

Article

Socioeconomic Implications of Upstream–Downstream Relationships and Watershed Communities: A New York City Watershed Case Study

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Abstract: The historic New York City (NYC) Watershed Memorandum of Agreement signed in 1997, which established the Watershed Protection and Partnership Program (WPPP), aimed to safeguard water quality for downstream NYC communities and enhance community vitality within the upstream watershed. Up to now, the focus has been on maintaining water quality, with less attention on the socioeconomic and demographic well-being of the upstream communities. This study bridges this gap by examining the socioeconomic and demographic trends within the upstream watershed communities. We collected census data from the U.S. Census Bureau and American Community Survey (ACS) from 1990, 2000, 2010, and 2020. The data were collected primarily for the Catskill-Delaware Watershed region, as well as the five immediate watershed counties, New York State, the U.S., and two rural counties similar in population density to the Watershed to serve as comparison areas. This study analyzed demographic factors and economic, and community characteristics to identify trends and shifts over time. Our findings reveal the demographic shift towards an older retiree population, decreasing labor force, higher unemployment rates, higher disparities in income distribution, and longer commute times in the Watershed compared to our comparison areas. The Watershed also experiences higher home vacancies than the comparison areas, suggesting a shift towards seasonal or second-home use of properties. While this study offers insights into socioeconomic and demographic shifts in watershed communities, its reliance on census data may limit the precision in establishing causal links between watershed protection measures and these shifts. Incorporating qualitative analysis in future research will deepen our understanding of these relationships.

Keywords: socioeconomic trends; demographic trends; community vitality; watershed communities; water; water users; watershed protection; time series analysis



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1. Introduction

Community vitality can be evident in communities where there is considerable economic prosperity, robust social capital, and overall well-being [1]. For many decades now, policies have rested on the belief that a thriving economy automatically translates to improved overall well-being [2,3]. More recently, this assumption of a correlation between economic growth and societal well-being is being challenged [4–8]. The 1971 Conference on Income and Wealth promoted the inclusion of essential information on economic and social measurements to better gauge community well-being, particularly focusing on income distribution and wealth gaps [9]. Daly and Cobb (1989) introduced the Index of Sustainable Economic Welfare (ISEW), which includes indicators such as income distribution, environmental degradation, natural capital, leisure time, unpaid household labor, and volunteer work [3]. Recently, efforts to explore alternative indicators for measuring community welfare have gained momentum, notably through initiatives such as the 2009

Stiglitz-Sen-Fitoussi report, which advocates for a more nuanced and holistic approach to measuring progress and increased attention to non-economic factors to measure quality of life such as income and wealth distribution, commuting, housing conditions, social networks, political participation, and governance [7]. In 2015, the United Nations developed the Sustainable Development Goals (SDGs) based on the three pillars of sustainability: environment, society, and economy. Some of the 17 SDGs include good health and well-being, poverty reduction, equality, viable employment, and economic growth [10]. In this paper, we focus on some of these indicators, including income distribution and wealth gaps, through the Gini index [11] alongside other economic indicators such as labor force, per capita income, median income, and demographic factors such as population, age, race, educational attainment, as well as community characteristics such as commute times, housing vacancy and unemployment rate, to identify trends and shifts over time in the New York City (NYC) Watershed. By focusing on these socioeconomic indicators of community well-being together with demographic factors and community characteristics, this study contributes to the larger discussion and evolving understanding of community well-being measures, particularly as it relates to upstream watersheds. This research employs time series analyses to examine the NYC Watershed and comparison areas at the rural, regional, state, and national levels, uncovering demographic changes and socioeconomic trends over three decades (1990–2020). It seeks to comprehend the impacts, if present, of the Watershed Protection and Partnership Program (WPPP) prior to its initiation in 1997, as well as during its early and later phases of implementation. By analyzing socioeconomic trends occurring at different spatial and temporal scales, this study recognizes the cross-scale dynamics of the NYC water supply system, contributing to a comprehensive understanding of community vitality, and offering insights for policy decisions and future planning.

1.1. NYC Water Supply System

New York City is among the growing list of urban areas worldwide that obtain their water from regions outside their political boundaries [12,13]. There is a long history of the NYC water supply's upstream–downstream relationship. In the early 1800s, NYC struggled to meet both its water quantity and water quality demands [14]. The cholera outbreak in 1832 and the Great Fire in 1835 accentuated the worsening water situation, and thus began the search for clean and plentiful water north of the city [14,15].

The Croton Watershed supply system, built in the 1800s, encompasses the Croton and Kensico Watersheds, extending across New York's Westchester, Putnam, and Dutchess counties, as well as Fairfield County, Connecticut. Once the primary water source for NYC, it spans 971 square kilometers and still plays a strategic role in sustaining the city, providing 10% of its daily water requirements, a figure that can rise to 30% during droughts or operational demands [16]. As NYC grew, city officials looked northwest, across the Hudson River, to the Catskill region to expand the water supply. In 1905, the eminent domain was used to build new reservoirs in the Catskill-Delaware Watershed within the boundaries of Delaware, Greene, Schoharie, Sullivan, and Ulster counties. In the process, 17 villages were flooded, 4464 people were relocated, 8093 bodies were recovered from 57 cemeteries, and 604 km of primary roads were closed as the reservoirs were filling up [14]. Spread over 4101 square kilometers, the Catskill-Delaware Watershed supplies 90% of NYC's daily water requirements. The system includes six reservoirs, the Ashokan, Cannonsville, Neversink, Pepacton, Rondout, and Schoharie, each playing a crucial role in sustaining the water supply for NYC. At present, almost 80% of the Catskill-Delaware system is forested, of which 64.3% is owned by private forestland owners [17].

Today, the entire NYC Watershed surface water infrastructure includes 19 reservoirs and 3 lakes with a combined storage capacity of over 2 trillion liters, serving approximately 9 million NYC residents, representing roughly half of New York State's population. An estimated 90% of the drinking water supplied to NYC remains gravity fed, unfiltered and treated with UV disinfection [18]. It should be noted that a filtration plant was built for the older Croton watershed due to widespread urban expansion across a substantial portion of

the region [18]. Nearly 80% of the Croton watershed has been transformed into suburban areas, characterized by development patterns that intensify the peak flows of stormwater runoff, leading to erosion and instability along streambanks, higher concentrations of pollutants, and an elevated risk of accidental spills [16]. To mitigate these impacts, the construction of the Croton Water Filtration Plant began in 2007 and was completed in 2015 at a cost of USD 3.2 billion [18].

Managing water supplies in densely populated urban areas like NYC presents unique regulatory and environmental challenges, significantly influenced by land ownership within the watershed. Unlike many U.S. cities with predominantly public lands in their watersheds, almost 65% of NYC's watershed is privately owned [17]. This distinction necessitates innovative management strategies to maintain water quality and sustainability. NYC has implemented conservation easements and partnerships, compensating landowners for practices that support watershed conservation, and has enforced stringent regulations and educational programs to promote awareness and compliance among private landowners [17,19]. These efforts exemplify how urban areas can engage both public and private stakeholders in sustainable water resource management. NYC's experience offers valuable insights for other cities with similar land ownership profiles, highlighting the need for collaborative strategies in water management.

1.1.1. The Two Alternatives

When the US Environmental Protection Agency (EPA) mandated the filtration of all surface water through the Surface Water Treatment Rule (SWTR) in 1989, NYC sought an exemption from having to build a multi-billion-dollar filtration plant. An alternative known as the Filtration Avoidance Determination (FAD) allowed managers of surface water supply systems to bypass filtration requirements, but only if they could demonstrate to the EPA that they had implemented conditions to effectively manage human activities within their respective systems that reduce the risk of bacteria and virus contamination while maintaining the drinking water's quality [19]. NYC was faced with a momentous decision: they could either construct an expensive multi-billion-dollar filtration plant or implement policies to control human behavior in the watershed.

