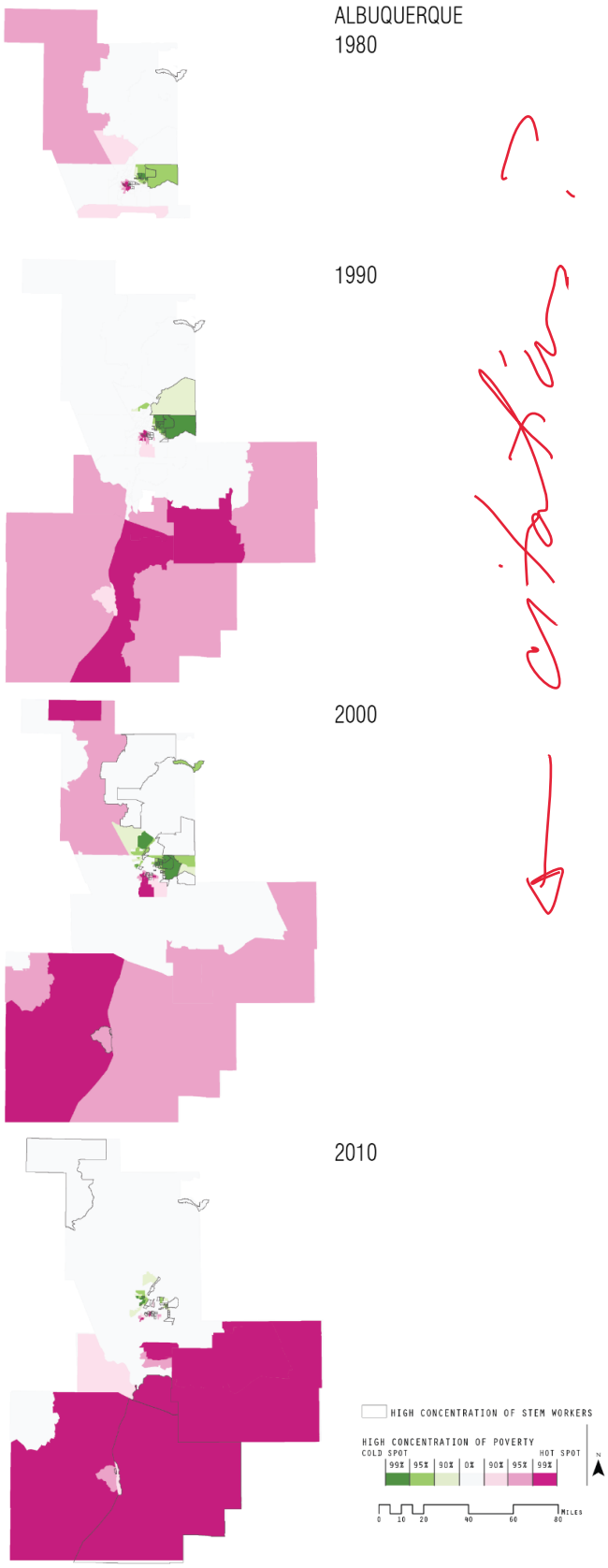


Figure 19: Location map- Albuquerque commuter zone and important commercial centers

3.3.5. Albuquerque (Santa Fe- Las Vegas)

The city of Albuquerque was founded in 1706 as the Spanish colonial outpost. The city had been a region of political tension until 1912 when it incorporated in the US.

The establishments critical for development in the region are US military-based organizations. The thick labor of STEM workers is maintained by the

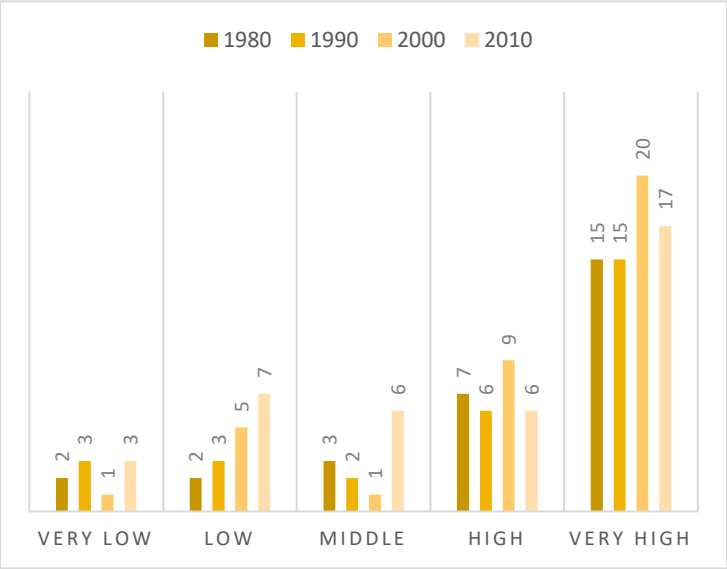


University of New Mexico, Kirtland Air Force Base, Sandia National Laboratories the National Museum of Nuclear Science & History and Lovelace Respiratory Research Institute. The city also has played a key role in the atomic age.

