Examination for the Decrease in US Birth Rate After the Great Recession the Change of Hispanic Fertility Rate and Education Convergence Behind It*

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Abstract

A nation's birth rate is critical for its society in many aspects. The birthrate of the US has been dropping over the past decade. This paper examines the decrease in the US birth rate, especially after the great recession. We analyzed the trend in the US birth rate during the past five decades, by demographical characteristics, also by geographical division. The results suggest the significant contribution of the dramatic decline of Hispanic women's fertility rate after the great recession to the whole of the United States birth rate. The possible education convergence behind it is also discussed. Based on our data, we were able to conclude that the birthrate of the US experienced a sharp drop after 2007, the great recession. Hispanic women's birthrate dropped significantly after the great recession, considered as the result of fertility convergence from educational convergence. By state-year analysis, we considered these as long-term non-regional factors to the sharp drop of birth rate after 2007 in the US. Besides, we further discussed the contribution to the stable fertility of educational effect on women as well as the long-term development to improve the birth rate in the US.

Introduction

The birth rate of a country is vital for society and even for the whole human species. Fertility could have a significant influence on future strategies. The declining birth rates in developed countries have brought continuous challenges in front of their policymakers. The United States of America, as one of the most powerful nations around the world, has been facing a drop in fertility over the past decades. Previous studies have found that delaying childbearing can lead to a complete cessation of childbearing. In fact, an increase in childlessness among all age groups is the primary explanation for the drop in fertility in the United States (Stone 2020). The birth rate could reflect a whole set of problems of different aspects, including economics, policy, and education. Starts From December 2007, the United States was in a great economic recession, which had numerous detrimental effects on the national and worldwide economies. According to Becker (1960), family wealth is a crucial predictor of birth decisions. After modeling, he suggests that children should be treated as normal goods. These ideas inspired us to investigate the potentially existing influence of the Great Recession on the declining birth rate in the US.

Mexican migration to the United States has been one of the major sources of US migration in the latter decades of the twentieth century (Villarreal 2014). The total fertility rate of Mexicans fell from around 6 children per woman in 1974 to 2.08 children per woman in 2009 (DÃAZ-VENEGAS et al. 2015). There are multiple possible reasons to explain this issue, however, we discovered that the birth rates among Hispanic women converge to the birth rate of other ethnic women. This is consistent with the pattern of educational convergence between races. However, there is not very much precious work done to explore this potential

*Code and data are available at https://github.com/YN7666/sta304-a2

connection. Thus, exploring whether educational convergence in the US women's society is responsible for the drop in the birth rate has become more interesting and crucial.

This paper examines the decrease in the US birth rate after the Great Recession. Specifically, we looked at how the change of Hispanic fertility rate and education convergence behind It. It aims to replicate some of the findings in "The Puzzle of Falling US Birth Rates since the Great Recession" (M. S. Kearney, Levine, and Pardue 2021)[1]. The results are consistent with the original findings that some demographic groups are contributors to the decline of population and birth rate. Specifically, the states in which Hispanics gathered have more significant changes in the birth rate.

The remaining part of the paper was organized into three major sections. In the Data section, we would first explain the source of the basic data and the methodology we used to process the data. We also included the data characteristic and how the results could be replicated by using the data from the original paper. In the Results section, we plotted three different figures. Figure 2 shows the trend in US birth rates. We also analyzed the US birth rates by population's demographic characteristics, by which we found the significant contribution of Hispanic subpopulation to the states' birth rate. To further investigate this issue, the birth rate by the state was illustrated in a US map. In the discussion section, we would begin by presenting and commenting on our findings. We would also discuss some potential weaknesses and biases in this replication study, as well as the original study. Finally, we gave some suggestions about the future works of this project.

Data

Data Source and Methodology

The basic data all comes from the Centers for Disease Control. The datasets provided by the original paper writers are also beneficial to this paper. The dataset was processed and analyzed in R(R Core Team (2021)) and I analyzed all these using R package including: readr(Wickham and Hester 2020), tidyverse(Wickham et al. 2019), ggplot2(Wickham 2016), haven(Wickham and Miller 2020), gcookbook(Chang 2018), ggrepel(Slowikowski 2021), gtrendsR(Massicotte and Eddelbuettel 2021), usmap(Di Lorenzo 2021), dplyr(Wickham et al. 2021), car(Fox and Weisberg 2019), patchwork(Pedersen 2020).