Ultimately, NYC chose to pursue the path of managing and regulating behavior. NYC enacted harsher restrictions on septic systems and agricultural and commercial runoff, as well as limiting the construction of impermeable surfaces in the upstream watersheds [15,20]. Because of this initial commitment, the first FAD was approved in 1993, and subsequently in 5-year intervals, and more recently every 10 years [21]. When adjusted for 2020 dollars, maintaining a watershed protection program costs about USD 100 million per year as opposed to the cost of building the filtration plant, which is estimated at USD 12 billion along with USD 600 million in annual maintenance costs [15,20].

1.1.2. Pushback from the Watershed Communities

When the draft watershed protection plan was released by the NYC Department of Environmental Protection (DEP) in 1990, local political leaders and inhabitants of the Catskill-Delaware Watershed were concerned that these restrictions would hinder economic development efforts, lower property values, erode the local tax base, and jeopardize other economic activities [21]. Consequently, a group of town supervisors throughout the region established the Coalition of Watershed Towns (CWT) to oppose the restrictions [21,22]. After several years of negotiation with NYC DEP, New York State (NYS), and several stakeholder groups, in 1997, the NYC Memorandum of Agreement (MOA) was signed, which aimed to safeguard water quality as well as strengthen community vitality in the upstream watersheds [21,22].

1.1.3. Brief Economic History of the Catskill Region

The economic history of the Catskill region encapsulates a journey from an agrarian base through industrialization to becoming a leisure destination and adapting to mod-

ern technological advancements. Initially, the 19th century saw the region thrive on the tanning industry alongside logging, sawmills, charcoal production, and later, cooperage mills (butter firkins, tubs, barrels, etc.), bluestone quarrying, sheep and cattle production, dairy farming, and furniture manufacturing, drastically transforming its landscape and economy [15,23,24]. As these industries waned, the 20th century marked a shift towards tourism and leisure, with dairy farming, the establishment of small resorts, ski areas, and the popularity of summer camps responding to improved transportation and the region's natural appeal [15,23,24]. The 21st century introduced substantial changes with the rise of second-home ownership, revitalizing tourism through boutique accommodations, wellness retreats, and artisanal enterprises [24,25]. However, these developments brought challenges, including demographic shifts and challenges to the sustainability of traditional farming and forestry [16]. The creation of the NYC water supply system in the early 1900s was a pivotal event, altering the Catskills' socioeconomic landscape and its relationship with NYC [25]. This history reflects the Catskills' resilience and adaptability, navigating between economic growth, environmental stewardship, and the preservation of its natural, social, and cultural heritage.

1.2. Research Objective and Significance

The Catskill-Delaware Watershed (referred to as the Watershed from hereon) was selected as the study area because the region presents an effective case study for understanding the socioeconomic implications of upstream–downstream relationships in watershed communities. Previous research within the study area has primarily focused on the bio-physical aspect, i.e., the water quantity and quality. However, limited attention has been given to the socioeconomic dynamics that shape the well-being of the communities in the Watershed region.

There is a dearth of literature on the social and/or economic well-being of the watershed communities. The West-of-Hudson Economic Development Study (1999) commissioned by the Catskill Watershed Corporation [26] reviewed the economy of the Catskill and Delaware systems in order to facilitate appropriate loan and grant programs and to advise on mechanisms for administering the Catskill Fund for the Future. Similarly, the publication, *Farms in Transition* [27], prepared following Section 4.2 of the NYS Department of Health 2017 FAD, focused on agricultural impacts within the watershed region.

Hoffman [13] delivered a socioeconomic snapshot of the Catskill region from 1990 to 2000. Building on Hoffman's work, this paper seeks to expand the socioeconomic analysis from the 1900–2000 period to include data from 2010 to 2020, thereby offering an updated overview, including the initial and later stages of the WPPP. Moreover, it builds upon Hoffman's insights by considering the potential effects of the WPPP on the Watershed, broader aspects such as economic and social well-being, and ultimately, the quality of life within the Watershed region.

A recent report, *Review of the NYC Watershed Protection Program* (2020) by the National Academies of Science, Engineering and Medicine (NASEM) assessed whether the existing set of individual programs is suitable and sufficient to meet the requirements of the SWTRs in the present and coming years. Notably, they report that the WPPP has successfully maintained water quality within the Watershed region, ensuring compliance with the SWTRs. Furthermore, there are strong indications that this program will continue to be effective in the years to come [25]. However, the report recommended focusing more on enhancing community vitality within the Watershed area in upcoming years.

The report highlights that in the last 25 years, many highly effective watershed management actions have been implemented, so moving forward, additional efforts are likely to be more expensive and less efficient in achieving water quality objectives per incremental investment. Since there are now numerous near-optimal combinations of program activities that can produce similar overall performance outcomes, this increased flexibility allows managers to choose watershed management actions that not only support community vitality but also have minimal or no adverse effects on water quality [25]. Building upon

this recommendation to pay attention to community vitality in the Watershed region, this study assesses the trends of various demographic and socioeconomic indicators of community vitality suggested by numerous studies [3,7,9,10] such as population, population density, race, age, housing, labor force, unemployment rates, commute, income, and income inequality for 1990, 2000, 2010, and 2020. It also will discern whether the WPPP has had a noteworthy impact on the watershed community's welfare [1–5,7,8,28].

2. Materials and Methods

2.1. Study Area

The study was conducted in the west-of-Hudson (WOH) Catskill-Delaware Watershed that supplies most of NYC's drinking water (Figure 1). The Watershed stretches across five upstate rural counties, Delaware, Greene, Schoharie, Sullivan, and Ulster, with almost half of the Watershed falling in Delaware County (Table 1).



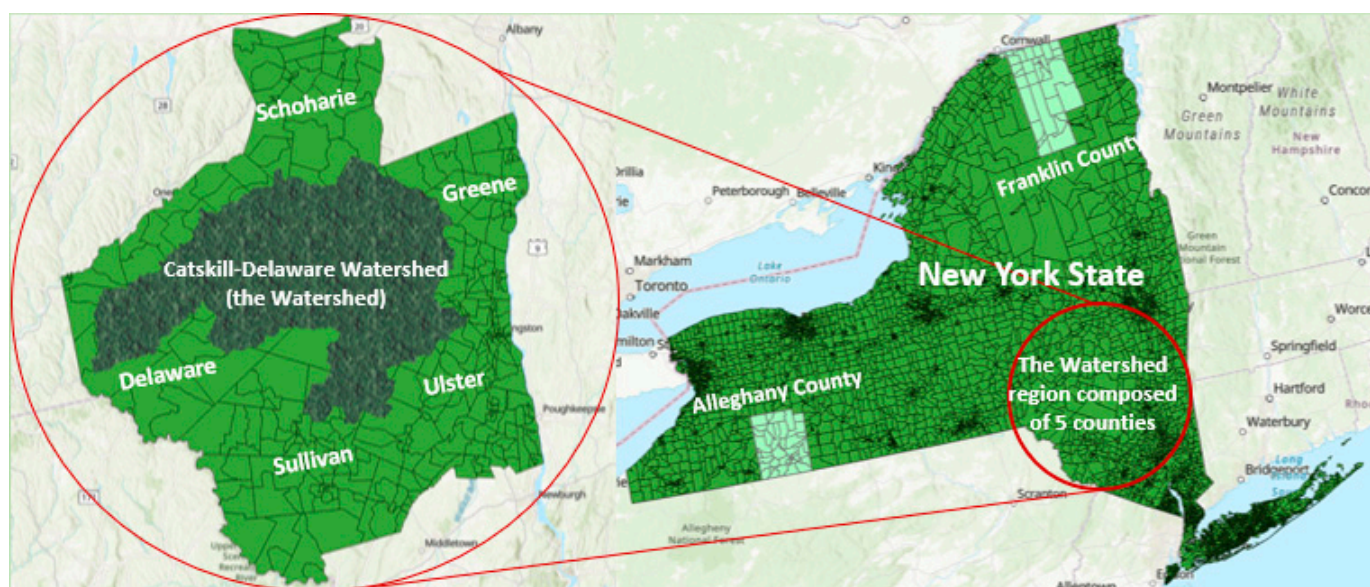
Figure 1. New York City (NYC) water supply system. Source: www.nyc.gov/dep (accessed on 21 February 2024).