Sandia National Laboratories (Honeywell) mentioned before developed non-nuclear components for nuclear weapons. During the cold war, this area witnessed increased investment. The boom of Albuquerque's economy was short lived. Its downtown entered a phase of urban decline in the 1980s.

The trends witnessed in Albuquerque are quite erratic. Constrained by development in West and East the

Figure 20: Spatial relationship between census tracts with high concentration of STEM workers and high concentration of 'very-low' income households (poorest 20 % households), Albuquerque 1980-2010.



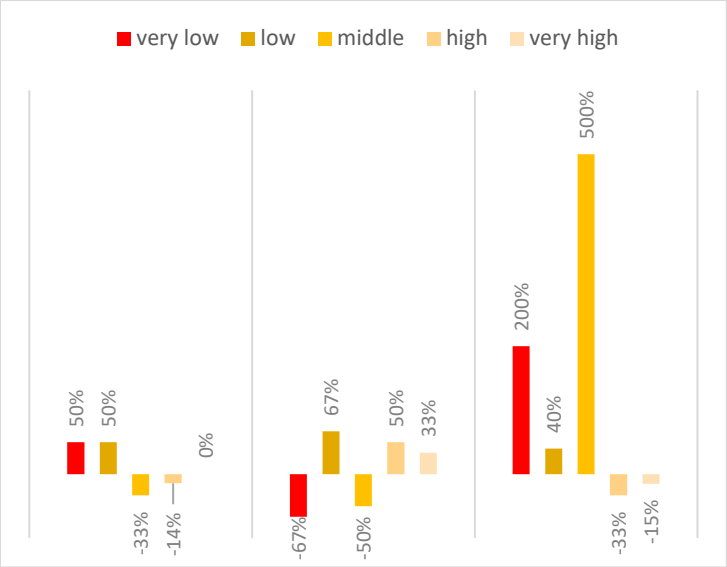


Figure 21a. Distribution of census tracts with high concentration of STEM workers across the five economic classes, very-low income, low income, middle income, high income and very-high income group for the commuter zone Albuquerque. 18b. percentage change in across the three time periods 1980-90, 1990-00, and 2000-10.

region grew South West and South East along the Rio Grande River. The concentration of poor income households remained at the periphery of the zone, with the center of the commuter zone remaining affluent throughout. The poverty levels are alleviated only in the time period 2000-2010, after three decades of sustained growth of STEM occupations.

Figure 21a and 21b indicate that although the number of STEM workers constantly high in the very-high-income census, tracts, the very-low, and low-income census tracts witnessed a substantial increase in STEM workers as well. The middle-income group saw an enormous increase in STEM workers in the years 2000-2010. Regarding spatial distribution of census tracts, there is observed a leapfrog effect in the growth 1980 to 2000 and then from 2000 to 2010 when the concentration of STEM workers moved from city center Albuquerque to portions of South

Valley (in the South West). This area subsequently seems to have transformed into a hub with an increased number of STEM employees choosing to locate here.

Paul Allen, the co-founder of Microsoft worked at Honeywell, and Bill Gates joined him in Albuquerque to create Microsoft, in 1975. It was evaluated at $3 Million when it moved to Bellevue in Seattle. This move singlehandedly changed the fate of two commuter zones studied here. While we saw Seattle coping with dramatic changes, in Albuquerque the cluster of low-income census tracts increased dramatically over the years.

3.3.6. Summary of findings

Regional Level
The percentage of STEM jobs increased/ stayed the same for all regions across all time periods.
The positive trend in STEM jobs did not simultaneously occur with a positive trend in theil index or concentration of poverty.
It can be interpreted that increase in STEM jobs does not necessarily imply a decrease in diversity or increase in the concentration of poverty
Census Tract Level
A regression model with STEM jobs as the explanatory variable and theil index as the dependent variable is statistically significant but not robust.
A regression model with STEM jobs as the explanatory variable and concentration of poverty as the dependent variable is statistically significant and more robust as compared to that of diversity index.
Theil index is directly proportionate to the concentration of STEM workers whereas the concentration of poverty is inversely proportionate.
Spatial Analysis
STEM workers live in wealthy neighborhoods across the five cities and timelines observed. This is despite sharp increases observed from time to time in concentrations of STEM workers in very-low, low and middle-income census tracts.
The percentage change is not constant and seems to be driven by larger political and economic constructs rather than occupation of local individuals.
There is clear suburbanization of STEM workers. They do not tend to reside in city centers, however, in cases such as Seattle and Denver, it is attempted to break this pattern.