There are several datasets we used in this project. The first dataset is "figs_1_2_3.csv" which was provided by Kearney, Melissa S., Phillip B. Levine, and Luke Pardue, the writer of the original paper. The original paper is named "The Puzzle of Falling US Birth Rates since the Great Recession." This paper mainly argues the US birth rates of Hispanic fertility dropped significantly over the years after the Great Recession. The authors studied a lot of factors including age, education, race and ethnicity, marital status, and birth parity. Based on these, they find out the downward trend is society-wide also rarely reversible in the next few years. The authors also produce another dataset called "figs_2a_2b.csv," which is useful in our replication project as well. The two datasets "figs_1_2_3.csv" and "figs_2a_2b.csv" contain many columns which include year, different types of birth rate, and descriptions of women's characters. Among 33 variables, there is only half of them that are meaningful to our replication interests, hence 10 variables from "figs_1_2_3.csv" and all 10 variables from "figs_2a_2b.csv" are used in our project.

"age_race_comp_seer" is another dataset that contains lots of informative variables of the total population. It is produced by the Centers for Disease Control and Prevention Surveillance, Epidemiology, and End Result (CDC SEER). CDC is funded in 1946 and it is an agency of the U.S. Department of Health and Human Services that provides reliable information to protect public health and safety (https://seer.cancer.gov/about/overview.html). CDC collected the data through the National Notifiable Diseases Surveillance System (NNDSS). The dataset we used in this project is also collected by about 3,000 health departments from local cities. The dataset "age_race_comp_seer," separates the data by different years and states. This dataset contains feathered variables of age, race, and the combination of age and race. The variable of age offers the information of the exact population of US women by 5 different age groups, which are age 15-19, 20-24, 25-34, 20-34, and 35-44. Besides, there is a group of variables in the data that give the information of

[1]Doi:10.1257/jep.36.1.151

population for each race as well as for s specific age group. For example, "popwhitenh1519" gives the total population of white women aged between 15-19.

"nchs_births_pop_1990_2019.dta" is delivered by The National Center for Health Statistics (NCHS). NCHS is a department under control by Centers for Disease Control and Prevention Surveillance (CDC), which provides statistical information to support CDC to prevent health crises from happening. NCHS collects the data using administrative records and medical records from the related facility. In this dataset, it presents 264 variables, grouped by name and state. The main data contain information related to nationality, ethnicity, education level, and population. Among them, "numbirth1544" is the variable we aim to analyze later. "numbirth1544" means the number of births given by the mother whose age is between 15-44 years old.

Data Characteristic

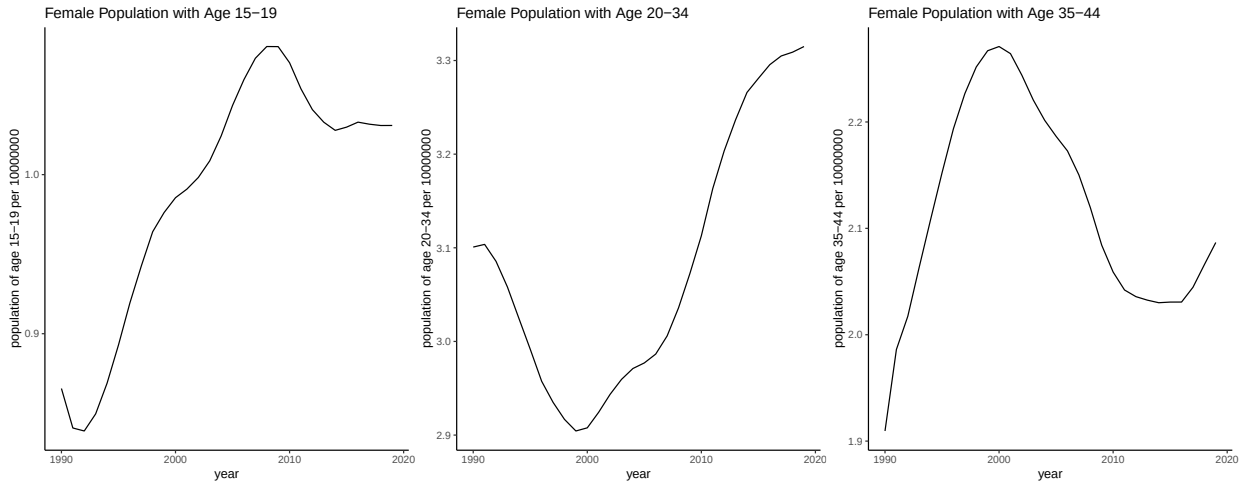

Figure 1: Female Population Trend in US From 1990 to 2020 by Age Group

By dataset "age_race_comp_seer," we generated three graphs for the female population of America, with ages between 15-19, 20-34, and 35-44. The year starts from 1990 and ends in 2020. Since the population is huge, we counted 10 million as 1 unit on the graph.