Table 1. Watershed composition by county.

Five Counties	Area (sq.km.)	Watershed (sq.km.)	% in Watershed	Watershed Composition (%)
Delaware	3799	2034	53.54	49.60
Greene	1703	807	47.39	19.68
Schoharie	1621	143	8.82	3.49
Sullivan	2508	183	7.30	4.46
Ulster	3006	934	31.07	22.77
Total	12,709	4101		100

2.2. Data Collection

Time series data for the four decennial years 1990, 2000, 2010, 2020 for several socioeconomic attributes of the Watershed (local) and rural, regional, state (Figure 2), and national levels were collected from the U.S. Census Bureau and American Community Survey (ACS). Whenever available, standardized census data available through the National Historic Geographic Information System (NHGIS) [29] were used.

**Figure 2.** Comparison areas at local, regional, rural, and state levels of the Catskill-Delaware Watershed.

2.3. Data Analysis

Since Watershed-level summary data are not provided by the Census Bureau nor NHGIS, these data were extracted from the smallest geography level available, either the block group-level data, whenever available, or county-level, and then apportioning values from records that overlap the Watershed boundary by area to obtain Watershed level totals. All spatial analyses were conducted using ArcGIS Pro v.3.1. Once the Watershed level data were extracted, they were exported to Excel for analysis.

2.3.1. Comparison and Control Areas

To determine patterns that could potentially be attributed to the WPPP, we compared the socioeconomic well-being trends of the Watershed residents (local trends) with those of individuals residing at varying spatial scales, including national, state, regional, and two control rural areas. This enumerative and comparative technique has been described by Bartik (1991) [30] and used in the NYC Watershed case study by Hoffman (2008) [13].

In this study, ‘comparison areas’ encompass all aerial units—local, rural, regional, state, and national—while ‘control areas’ are limited to rural units. While the two rural control areas, Alleghany and Franklin counties, may not have a rich history in relation

to watershed protection, they do have similarities with the Watershed region [13]. They were chosen based on the following similarities: located in New York State, and therefore required to follow similar state regulations related to water management, small spatial extent (county level) to ensure compatible aerial units, and a comparable population to the Watershed, reflecting comparable rural economic and social population characteristics. The rural counties still had differences in characteristics with the Watershed, such as Allegheny County being smaller, i.e., 65% of the area of the Watershed, and Franklin County lacking access to and influence from a metropolitan center. The time series of socioeconomic values were analyzed in terms of total counts, densities, percent change along the timeline, or the average of the five counties when relevant.

2.3.2. Statistical Analysis

We analyzed census data at multiple spatial scales—local (the Watershed), rural (Allegheny and Franklin counties), regional (Delaware, Greene, Schoharie, Sullivan, Ulster counties), state (New York State), and national (U.S.) trends (Table 2). Since the Watershed is geographically independent from the two rural counties, but nested within the boundaries of the rest of the comparable areas, we conducted statistical analyses to compare the Watershed with the control areas, i.e., Allegheny and Franklin counties. Consequently, the figures presented in the paper primarily show differences in temporal trends in socioeconomic indicators at local and rural spatial scales, while the discussion incorporates all comparison areas including additional data from regional, state, and national levels.

Table 2. Different spatial scales against which to compare temporal trends in social indicators observed in the Watershed.

Areal Unit	Comparison Areas	Reason(s) to Compare
Local	The Watershed	Local trends
Rural	Allegheny and Franklin counties	Rural trends
Regional	Delaware, Greene, Schoharie, Sullivan, Ulster counties	Regional trends
State	New York State	State trends
National	The United States	National trends

To test for temporal trends in the socioeconomic indicators among the local and rural control areas, throughout the 30-year period, a linear model with an interaction term between the spatial group and year was employed. The model is structured as follows:

$$Y = \beta_0 + \beta_1 G + \beta_2 T + \beta_3 (G * T) + \varepsilon$$

where Y is the socioeconomic indicator value, β_0 is the grand mean, G represents the spatial group with three levels (Watershed, Allegheny Co., and Franklin Co.), T represents the year, the coefficients β_1 , β_2 , and β_3 represent the main effects of group, time, and their interaction, respectively, and ε is the error term. The interaction term allows us to test whether the time trend differs between the groups.

Upon obtaining significant main and interaction effects from the statistical model, we proceeded with pair-wise comparisons among spatial groups (i.e., Watershed vs. Franklin County; Watershed vs. Allegheny County; and Franklin vs. Allegheny County) for differences in the slope of temporal trends and predicted indicator value for the year 2020 using a Tukey test. This subsequent step was critical for pinpointing whether the differences observed were particularly pronounced for the Watershed compared to the other equivalent rural area. The utilization of the Tukey test served as a confirmation of the initial trends suggested by our graphical analyses, thereby reinforcing the validity of our findings. All statistical analyses were conducted using SAS v.9 [31].

3. Results

3.1. Population and Population Density

In 2020, NYS recorded the highest population density at 161 persons per square kilometer (boosted by the greater NYC area), in stark contrast to both the Watershed and Franklin County, which shared the lowest density at 11 persons per square kilometer (Table 3). It should be noted that both have substantial areas dedicated to the Catskill and Adirondack Preserves, respectively. Throughout the three decades, the population density figures for local, regional, and two rural areas remained fairly consistent around 11, 30, 17, and 11 persons per square kilometer, respectively. However, there was a noticeable increase in population density within NYS and the U.S., rising from 143 to 161 persons per square kilometer and from 27 to 36 persons per square kilometer, respectively.

Table 3. Population density for each decade from 1990 to 2020, at different spatial scales.

Trends	Comparison Areas	Population Density (per sq. km.)			
		1990	2000	2010	2020
Local	The Watershed	11	12	12	11
Rural	Alleghany	19	19	18	17
	Franklin	11	12	12	11
Regional	5 counties	28	30	31	30
State	NYS	143	151	154	161
National	US	27	30	33	36

In 2020, the Watershed's population was roughly 45,000 individuals. From 1990 to 2020, the population growth rate was the highest nationally, at a 2.5% annual increase, while Alleghany experienced the lowest change, with a decline of 0.86% (Table 4). Meanwhile, Franklin saw a modest annual population growth of 0.21%, in contrast to decreases of 0.86% in Alleghany and 0.15% across the Watershed.

Table 4. Annual percent change in total population for each decade from 1990 to 2020, and for the full 30-year time period at different spatial scales.

Spatial Scale	Comparison Areas	Annual % Change in Total Population			
		1990–2000	2000–2010	2010–2020	1990–2020
Local	The Watershed	0.42	0.04	−0.63	−0.15
Rural	Alleghany	−0.11	−0.20	−0.54	−0.86
	Franklin	0.90	0.09	−0.85	0.21
Regional	5 counties	0.56	0.27	−0.20	0.63
State	NYS	0.52	0.21	0.41	1.09
National	US	1.16	0.88	0.68	2.50

3.2. Race

In 1990, the demographic makeup of the Watershed was predominantly white, constituting 98% of the population. By 2020, this figure had declined to 88%, an annual decrease rate of 0.15%—the second lowest after Alleghany, which experienced an overall decline of 0.865%. This trend of a decreasing white population was observed exclusively in the Watershed and Alleghany, in contrast to the other areas under comparison, which all saw an increase in their white populations from 1990 to 2020 (Table 5). The decline in the white population within the Watershed was compensated by growths in the Hispanic, Black or African American, Native American, and Asian communities.

Table 5. Annual percent change in white populations for each decade from 1990 to 2020, and for the full 30-year time period at different spatial scales.