It is interesting that at a regional level, the relationship is not apparent between STEM jobs and the selected measures. However, at a census tract level, all the readings indicated towards a specific relationship. This clearly speaks to the robustness of the model, in addition to the R squared statistics. It also suggests that at a regional level, when readings of specific census tracts are not observed, the relationship might be inverse as the effects created by census tracts cancel out by others. More specifically, if the city of Tacoma is consistently representing a high concentration of poverty, the statistic can be neutralized by a low concentration of poverty in Seattle or Bellevue. This is intuitive; however, it brings to light a larger issue. In regions where a specific city is an economic driver, there is concentrated investment in the amenities of that area. The viability of the city makes it more sought after and it becomes unaffordable which drives individuals working in the city and who are not particularly wealthy, to live far off from the city centers creating lower access to opportunities for them. Therefore, this arrangement is not desirable for the local city center and the region as well. Thus, the relationship between STEM jobs and the measures of economic segregation are more local in nature and even to observe regional patterns, the research needs to consider specific census tracts to understand the picture.

Moreover, in the analysis of spatial patterns, it is consistently observed that high concentration of STEM workers places themselves in high and very-high-income level census tracts. The maps also indicate clusters of low-income census tracts and lower concentration of STEM workers in them. This spatial relationship is not captured in the statistics calculated and the regression model. Theil index is non-spatial in nature. Therefore it fails to reveal how spatially occurrence of STEM jobs segregate clusters of low-income households.

3.4. Limitations

The data used for the analysis is aggregated based on census tracts, and the hot-spots for the concentration of income clusters were created based on the contiguous edges option while calculating the Getis-Ord Gi* statistic. Thus, the concentration of poverty might seem to appear larger area than they in-fact are. This could be deceptive, especially in the case of Albuquerque where a large census tract seems to have a high cluster of poor, it can seem that a large area is poor, whereas the poverty could be concentrated in just a part of the census tract. A daysymmetric mapping of clusters of poor and diversity index might help resolve this issue, a could be a way to move forward from this research.

The household income is accounted for by Census Bureau in specific income buckets, and thus breaking off households based on quantiles of median income and calculating the number of households with the help of these categories can depend on the device of interpolation. In this study, we use the polynomial curve to interpolate the breakdowns.

CHAPTER 4 – Conclusion

It is clear from the findings that the relationship at a regional level between the occurrence of STEM workers and the indicators chosen, do not reveal a consistent relationship. Whereas the number of census tracts wherein concentration of STEM workers is high across all five cities in high-income census tracts. This confirms that the individuals in STEM workforce tend to be

wealthy. Moreover, if there was a consistent increase in STEM workers across the five commuter zones and timelines, there was little done to redistribute the wealth and maintain equity, as demonstrated by erratic increase/ decrease in concentration of poverty and theil index.

In the commuter zones Seattle and Denver, one can observe patterns of high concentration of poverty seen in the years 1980-2000, being broken in the years 2000-2010. Both the commuter zones were somewhat able to move STEM workers from their suburban dwellings to populate city center. This could be a resultant of the comprehensive plans adopted by the region in the late 1990s and early 2000s which targeted growth of the city centers. In other commuter zones, the commercial instruments seem to determine the growth to a large extent. Fort-Worth and Albuquerque both witness sprawl and growth of clusters of low-income census tracts. This clearly indicates a lack of a common mission for the region. This demand-driven approach will be costly over a long term, as the large area would require being serviced.

In the maps of all the region and across the timeline, it is observed that the clusters of low-income households continued to thrive at the same location and increased in size over time. Thus, there seems to be a pattern of propagation of poverty in the region. Interconnectivity and accessibility to opportunities, such as job centers, need to be maintained from these census tracts, however as the cluster grows it becomes increasingly difficult to do so. It is important to break the patterns such as these clusters to distribute resources equitably and sustain economic development in the area.

Another observation that seems consistent across the region is that the STEM workers located themselves in census tracts that are suburban, rather than within the city. The affluent middle-

class image of a suburb continues to exist, a trend dwindling in Denver and Seattle. This pattern is still prevalent in the other three regions discussed and are indicative of lack of mixed-use development, except in Portland, wherein the infrastructure ensures mixed-use of land resources across the regions many city centers. This lack of mixed-use development poses increased risk as the contingencies are not distributed over various land use types. Moreover, they allow for various uses to exist nearby which is the basis of walkable and livable cities.