- The first graph represents the population of females from the age group 15-19. It shows a left-skewed and unimodal plot. The highest population happened in 2008 and the lowest one was in 1992.
- In the second graph, there is a huge trough in the middle of the graph, so it follows bimodal. It hit the highest value in 2019 and reaches the lowest one in 1999.
- The last plot is for the female from the age group 35-44. The highest population happened in 2000 and the lowest one was in 1990. If you add up the total number of the population in 3 age groups in the same year it is approximately 50 million, about 15% of the total U.S population, which is reasonable. Therefore, the data we based on is reliable.

Reproduction[2]

- Figure 2:

[2]Reproduction DOI: https://doi.org/10.48152/ssrp-pep2-jn21

We used the dataset provided by the authors to reproduce figure2, which is named as "Births per 1,000 women age 15_44." In the process, we simply take year as the x axis and brate_all as the y axis for the graph and plot it by ggplot line.

- Figure 3, Panel A and B:

We adopted the dataset "figs_2a_2b" provided by the authors to reproduce panels A and B in figure 2, which is named as "Five-year Age Group from 15 to 44" and "Race and Ethnicity from 15 to 44." To begin with, we renamed the variables into "year,""15-19,""20-24," "25-29," "30-34," "35-39," "40-44," "White_non_H," "Black_non_H," "Hispanic." Then, we collected a set of subgroups together using function gather to form a new dataframe and plotted the ggplot. In panel A, we gathered 6 age groups, including "15-19," "20-24," "25-29," "30-34," "35-39," and "40-44" from the dataset "figs_2a_2b." The rest variables in the dataset, including "White_non_H," "Black_non_H," and "Hispanic," are selected to a newly created dataframe for panel B. Finally, with dataframe ready for each panel, we draw their graph using ggplot.

- Figure 3, Panel C, D, and E:

We used the dataset "figs_1_2_3" provided by the authors to reproduce panel C, D, and E in figure 2, which is named as "Hispanic subpopulation from 15 to 44," "Mother's level of education from 20 to 44," and "Marital status from 15 to 44." Firstly, we located the related four columns by index 20, 21, 22, 23 and renamed them as "Native_born_Mexican," "Foreign_born_Mexican," "Native_born_non_Mexican," "Foreign_born_non_Mexican" for panel C; located columns by index 13, 14, 15, 16 and renamed them as "No_high_school_degree," "high_school_degree," "Some_college," "College_graduate" for panel D; and located columns by index 17 and 18 and renamed them as "Unmarried" and "Married" for panel E. Then, we filtered out the missing value and selected columns by year. We gathered the value and rename the three columns as "year," "Hispanic," and "value." In the end, we created graphs for each panel by ggplot.

- Figure 3, Panel F:

We used the datasets "age_race_comp_seer" and "nchs_births_pop_1990_2019" provided by the authors to reproduce panel F in figure 2, which is named as "Parity from ages 15 to 44." First, we merged these two datasets by "stname" (state name) and year. Then, we added up a new column called "pop2044," which is created by calculating the sum of "pop2024.x," "pop2534.x" and "pop3544.x" using function mutate. Then, by function sum, we collapsed the "numbirth_first," "numbirth_second," "numbirth_third," "numbirth_fourth" and "pop1544," "pop2044" by year. For each variable in "numbirth_first," "numbirth_second," "numbirth_third," "numbirth_fourth," we generated a new value by calculating "numbirth" divided by "pop1544" multiplied 1000. Last but not least, we selected the new columns after the calculation and year. We renamed them into "year," "first_child," "second_child," "third_child," and "forth_child" by the same method. Insert this dataframe into ggplot and we got the panel F.

- Figure 4:

Figure 3 is a state-level US map that indicates the changes in birth rates among women aged 15 to 44 between two five-year periods (2004-2008, 2015-2019) before and after the Great Recession. We plotted this figure using the datasets "nchs_births_pop_1990_2019" and "numbirth1544" provided by the authors. To begin with, we filtered out the missing value and observations outside the two five year period. We dropped the states with names of "AB,""BC,""MB,""NB,""NS,""ON,""QC,""SK,""XX" as well. Then, we selected useful variables from a large number of columns in each dataset to create a new one. For "state_births_1," we collapsed the sum of "numbirth1544" and grouped it by the data under "stname" (state name) and "year." A similar procedure is adopted for "state_births_2," except to summarize the "pop1544" instead. Then we merged them into one dataframe by "stname"and "year." We separated the data into two periods and called