Spatial Scale	Comparison Areas	Annual % Change in White Population			
		1990–2000	2000–2010	2010–2020	1990–2020
Local	The Watershed	0.42	0.04	−0.63	−0.15
Rural	Alleghany	−0.11	−0.20	−0.54	−0.86
	Franklin	0.90	0.09	−0.85	0.21
Regional	5 counties	0.56	0.27	−0.20	0.63
State	NYS	0.52	0.21	0.41	1.09
National	US	1.16	0.88	0.68	2.50

3.3. Age

Over the past 30 years, there was an increase in the proportion of the population aged over 65 years, or the retiree demographic, across both the control areas and the Watershed (Figure 3). By 2020, the Watershed reported the significantly highest share of the retiree population at 23%, while the lowest was observed at the national level, with only 12%. In comparison, the retiree population percentages in the rural counties of Alleghany and Franklin were lower than the Watershed, standing at 16% and 15%, respectively.

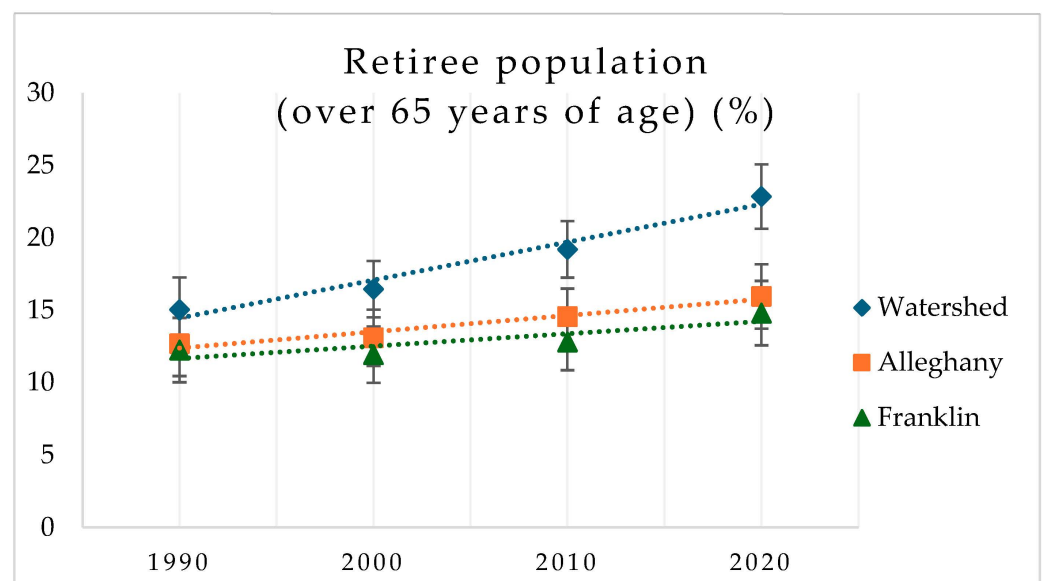


Figure 3. Retiree population (65+ Years) of the Watershed for decennial years 1990, 2000, 2010, and 2020 at local and rural spatial scales. Vertical bars represent standard errors of predicted values from linear model.

Similar to the percentage of people over the age of 65, the median age increased across all comparison areas over the 30-year period from 1990 to 2020. The Watershed had a significantly greater median age throughout the 30-year period compared to the control areas with the highest median age of 69 years in 2020 (Figure 4). The five-county region around the Watershed had the second highest median age in 2020 of 46 years, while Alleghany and Franklin counties have median ages in 2020 of 39 years and 40 years, respectively, which is closer to the state and national trends. The increase in median age over the 30-year period was significantly higher for the Watershed (Table 6), at 0.56 years per year.

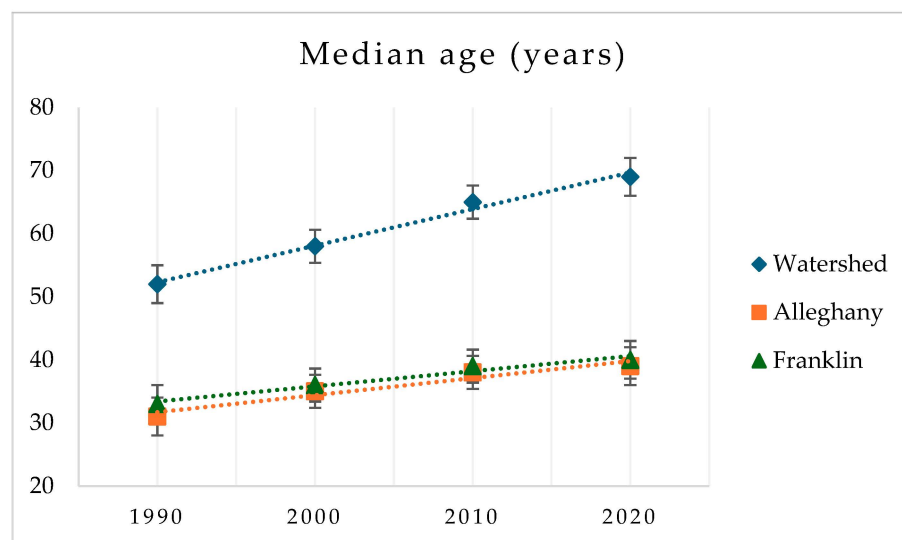


Figure 4. Median age (years) for the Watershed for decennial years 1990, 2000, 2010, and 2020 at local and rural spatial scales.

Table 6. Results from the analysis comparing the watershed to the two rural comparison areas for each decennial year from 1990 to 2020.

Indicators	Main Effects	df	F-Value	p Value
Retiree Population	Group	2	67.78	<0.0001
	Year	1	72.39	0.0001
	Group * Year	2	9.28	0.0146
Median Age	Group	2	917.08	<0.0001
	Year	1	224.17	<0.0001
	Group * Year	2	20.06	0.0022
Labor Force Population	Group	2	5.90	0.0383
	Year	1	2.59	0.1586
	Group * Year	2	0.76	0.5090
Daily Commute	Group	2	297.54	<0.001
	Year	1	11.68	0.0142
	Group * Year	2	3.45	0.1008
Unemployment Rate	Group	2	21.34	0.0019
	Year	1	2.37	0.1748
	Group * Year	2	0.18	0.8423
Graduate or Professional Degree	Group	2	699.89	<0.001
	Year	1	233.13	<0.001
	Group * Year	2	61.94	<0.001
Per Capita Income	Group	2	753.63	<0.001
	Year	1	1860.47	<0.001
	Group * Year	2	62.97	<0.001
Median Income	Group	2	399.63	<0.001
	Year	1	1033.26	<0.001
	Group * Year	2	30.71	0.0007
Gini Index	Group	2	223.43	<0.001
	Year	1	10.67	0.0171
	Group * Year	2	0.14	0.8715
Housing Vacancy	Group	2	73.56	<0.001
	Year	1	0.02	0.8839
	Group * Year	2	0.66	0.5518

3.4. Labor Force Population

The labor force is experiencing growth in all areas except the Watershed. The Watershed exhibits a significantly lower and declining labor force at 61% in 2020 (Table 6, Figure 5).