This sprawl pattern observed also adds to the cost of amenities. This system also creates a framework that favors individuals who are employed in the STEM and works towards betterment for their children's education, is mindful of access to employment based on their location and increases the quality of life that they enjoy. This fosters livability in the towns and cities where the STEM workers reside, away from the city centers. On the other hand, it makes the living conditions worse for the rest of the population, living either in the city centers or in other pockets of the region. In economies such as Denver and Seattle, once the city centers became more viable, the low-income clusters were pushed out to the suburbs. In such cases, it is increasingly difficult to sustain the urban poor in the areas. While driving these individuals further from the centers, the system increases their travel cost and travel time and provides more unpredictability in the choices of urban amenities and infrastructure access, an issue currently faced by both the regions and other mature economies such as New York, Chicago, and San Francisco.

While this phenomenon can be considered similar to the suburban flight, there is a stark contrast. While suburbanization the typically wealthy lived far away from the city. This cohort had the wealth to maintain infrastructure for themselves through private investments, even when the

government was unable to provide for them. They maintained their access to employment opportunities and enjoyed living by choice in socio-economic groups that mirror their choices in the neighborhood and make the same income.

In the current situation when the poor are being suburbanization. First and foremost is not a choice for them but merely a result of economic woes. It results in complete segregation of the low-income households resulting in their isolation. It reduces access to amenities and infrastructure, facilities which are essential for survival. It reduces access to employment which might increase the levels of unemployment, and consequently increase crime. It also isolates the individuals living in lower-income groups from the network of innovation. It reduces their probability of collaboration with like-minded individuals and creates economically viable products.

This paragraph underlines two hidden costs attributed to segregation. The low-income households, when distributed in sparsely populated census tracts, makes it difficult to provide for infrastructures such as electricity, water, sewage, and internet. Urbanists have focused so much on concentrated carbon footprint due to back to city movement of the erstwhile suburban (affluent) dwellers, that they fail to recognize the increased cost of providing amenities to the urban poor. Another cost that arises from this isolation of low-income households is the cost of innovation due to a lack of social network which had the potential to accelerate and co-curated an innovative idea into brilliant solutions which could possibly help alleviate our standard of living.

Due to limited investment in these areas, there is also a danger of urban decay and the towns and cities which were functioning cities when the affluent resided can fall into disrepair. This cost of blight is another underlying cost of segregation.

In the case of Portland, it is observed how the geographic divide is it natural such as the river or man-made, such as the urban growth boundary affect the patterns of STEM workers and segregation. Despite lower taxes and more affordable land in Washington, the individuals in tech-sector preferred to locate themselves to the south-west of the commuter zone. Due to the urban growth boundary, the region remained contained which drove up the costs of living in the region and previously middle to high-income census tracts converted into low-income clusters. Moreover, the case study of Portland is also representative of how infrastructure affects or directs growth. The tech-jobs clustered around the Portland-Hillsboro region due to the presence of anchor institution- the Intel campus. With the high speed-rail connecting the center of Portland and Hillsboro, more census tracts in the central Portland and along the route started to attract a high number of STEM workers. Observing the cases of Portland, Seattle and Denver it could be stated that they are influenced by devices of planning and the lack of it.

Another event to highlight is that in recent times, the growth in the number of STEM workers in census tracts belonging to high and very-high-income level has been decreasing, highlighted by the percentage change charts in the distribution of STEM workers summary in all the five case study commuter zones. This can be attributed by two reasons; that after several years of strong growth, wages across STEM industries, however, study shows the compensation data shows that they are declining (Vincent, Kehrig, 2017). This could also be the result of inter-region competition wherein, their other regions are restructuring themselves as tech-hubs which may be driving the high-wage earning STEM workers to a different geographic location.

The conclusion section highlights the positives and pain points delineated by the spatial location of STEM workers vis-à-vis clusters of low-income census tracts. Planners and policymakers for decades have been approaching strategies of urban growth to manipulate the choices of individuals who are involved in knowledge-based communities banking on their tolerance, flexibility, and eccentricity, hoping to resolve the rigid patterns of economic divide created by industrialization and to bounce back from the financial impacts of the economic downturn caused during deindustrialization of American cities in 1980s. Thus, building on the observations, planners and policymakers the following section outlines specific recommendations for planning at the regional level which can enable equitable distribution of resources.