it “year2.” The first period is from 2004 to 2008, which was named as “2004”; the second period is from 2015 to 2019, which was named as “2019.” After this, we summarised the sum of “numbirth1544” and “pop1544,” grouped by “stname,””year2”. The rate of birth among women aged 15 to 44 is calculated by dividing the number of the new birth (“numbirth1544”) by the number of existing populations (“pop1544”) multiplied by one thousand, and named it as “brate1544_thsnds.” we created two dataframes to separate observations of the year “2014” and year “2019” and kept only state name (“state”), year (“year”), and corresponding birth rate (“brate_bef” for 2004 and “brate_aft” for 2019) in the dataframes. Using function merge, we converted these two dataframes into one final dataframe. We added up a new column to record the changes in birth rates between two periods by function mutate and called it “diff.” we made a plot of 50 states in the US with percentage change of birth rate and named as “Change in Birth Rates by State between 2004-2008 and 2015-2019.” Specifically, the higher a state’s fertility rate, the redder it is plotted. The color approaches white when the birth rate reaches negative twenty percentage points and approaches bright red when the birth rate is turned to be positive. The labels are zoomed out into size 3 to avoid the messy looking on the east coast.

Result

Trend in US Birth Rates

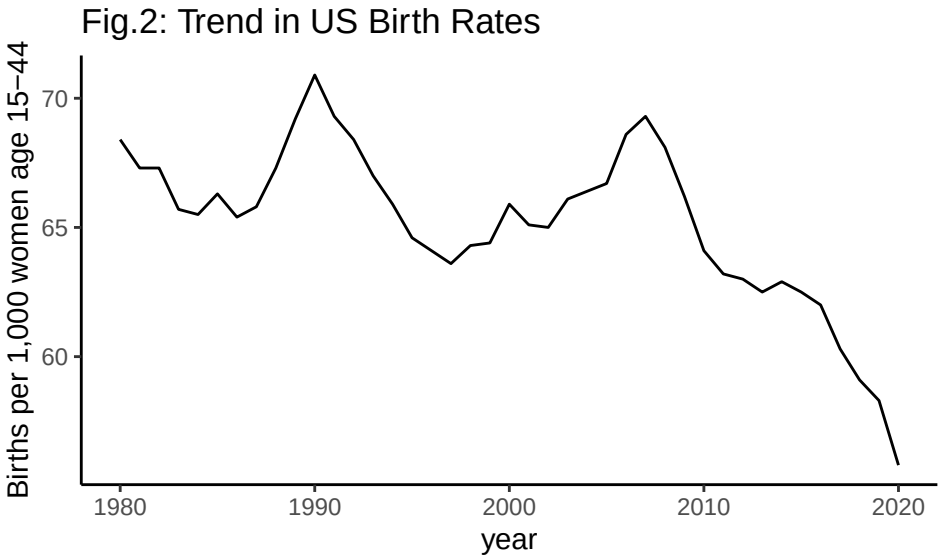

Figure 2: Trend in US Birth Rates

Figure 2 reflects trends in U.S. fertility from 1980 to 2020, using data on the universe of US births from the Vital Statistics system. It can be seen that the overall fertility rate in the United States is on a downward trend, from about 68% in 1980 to about 56% in 2020. During this time, there were two obvious fluctuations, near the year 1990 and 2007, respectively. The decline around 1990 began to pick up around 1996; the fertility decline that began in 2007, however, was sharp and persistent. This paper takes the fertility decline since 2007 as the research subject and aims to explore the potential strong correlation factors behind it. We retrieved major events, including politics, economy, and culture, during this period as potential causes of the great turning point in 2007, and found that the great recession was one of the significant events.

The great recession brought enormous economic stress to people at the time: Between 2007 and 2010, the unemployment rate rose from 4.6% to 9.6%, about 5 percentage points. The appearance of a newborn will bring new expenses to a family, but at the same time, it can also bring economic income as a new labor force

for the family in the near future. There is a lot of literature trying to define the economic impact on the birth rate. Some scholars mentioned that increased income leads people to choose to have more children. However, high economic prosperity also raises the standards and costs of raising children, such as in education and quality of life (J.Dettling and S.Kearney 2014). Others draw conclusions based on this fact that people tend to have fewer children while ensuring high-quality investment in each child, as society grows richer (Becker and Lewis 1973). Therefore, without quantitative analysis, we cannot confirm the specific impact of the Great Recession on U.S. birth rates.

To be sure, however, the birth rate continued to decline after the recession ended. As can be seen from figure 2, after 2010, the birth rate was still falling. Although a rebound occurred in 2013, it is too slight and brief to reverse the overall sharp decline. Therefore, it can be concluded that factors other than the Great Recession played a role in the continued decline in the birth rate since 2007.