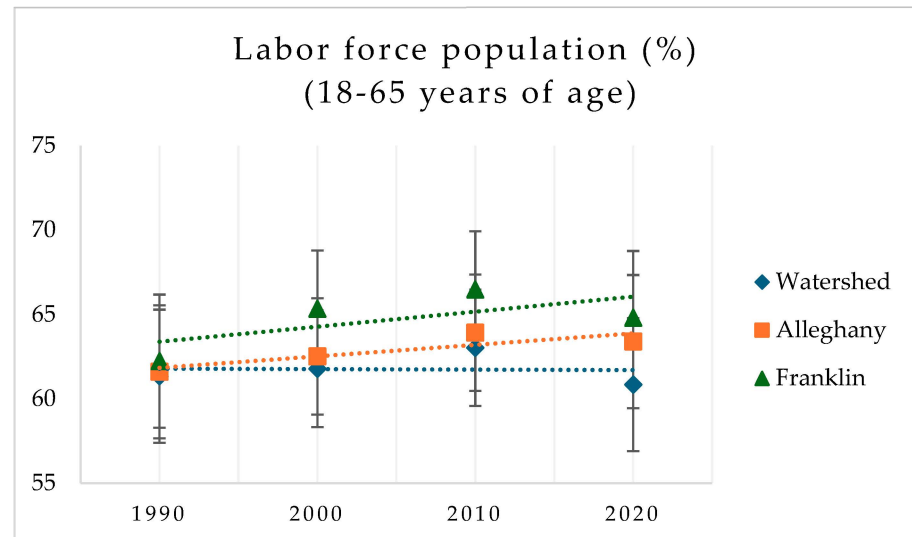


Figure 5. Labor force population (18–65 years) for the Watershed for decennial years 1990, 2000, 2010, and 2020 at local and rural spatial scales.

3.5. Commute

The labor force population in the Watershed, compared to the control areas, must commute longer (Figure 6). The average daily commute time has been increasing in the Watershed throughout the last 30 years, with 2020 having the significantly highest (Table 6) average commute time among comparison areas at 46 min followed by the state level at 21 min.

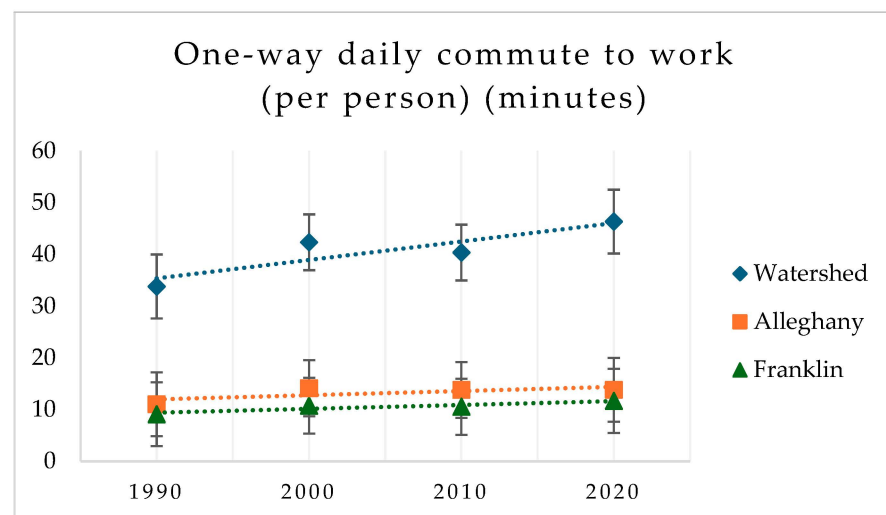


Figure 6. One-way daily commute time to work per person (minutes) for the Watershed for decennial years 1990, 2000, 2010, and 2020 at local and rural spatial scales.

3.6. Unemployment

The unemployment rate, as reported in Census data, reflects the proportion of individuals within the labor force who are not currently employed. There was no statistically significant temporal trend in unemployment for any areas over the 30-year period. However, compared to the control areas, the unemployment rate for the Watershed is the highest

statistically throughout the 30-year period at nearly 10% in 2020 (Table 6, Figure 7). This corresponds with the lowest and declining labor force in the population and the highest and increasing both median age and retiree population in the Watershed.

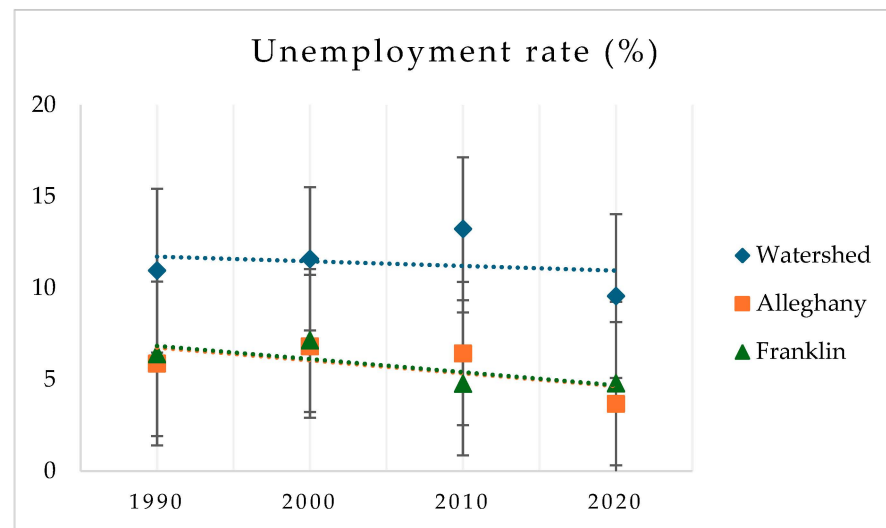


Figure 7. Unemployment rate (%) for the Watershed for decennial years 1990, 2000, 2010, and 2020 at local and rural spatial scales.

For the national, state, regional, and rural areas, it is less than 5%, with Franklin and Alleghany counties in 2020 at 4.8% and 3.7%, respectively.

3.7. Educational Attainment

The data depict a clear upward trajectory in the proportion of individuals holding graduate or professional degrees across all comparison areas from 1990 to 2020, with the highest proportion for the Watershed. Notably, the Watershed leads the trend significantly (Table 6), with the proportion more than doubling from 11% to 24% over the 30-year span, perhaps suggesting a robust educational or professional development environment.

The state-level educational attainment is second to the Watershed at 11%. Conversely, the rural control areas, while showing the lowest proportions at almost 7% (Figure 8), still reflect a positive momentum, indicating growing educational attainment.

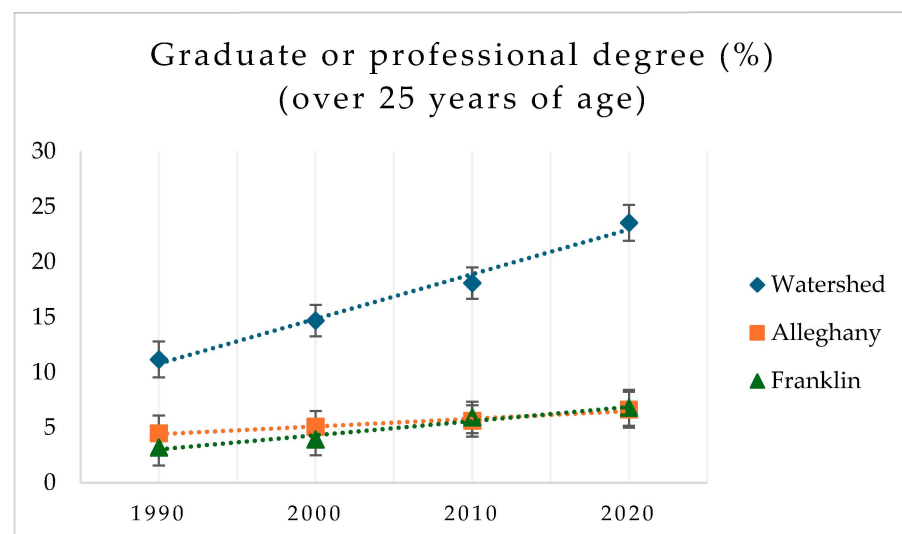


Figure 8. Graduate or professional degree (25 Years +) (%) for the Watershed for decennial years 1990, 2000, 2010, and 2020 at local and rural spatial scales.

3.8. Income

Over a 30-year span, income levels, including per capita income (PCI) and median income (both adjusted for inflation), have shown an increase across all comparison areas, with the Watershed area showcasing the significantly highest increases, reaching USD 46,000 for PCI and USD 109,800 for median income in 2020 (Table 6, Figures 9 and 10).