CHAPTER 5 – Recommendation

It appears that some of the case study regions have been more successful than others in strategically alleviating the clusters of poverty and controlling the urban sprawl. It is established that the concentration of poor can lead to disinvestment. Based on previous knowledge and inferences from the case studies, the study provides a few recommendations which will allow policymakers and urban planners to plan for growth while accounting for the negative externalities observed.

Robust Workforce Development-Areas affected with a concentration of poor in a region must focus on retaining local talent while drawing new leaders from outside to serve as a creative

catalyst. Efforts should be delineated to cultivate a pool of talented younger individuals who can step into leadership roles as they arise. A healthy population of young professionals can ensure replenishing civic leadership essential for creating consensus on policies determining economic growth and representation of the city within the region.

Moreover, there is already existing pool of professionals from STEM industries. This provides an opportunity to develop robust workforce development program wherein students, and disconnected youth can be connected to mentors working in the industry. Due to proximity to the industry, there is a possibility of creating an alternative curriculum for students than the traditional schooling. For the disconnected youth, resources can be provided wherein they can develop their skillsets in collaboration with the industry (devices such as internship program can be used), and they can be prepared for more blue-collared jobs.

The workforce development programs can ensure and add on to the thick labor workforce that these regions have access to. Such activities will allow access to opportunities to individuals who were previously marginalized due to their location.

Diversifying the economy- With the economy studded with uncertainties, it is essential to prepare for an event that can lead to a situation where demand for STEM occupations or demand for specific industries may decline. While the sluggish global economy is creating economic problems for traditional exports, other economic trends offer new routes and opportunities for poor countries to diversify. The trend toward the spatial splitting up of production across wide geographic areas and the emergence and growth of regional and global value chains offer new

ways for developing countries to export tasks, services, and other activities. Value chains offer developing countries a path out of the trap of having to specialize in whole industries, with all of the cost and risk that such a strategy entail. These steps will not only be a step forward in ensuring employment for all but will also open opportunities for blue collar jobs in low-income census tracts.

Moreover, needs to be a diversity has been considered valuable by economists both regarding consumption and production. Jacobs (1969) attributes the prosperity of cities to their industrial diversity. Quigley (1998) and Glaeser et al. (2001) identify the diversity of available consumer goods and services as one of the attractive features of cities. It is also a source of innovation as argued by Florida (2002a, 2002b), who stresses the importance of the diversity of creative professions employed in research and development or high-tech industries. More generally, Fujita et al. (1999) use the "love of variety" in preferences and technology as the building block of their theory of spatial development: the production of a larger variety of goods and services in a given location increases the productivity and utility of people living in that location.

Collaboration for a global economy- For regions, long-term success will hinge on aligning economic growth of all the economic centers within a city. The nodes should be incentivized to rebuild and brand themselves while building on synergies. This will promote the region's asset such as strong technology companies and vibrant neighborhoods with the relatively low cost of living, enabling, the region to compete for national and global employers drawing new businesses and residences. In such cases, regions together can compete for state grants and incentives. This will ensure a

comprehensive plan for a larger region and allocation and resources for households spread out in a larger expanse.

Moreover, smaller economic centers in the proximity to a large city within a region can create a niche for themselves while competing at a global level. Such centers can be the historical and cultural center of the region, the bedroom community of the area or a staging ground for a major industry. Such synergies maintain critical mass for local economic activities such as retail, for smaller as well as larger city centers and can sustain the economic engine within the region.

Share a regional vision for infrastructure and conservation – A competing visions among cities within a region might instigate the phenomena of the race to the bottom. This compromises quality of amenities, the safety of neighborhoods and most of all the conservation of the environment. There is a broad consensus among urbanists, economists, and local economic policy experts are that outlandish tax breaks ultimately have little influence on where a company decides to locate. Those decisions are based on more fundamental factors like location, talent, access to markets, and real estate costs. Instead, tax breaks simply transfer public funds that could be used for more much-needed public services like schools, housing programs, job training, and transportation to private corporations. Thus, the only real solution here is to instead of competing against each other regions should compete as a package. For instance, a region with multiple types of city centers can market themselves as affordable, culturally diverse and connected giving households more options based on their personal choices. Thus, the region collectively should plan for infrastructure which takes care of the low-income neighborhood. A sprawled region would be cost intensive and therefore, makes the regions comparatively less economically viable.

Growth can also be controlled by the urban service area, a device which physically constrains the development, the urban service area does so by controlling the level of service of infrastructure and extension of public water and sewer systems. St.Paul- Minneapolis adopted this strategy. Although a creative strategy it failed to curb the development of the policy failed to outline strict repercussions for developers not adhering to the policy (Fulton, 2001).

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