Trends in Birth Rates by Population Subgroup

In Figure 3 panel A, we draw the change in the birth rate of each year from 1980 to 2020, between 6 age groups. The change in births between age groups 15-19 is the most distinct pattern in all 6 lines. The births per 1,000 women show a downward trend after reaching a peak in the year 1991. At around the year of 2007, the rate of decline slowed for around 3 years before speeding up in the following years. Women from the age groups of 20-24, and 25-29, both experienced a decrease in births. The birth rate of elder women (age 30-34, age 35-39, and age 40-44) rose gradually during the 40 years. However, these increases in birth among elder women are not even close to compensating for the significant reductions in births in younger age groups. With the increasing average levels of education becoming higher, society is more prosperous, young people know more about contraception, and the rate of adolescent pregnancy has fallen (Alcaraz, Hayford, and Glick 2021).

Panel B of Figure 3 investigates birth rates by race. We see from the graph that the birth rate of Hispanics experienced the most significant drop. The birth rate of Hispanics drops from 97.4 in 2007, to 62.8 by 2020. Birth rates for non-Hispanic Black and White women declined as well, but by considerably lower percentages. When the Great Recession hit, race and ethnicity had a significant impact on birth rates. By 2020, racial and ethnic inequalities in birth rates will still exist, but they will be significantly reduced. The graph shows a pattern of fertility convergence among ethnicity after 2007. Fertility convergence is strongly associated with educational convergence. The significant improvements in educational attainment across immigrant generations have become a driving factor of fertility convergence among ethnicities (Parrado and Morgan 2008). A possible explanation for this phenomenon is that the Great Recession resulted in educational convergence among races, which further led to fertility convergence among Hispanic, non-Hispanic Black and White.

From Figure 3 panel C, it's not hard to see that Hispanics were the group whose fertility rate is decreasing the most. Thus, we analyzed the trend of the Hispanic subgroup separately in panel C. Specifically, we examine birth rates among native-born and foreign-born Hispanics separately, as well as Hispanics by country of origin, Mexican and non-Mexican. The birth rate of foreign-born Mexican and native-born Mexican both dropped to a large extent. While the birth rate non-Mexican Hispanic women only fluctuates in a small range. The hard drop in Mexican contributes to the significant decline of the Hispanic subpopulation birth rate. The figure shows that the birth rate of foreign-born Mexican is higher than that of native-born Mexican, which supports assimilation.

Following that, we'll look at birth rates for four different maternal education groups: those with less than a high school diploma, those with a high school diploma, those with some college diploma, and those with a four-year college diploma or more. Because many teenagers have not completed their education, we excluded them from this study. The most recently educated and least educated women, women with four-year college degrees (36.3 percent of women aged 20 to 44 in 2018) and women without a high school diploma (8.1 percent of these women), saw the highest decreases in birth rates, as seen in Group D in Figure 3. Between 2007 and 2019, the birth rate for college-educated women declined from 72.5 to 59.4 per 1,000, while it fell from 119 to 97.5 for women without a high school diploma. Since 2007, both groups of women, with a high school diploma and those who have gone to some college, have had very constant birth rates.