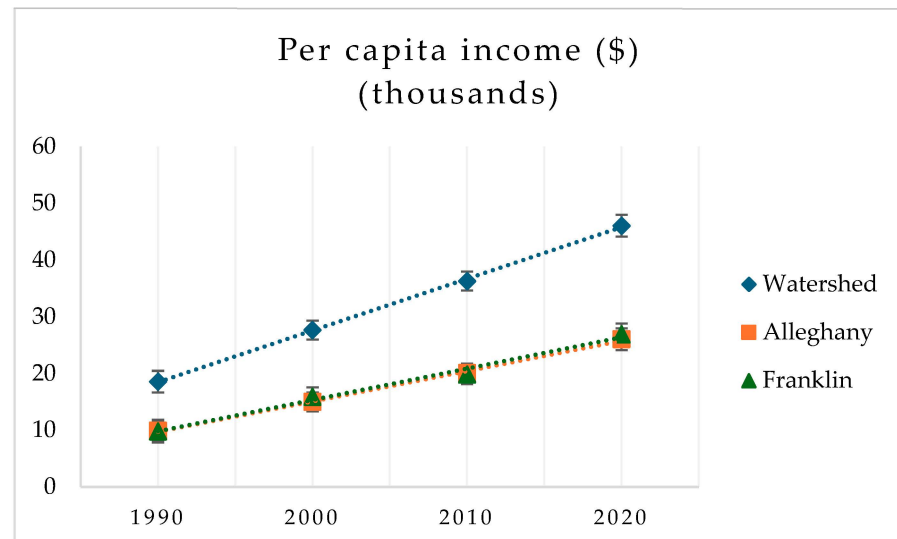


Figure 9. Per capita income in thousands (USD) for the Watershed for decennial years 1990, 2000, 2010, and 2020 at local and rural spatial scales.

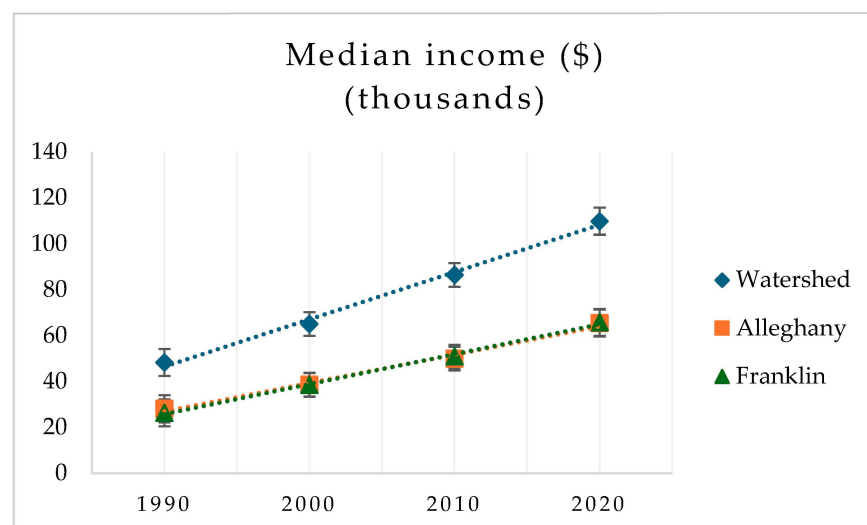


Figure 10. Median income in thousands (USD) for the Watershed for decennial years 1990, 2000, 2010, and 2020 at local and rural spatial scales.

It is important to note that income figures are based on data from the year before each Census. Thus, for clarity in graphical representations, the years 1989 and 1999 are labeled as 1990 and 2000, respectively, to maintain consistency along with other graphs. The 2010 and 2020 data utilize 5-year estimates from the ACS dataset.

3.9. Gini Index

The Gini index is responsive to changes in the middle of the income distribution and measures the distribution of income or wealth within a specific group. The index ranges from 0 to 1, where 0 signifies complete equality, and 1 indicates complete inequality [11].

While there has been an overall increasing trend in the Gini index in all comparison areas over the last three decades, it is significantly higher for the Watershed throughout the period (Table 6), with a value of 0.64 in 2020 (Figure 11). A higher Gini index suggests higher income inequality and irregular distribution of the income in the Watershed.

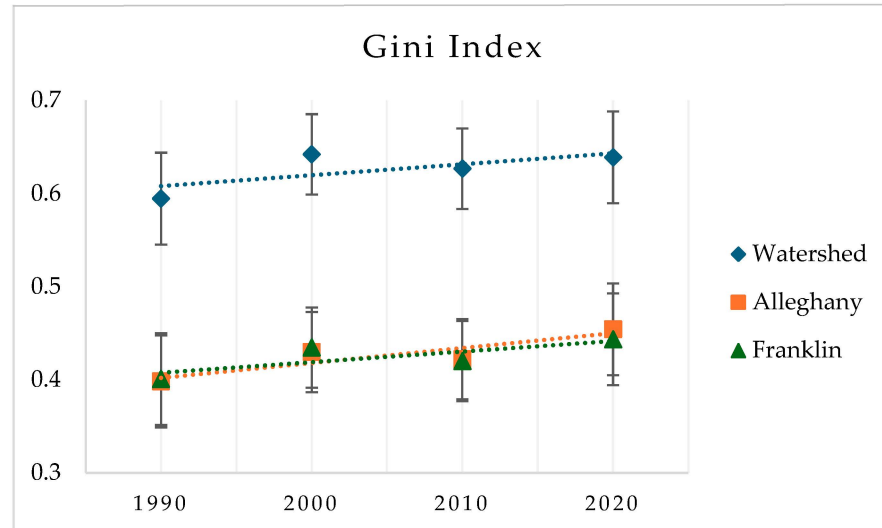


Figure 11. Gini index for the Watershed for decennial years 1990, 2000, 2010, and 2020 at local and rural spatial scales.

In contrast, the Gini index was the lowest in 2020 for the five-county region surrounding the Watershed at 0.44 and the rural counties of Alleghany and Franklin at 0.45 and 0.44, respectively.

3.10. Housing Vacancy

Vacant housing includes both temporary residences and second homes (United States Census Bureau, 2024). While the overall trend is somewhat stable for all comparison areas, an estimated 42% of the housing units in the Watershed were vacant in 2020 (Figure 12), significantly higher than the other comparison areas (Table 6). The Watershed surpasses the vacancy rates at regional (26%), rural (25%, 25%), national (10%), and state (9%) levels in 2020 (Figure 12).

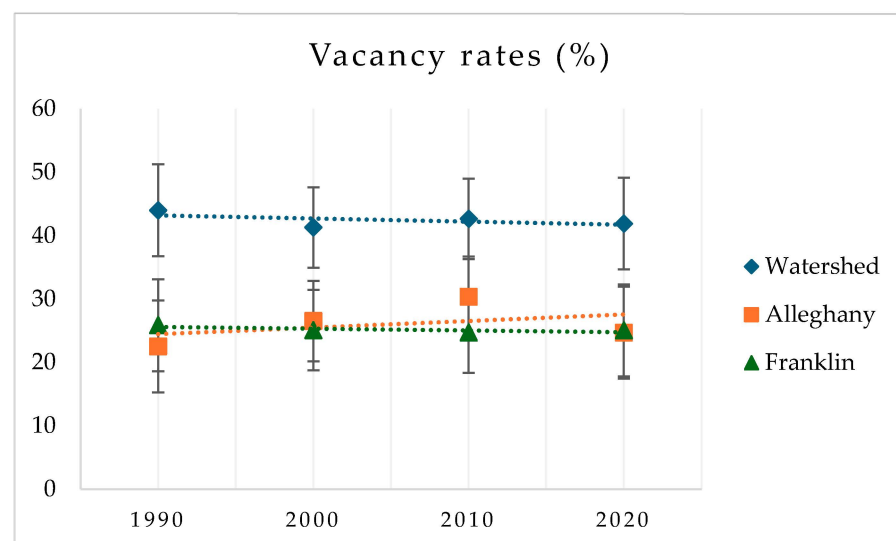


Figure 12. Vacancy rates (%) for the Watershed for decennial years 1990, 2000, 2010, and 2020 at local and rural spatial scales.