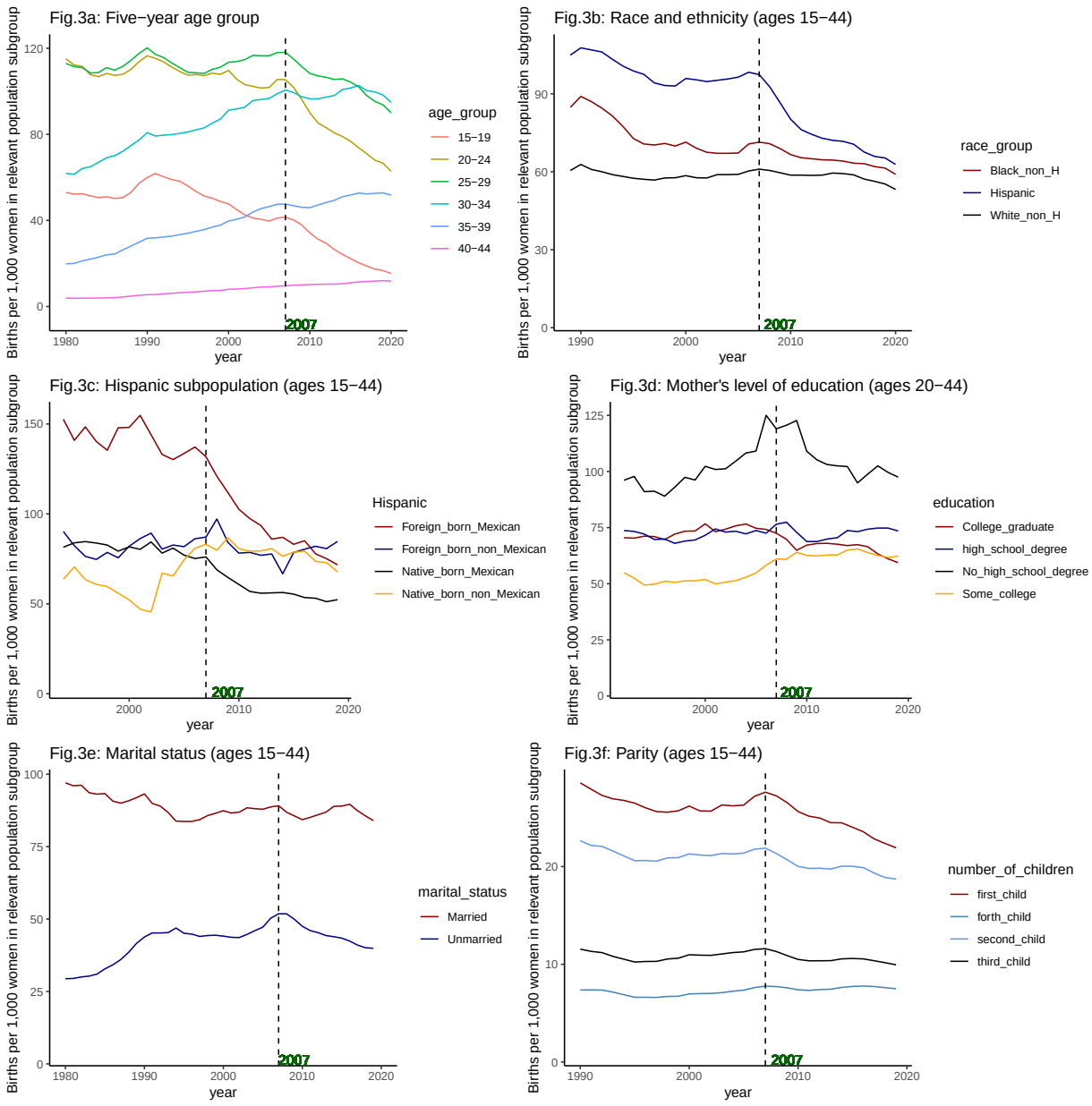

Figure 3: Trends in Birth Rates by Population Subgroup

We then want to investigate if the marital status of mothers would influence the birth rate. Panel E of Figure 3 separately plots births by two maternal groups, married and unmarried. From 1980 to around 1994, the births of two maternal groups experienced substantially different trends. The births of both groups of women slightly flatulated between the year 1995 to 2007. Nevertheless, between 2007 and 2010, the birth rate of married women and unmarried women went down by similar extents. Starting from 2010, the births given by married women in the US society rose again after a fall. However, the number of births of unmarried women has been dropping continuously since 2010. After 2007, although there exists a difference between the change of birth rate in the between years, the overall patterns of the two maternal marital status groups are similar, each experiencing a small drop. Hence, it is eligible to conclude that marriage status only influences the birth rate in a small range.

Panel F of figure 3 depicts parity of the number of women who give birth per 1,000 women, where parity refers to the number of times that a specific woman has given birth to a fetus. The line of the First birth has the most significant change, while the line for women who have their fourth or more birth, which suggests that the drop in births after 2007 is due to a decrease in starting to have kids rather than women not willing to have larger families.

To further explore if the above attributes indeed contribute to the drop in birth rate, we try to show the trend of change in birth rate by geographical division.

Change in Birth Rate by State, 2004-2008 to 2015-2019

Fig.4: Change in Birth Rates by State between 2004−2008 and 2015−2019

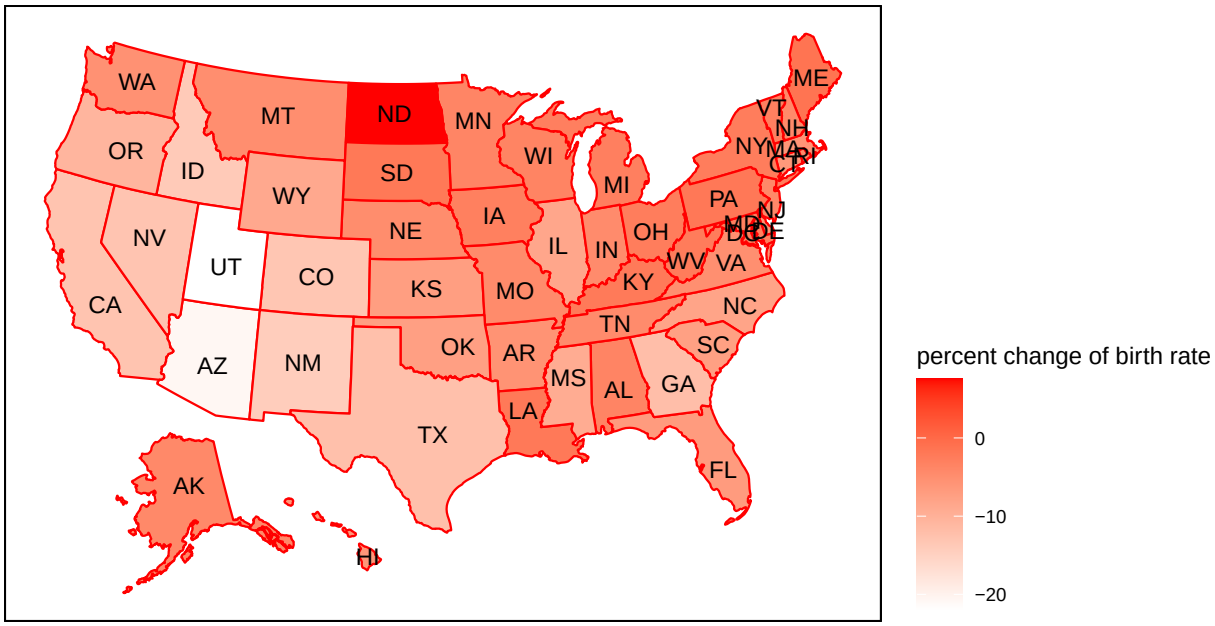

Figure 4: Change in Birth Rate by State

There are many reasons for the decline in fertility, such as the increase in the effectiveness of contraceptive methods, the increase in social competition pressure, and the improvement of women's social rights. But

which of these could explain the long-term and persistent fall in birth rates of the US after 2007 remains to be determined. Figure 4 depicts the state-by-state trends in the U.S. population, measuring changes in birth rates by calculating population changes over two five-year periods before and after the great recession (2004-2008, 2015-2019). By taking five-year averages to measure population status and calculating birth trends across more than 10 years, we can somewhat circumvent reasons for short-term fluctuations.

As shown in Figure 4, the overall fertility rate in the United States is on a downward trend. Except for the positive fertility growth rate in North Dakota, all other states are in negative growth. Fertility declines in most states ranged from zero to five percentage points, followed by declines of more than ten percentage points. Among them, the overall decline in fertility in the western and southwestern states of the United States was larger, with OR, ID, CA, NV, UT, CO, AZ, NM, and TX fertility declining by more than ten percentage points. By contrast, the northern and eastern states saw smaller declines in fertility, mostly zero to five percentage points decline. And one possible explanation for the rising birth rate in North Dakota is that the state has experienced a fracking boom over the years, which other studies suggest has increased birth rates (Melissa S. Kearney and Wilson 2018).

The Southwest and Western states saw the biggest drop in birth rates. In much of the region, the Hispanic population is sizable, consistent with a sharp drop in the birth rate for Hispanic women. We know from Figure 3 that this is due to a decline in the birth rate of native and foreign-born Mexicans.

Thus, the importance of declining birthrates for Hispanic women is corroborated by state-year analysis as a potential long-term and slow meaningful effect, rather than a short-term disturbance, as one of the reasons for the continued decline in U.S. fertility rates after 2007. It is worth noting that, according to the conclusions drawn from Figure 3, Hispanic women's fertility has experienced convergence, and a study shows that education convergence is the main reason behind the fertility convergence (Parrado and Morgan 2008). Therefore, we can infer that education change can be considered as a potential reason for the decline in the US fertility rate after 2007.

Discussion

Discussion of Research Findings

1. The birth rate fell the most among Hispanics

Fertility rates in the United States have fallen sharply since the economic crisis in 2007 and have continued to fall until 2020, the year the data were collected. Considering such as noticeable continuous downward trend, we aim to analyze the factors from social, economic, and political perspectives behind this phenomenon. Since fertility continued to decline rapidly even after the recession ended, it is reasonable to assume that factors other than the economic shock are continuing to cause fertility declines. In order to further explore, we attempted to study different demographic groups, including five-year age group race and ethnicity, Hispanic subpopulation, mother's level of education, marital status, and parity, by drawing line charts for analysis. We found that Hispanic women had the largest decline in fertility rates in terms of race and ethnicity, while Mexicans, especially foreign-born Mexicans, contributed the most to this decline. Therefore, we focused on changes in fertility rates among Hispanic women.