4. Discussion

4.1. Aging of the Watershed Population

The Watershed, along with the five-county region, Franklin, and Allegheny counties, all maintained a consistent population density across the study time period. However, the Watershed was unique in having the highest proportion of retirees and the highest median age compared to other areas of comparison. Although the retiree population and median age were on the rise across all geographical scales, the median age in the Watershed increased at a notably faster rate. This observation is of critical importance as the aging of the population has implications for both demographic and socioeconomic aspects [32]. The increased median age in an area may be attributed to several factors, including a noteworthy out-migration of younger individuals due to a lack of services and opportunities [33] and in search of better employment opportunities and education [34], a declining fertility rate coupled with a reduced mortality rate [35] as well as retirees moving into their second homes [36]. In the context of the Watershed, Hoffman reported that young people are leaving the area to apply their education elsewhere. The likely influx of affluent elderly residents into the Watershed also contributes further to its aging demographic [13].

The implications of an aging population for societies and economies are not a new phenomenon or unique to the Watershed [37]. It has wide-ranging effects, influencing the labor force, savings and consumption patterns, family and household structures, social networks and interactions, health and welfare services, housing, and transportation, as well as leisure and community behavior [35]. The concept of a demographic deficit views the decrease in the proportion of younger individuals as a potential cause for a decline in economic activity [37]. The scarcity of young individuals in the Watershed could lead to a greater reliance on external workers for seasonal employment in the Watershed's agricultural, industrial, and tourism sectors. For example, there are many farms in the Watershed already grappling with the threat of foreclosure, the retirement of farmers, and farms transitioning to non-agricultural use [27]. These farmers are facing pressures to transition out of agricultural use because of the absence of an interest in farming among the younger generation [16]. It appears that the economic vitality of the Watershed is being compromised by the dwindling number of young residents and their disinterest in traditional local professions.

4.2. Labor Force and Unemployment in the Watershed

The Watershed's persistently high unemployment rate, nearing 10% in 2020, against the backdrop of demographic challenges such as a shrinking labor force and an increasingly elderly population, underlines urgent socioeconomic issues that demand attention, particularly youth outmigration. While the WPPP aimed to generate employment opportunities through its diverse sub-programs, this high unemployment rate, the highest observed in the region, signifies not just immediate economic distress but also a long-term threat to the sustainability and vibrancy of the local economy.

The declining labor force in the Watershed suggests limited job opportunities and less economically viable employment, making the region less appealing for young individuals seeking to start or enhance their careers [33]. Compared to other areas, the local job market lacks competitiveness, which may drive these individuals to relocate to regions with stronger job prospects [38]. Moreover, the long commute times in the Watershed, associated with reduced job satisfaction and increased daily stress, may particularly affect young workers who prioritize work-life balance and are less inclined to endure lengthy commutes [39]. This inconvenience can prompt them to seek out areas with better transportation systems and job opportunities nearer to residential locations [40]. Additionally, the high unemployment rate contributes to a cycle of economic downturn, characterized by fewer new businesses and reduced investment, which further limits job opportunities [38]. This environment restricts career development for young residents, making relocation a more viable option for those seeking to fulfill their professional and personal aspirations [33,38]. The economic conditions of the Watershed starkly contrast with those in

regions like Franklin and Allegheny counties, where unemployment rates are significantly lower. This disparity highlights the economic challenges faced by Watershed residents and validates the rationale for the youth migrating in search of better prospects.

However, the Watershed's educational landscape offers a glimmer of hope and a potential pathway to economic rejuvenation. The doubling of residents with graduate or professional degrees within three decades is not merely a statistic; it represents a transformative shift towards a more educated and capable workforce. This educational upswing has the potential to catalyze a shift in the economic paradigm of the Watershed from traditional, labor-intensive industries to more knowledge-driven sectors. Such a shift could not only provide employment opportunities for the highly educated populace but also attract businesses and industries seeking a skilled workforce. However, this positive trend in education also raises critical questions about the alignment between educational outcomes and job market needs. Ensuring that educational programs are tailored to meet the demands of emerging industries and sectors could bridge the gap between the availability of a skilled workforce and the presence of suitable employment opportunities, thereby mitigating the unemployment issue.

The question remains whether this educated workforce is available to work. The Hoffman study backs the assertion that there is a noticeable pattern of highly educated retirees moving to the Watershed and an influential number of these retirees originating from the greater NYC region [13]. Their educational background could serve as an asset to the local economy, either by contributing skilled labor as an older workforce or through engagement in community activities.

4.3. Income Disparities in the Watershed

On one hand, the rise in median income and PCI suggests that the Watershed is experiencing economic growth, with a significant portion of the population earning more, leading to potential improvements in their standard of living, including better housing, healthcare, and education. This growth, however, is contrasted by the high and increasing Gini coefficient, signaling that this economic prosperity is not evenly distributed, i.e., wealth is becoming more concentrated among the higher-income groups, leading to a widening income gap. The Watershed region always has been home to many wealthy residents [13]. The area's growing retiree demographic likely contributes to this trend, possibly reflecting an influx of retirement income. A higher Gini coefficient indicates growing income inequality, which can lead to social unrest and a divide between socioeconomic groups. This disparity in income can result in unequal access to quality education, healthcare, and other essential services and may require targeted policy interventions for more inclusive growth. Rising inequality may also undermine political and legal institutions, adversely impact social trust, and hinder innovation [11]. It is important to note that income inequality is on the rise globally; therefore, some enjoy the benefits of economic growth while the lower and middle-income groups may struggle with rising living costs without corresponding increases in income [41]. The housing market may reflect this divide, with real estate prices escalating due to higher demand from wealthier residents, potentially leading to gentrification and displacement of lower-income residents [42]. Socially and culturally, this could lead to greater stratification within the community, as disparities in income create divisions and change the social fabric [43]. While the increasing median income may indicate economic progress in the Watershed, the rising Gini coefficient highlights the critical need for inclusive growth strategies to ensure a more equitable distribution of the benefits of this prosperity.

To address these challenges, the region could implement progressive taxation to redistribute wealth more fairly, ensuring that all socioeconomic groups benefit from the region's prosperity [44]. Increased investment in public services can mitigate the impacts of economic disparities [45]. Affordable housing programs and anti-gentrification measures are crucial in maintaining community integrity and preventing the displacement of lower-income families [46,47]. Furthermore, investments in job training and subsidies for

emerging industries could help equitably boost employment opportunities across all income levels [48–50]. These measures, when effectively implemented, can help counteract the negative impacts of rising inequality and foster a more inclusive and harmonious community.

4.4. Housing Dynamics and Vacancy Rates

Analysis of the housing dynamics within the Watershed area unveiled an increase in the overall unoccupied housing units, aligning with the trends observed at rural, regional, state, and national levels. Notably, the Watershed area exhibits a higher number of unoccupied housing units compared to the comparison areas, with 42% of the housing units in the watershed being vacant in 2020. High vacancy rates in the Watershed indicate a widespread presence of properties not used as primary residences, which includes second homes or vacation properties. Such trends are frequently observed in areas that are attractive for seasonal or recreational use, or in regions experiencing economic transformations that encourage investment in real estate as second homes.

Several factors contribute to the higher vacancy rates, including a rise in retirement communities [51], out-migration of youth populations due to a lack of services and opportunities [33] and in search of better employment opportunities and education [34], retirees moving into their second homes [36], increasing rents [52], and declining employment and populations [53]. Additionally, a significant portion of housing in the Watershed is used seasonally [13].

External events have also influenced local housing demand. The 2001 World Trade Center attack and the subsequent 2020 COVID-19 pandemic collectively exerted spikes in demand on the housing market across various regions, including the Watershed. Following the attack on the World Trade Center, there was a notable increase in the demand for housing in the Watershed area, as individuals and families sought safer, more tranquil environments away from urban vulnerabilities [13]. This trend was suggestively amplified by the COVID-19 pandemic, which further changed societal priorities and lifestyle preferences on a larger scale [54]. The combined effect of seeking security post-9/11 and the lifestyle flexibility enabled by the pandemic has led to a general surge in demand for housing in the Watershed.

Increasing second-home ownership often exacerbates income inequality, contributing to a higher Gini index. Vacant housing plays a crucial role in maintaining economic stability [55], with economically stable areas typically exhibiting more vibrant housing markets and lower vacancy rates [56]. Excessive housing vacancies can serve as an indicator of crisis within the local economy [57] and a concern in community development and neighborhood planning [53]. This trend can create a dynamic of ‘part-time’ residents, affecting local businesses with seasonal demand fluctuations, while simultaneously pressuring the housing market and elevating prices beyond the reach of lower-income local residents, ultimately altering the community’s social fabric [58].

To address these issues, several strategies could be employed. Comprehensive community initiatives could help retain and attract younger populations, countering the trend of out-migration and revitalizing local economies [49,51]. Affordable housing initiatives are critical to reducing high vacancy rates and supporting sustainable economic development [46]. Additionally, regulating second-home ownership through higher property taxes on non-primary residences could help stabilize the local housing market [44].

4.5. Commute Dynamics and Economic Vulnerabilities

In general, Americans undertake longer commutes than strictly necessary, incurring costs in terms of money, time, emotional well-being, and safety [39]. The analysis of commute durations in the Watershed area revealed an increasing trend in travel time to work over the past three decades, surpassing trends observed at rural, regional, state, and national levels. The higher unemployment rate of the Watershed compared to the rural, regional, state, and national levels combined with a longer commute time in the Watershed suggests a lack of job opportunities. The lack of local job opportunities may compel individuals to seek employment in distant regions. This extended commute duration not

only incurs increased living costs but also exacerbates economic challenges for the local population, making them more vulnerable to economic fluctuations in other areas. This recognition of the economic stress impacts associated with daily mobility highlights the importance of understanding and addressing the expenses associated with commuting [59]. The additional time spent commuting reduces time available for personal activities and family, which negatively impacts life satisfaction and well-being.

Research has shown a negative association between commute duration and life satisfaction, indicating that factors such as the opportunity cost of time and the emotional costs of commuting significantly mediate this relationship [60]. This correlation highlights the importance of understanding and addressing the expenses associated with commuting. Therefore, the extended commute durations in the Watershed not only represent a logistical challenge but also have implications on the emotional and economic health of the community.

Addressing these issues requires targeted interventions to enhance local employment opportunities [48] and improve public transportation infrastructure [61]. By creating more job opportunities closer to home and making commuting less demanding and more efficient, the region can improve overall life satisfaction and economic stability for its residents. Such policies would not only mitigate the direct costs associated with long commutes but also enhance the general well-being and safety of the workforce in the Watershed.

5. Conclusions

This study analyzed socioeconomic and demographic trends in upstream watershed communities, highlighting a gap in the momentous 1997 NYC Watershed Memorandum of Agreement that protected water quality but may have overlooked local community well-being. As long as NYC residents, numbering over 9 million, require clean drinking water, it is most effective to safeguard the water at its source. Even if NYC eventually needs a filtration plant, treating cleaner water is more cost-effective and achievable through protected water sources. Therefore, watershed protection programs are essential, regardless of Filtration Avoidance Determinations (FADs). It is crucial to maintain a strong partnership and relationship between watershed communities and NYC. Consequently, watershed management plans must be sustainable. Policies and regulations should support not only the water quality for the city but also the social and economic well-being of the communities that supply the water. We provided an analysis of the demographic and socioeconomic changes within the Catskill-Delaware Watershed over a thirty-year period that could be addressed by future management policies and regulations. We highlighted the unique challenges and opportunities that have emerged in this area. The findings reveal a multifaceted narrative of demographic shifts, increasing income inequality, and consequential changes in housing patterns. These trends and shifts, amid broader regional and national trends, point to the need for targeted interventions to address the specific challenges faced in the study region.

The decline in the labor force, coupled with youth outmigration, an aging population and high median age, signals a critical need for strategies to attract and retain younger residents. This may involve enhancing employment opportunities, improving transportation infrastructure to reduce commute times, and developing amenities and services that cater to a younger demographic. Such initiatives not only support demographic rejuvenation but are also crucial for fostering a community capable of sustaining long-term watershed management practices. Simultaneously, addressing the high unemployment rate and supporting workforce development initiatives will be essential not just for revitalizing the local economy but also for ensuring that residents are prepared to participate actively in and support advanced water management systems. Building a robust, employed, and engaged community is key to implementing sustainable water practices that maintain water quality and manage water resources effectively.

Economic indicators suggest growth, yet the rising income inequality and the high Gini coefficient call for policies aimed at ensuring that the benefits of economic development are

more equitably distributed. Introducing social programs, enhancing educational opportunities, and providing economic incentives that support lower-income residents are crucial not only for bridging socioeconomic divides but also for fostering community investment in local environmental stewardship. Such empowered and equitable communities are more likely to support and participate in sustainable watershed management initiatives. The influx of retirees into second homes, income inequality, higher Gini index, and the housing dynamics suggest the emergence of gentrification within the area. This underscores the importance of integrating housing policies with water management strategies to prevent displacement and maintain local engagement in watershed conservation efforts.

The high rate of housing vacancies, particularly with the increase in second homes, presents both challenges and opportunities. On one hand, it reflects a potential shift in the Watershed's role as a residential community to one more oriented towards seasonal use; on the other, it offers a chance to leverage this trend for economic benefits through tourism and seasonal activities. However, it is crucial to balance these opportunities with the needs of permanent residents, ensuring affordable housing and maintaining the social character of local communities. These considerations are pivotal not only for community well-being but also for engaging both permanent and seasonal residents in sustainable watershed management practices. The upcoming stage of our research will involve conducting a survey among the Watershed residents, focusing on those with first or second homes in the area, aiming to understand their perspectives and involvement in watershed management strategies. Furthermore, future research could potentially delve into the impacts of the work-from-home and remote work culture, particularly given its rapid expansion in recent years. Examining this shift could offer valuable insights into changes in productivity, well-being, and work-life balance, as well as its broader socioeconomic effects.

Addressing the issues of workforce decline, income inequality, and housing market dynamics will involve not only mitigating the challenges identified but also capitalizing on the opportunities presented by the changing demographic and economic patterns. Ultimately, the goal should be to foster a vibrant, inclusive, and sustainable community that meets the needs of all its residents, both today and in the future.

This initial phase of this study explored available Census data for a time series analysis, providing an initial understanding of socioeconomic well-being and quality of life within the Watershed. Although the observed socioeconomic trends over the past 30 years closely align with broader spatial trends, making it challenging to directly attribute these patterns to the Watershed Protection and Partnership Program (WPPP), this analysis has set the stage for posing critical questions about the WPPP's impact and contribution on socioeconomic development as envisioned in the Memorandum of Agreement (MOA). The forthcoming phase of this research will build on this foundation by collecting and analyzing survey data collected from the Watershed residents about their perceptions of community vitality, coupled with interviews with MOA signatories and decision makers. This approach addresses the immediate scholarly needs by assessing current data and trends and lays the groundwork for future academic contributions by providing a deeper, qualitative understanding of the community's dynamics. Through this dual-method investigation, we aim to weave together a comprehensive narrative of socioeconomic well-being and quality of life within the Watershed, enriching both our theoretical understanding and practical insights into the area's development.

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Data Availability Statement: The datasets used for the United States, New York State, regional counties Delaware, Greene, Schoharie, Sullivan and Ulster and rural counties Franklin and Allegheny are publicly available on the U.S. Census Bureau webpage at <https://www.census.gov/> (accessed on 28 February 2024). The datasets generated for the Watershed are available upon reasonable request.

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