2. The change of Hispanic fertility rate and the educational convergence behind it are long-term non-regional factors

According to the relevant literature, the continuous decline in the fertility rate of Hispanic women is likely to be caused by the assimilation of other native ethnic groups in the US, resulting in a fertility convergence. The main reason for fertility convergence is educational convergence. We then looked at changes in birth rates by the state over two five-year periods, from 2004 to 2008 to 2015 to 2019, to further identify factors that have significant long-term effects on the fertility rate after 2007. This is because such research methods

can avoid regional and short-term variation, which may cause temporary influence on the US birth rate. During the analysis, we find that the most serious decline in fertility rate is concentrated in the western and southwestern states, where the large Hispanic share is held. Therefore, we believe that the decline in fertility among Hispanic women of childbearing age can be considered as one of the reasons for the sustained and dramatic decline in the birth rate in the US after 2007, and the education convergence behind it can also be taken into account.

3. Female education helps stabilize fertility rates

Meanwhile, there are many factors affecting the birth rate, such as age, marital status, education level, as well as social and political environment factors, including the government's attention to women of childbearing age, infant welfare and other factors. In addition to focusing on fertility rates and ethnic and cultural linkages, we also recognized that education and literacy levels largely determine a country's stable development. As can be seen from figure4, from 2007 to 2020, the fertility rate of women with higher education levels is significantly lower than that of women with lower education levels. Among them, women with some college education have the lowest fertility rate, followed by high school and college graduates, while women with no high school degree have the highest fertility rate. We can't define fertility in terms of good or bad. But it is certain that a stable fertility level can maintain the stable development and order of the society, while sharp changes in infertility may bring a huge burden and impact to the society. Among women with no high school degrees, fertility rates rose sharply before the economic crisis and fell sharply after it. This may be because of the family's financial income changes and lacking long-term plans, which increases the potential hidden trouble of welfare policy and social security. In contrast, the fertility rate of women of childbearing age with a high school education or above has remained stable with a small overall change, indicating that the social burden of family payments, infant education, and upbringing has not fluctuated significantly.

4. Social and technological progress is necessary for a long-term increase in fertility

The level of fertility is undoubtedly important for a country, and a continuous decline in fertility will lead to a crisis of poor social structure and productivity. An aging society has a negative impact on the speed of national development and social welfare pressure. Although the level of education is currently inversely proportional to fertility, this does not mean that giving women access to higher education will have a negative impact on the fertility status of the country. Instead, as we mentioned above, it is better to maintain social stability. Alternatives should be widely considered, such as radically increasing the country's productivity through the exploration of more advanced social and political systems and the development of new technologies; At the same time, attention should be paid to the maintenance and development of human capital, such as the establishment of a sound social insurance and medical system, to provide confidence and a prepared environment for women who may want to give birth.

Weakness

1. Lack of Discussion of Population Base for Hispanic Women

We have examined the magnitude of changes in fertility rates for Hispanic women. Educational convergence is a key reason behind the dramatic decline in birth rates among Hispanic women due to assimilation toward native non-Hispanic American women. In addition, through state-to-state analysis, we found that fertility changes among Hispanic women have long-term and regional effects on U.S. birth rates after 2007. Therefore, it is clear that the fertility rate of Hispanic women and the educational convergence behind it may be one of the reasons for the continued decline in the birth rate in the United States after 2007.

However, the impact of a subgroup on the overall population depends not only on its magnitude of change, but also on its population base. We did not examine the percentage of Hispanic women of childbearing age in the United States after 2007. In fact, despite the plummeting birth rate among Hispanic women,

they make up only 16.7 percent of the population. So, observed from a mathematical perspective, their impact on overall fertility would be greatly reduced. While we acknowledge the persistence and impact of this factor, it is uncertain whether the decline in the birth rate among Hispanic women and the educational convergence behind it will lead to a sharp decline in the birth rate in the United States after 2007. In other words, it is only eligible to say that it will drop the US fertility rate after 2007, but the extent of the effect is undetermined.

2. Uncertain Data Usage

The todo list in readme file for figure 4 has different values as it shows in the final product report. The readme file indicates the second period as from 2015 to 2018, but the report shows the time period between 2015 to 2019. If we use 2015-2018 instead of 2015-2019, the difference between the rate of change of the first period and second period could be larger.

Future Work

To determine the contribution of the decline in the fertility level of Hispanic women to the continued fall in the overall fertility rate in the United States after 2007, we can further establish statistical models, such as the linear regression model, for quantitative analysis. As a replication study, this article can assess the modeling method used in the original paper, that is, to classify race, age, and education level, and design a total of 63 demographic groups. On this basis, we can focus on the Hispanic fertility rate, study its contribution proportion to the whole, as well as its characteristics in various age stages and educational backgrounds.

Moreover, according to the cohort analysis in the original paper, the fertility rate of women born from 1983 to 1987,1988 to 1992, and 1993 to 1997 dropped significantly when they reached their childbearing age. Further detailed analysis of the education and race of this group is needed to obtain more sufficient data support.

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