Does temperature affect fertility via the economy? Elaborating on the role of female labor supply and productivity

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Abstract

Women are still devoting more time than men to child-rearing. That makes women's time spent at work crucial for their fertility decisions. At the same time, the global temperature has been rising, affecting labor supply and productivity. In this study, we investigate whether temperature influences fertility through its effect on the female labor supply (number of hours worked) and productivity. We also test the adaptation hypothesis. According to the latter, couples' fertility in warmer climates may be less affected by higher temperatures. We employ individual-level data from the IPUMS-USA for the period 2002-2019 and temperature data from the World Bank between 1901 and 2001. The obtained results show that temperature affects fertility mainly in the category of women who work full-time in jobs with lower educational demands. We found no effect on fertility for women of either higher or lower education, who work part-time. We also found some evidence in favor of the adaptation hypothesis.

Keywords: Global warming, Fertility, Female labor supply, Labor productivity
JEL Classification: Q54; J13; J22; J24

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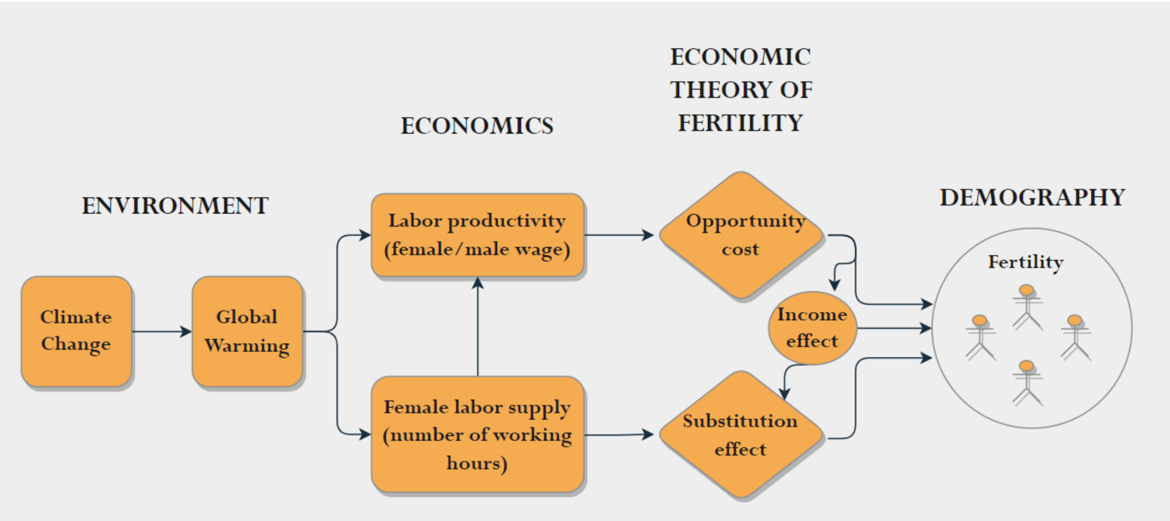
1 Introduction

Climate is changing. Global warming is one of its major repercussions. The mean ambient temperature of the Earth is anticipated to rise from 3 to 6 $^{\circ}C$ in the coming decades (IPCC report, 2013). Apart from other important aspects, environmental changes are also expected to affect human fertility (1). There is a growing but still limited number of studies on this issue. The mechanisms that have been thought to drive the temperature-fertility nexus are usually the following: increased fatigue and heat-related diseases (2), reduced sexual desire (3), deterioration of female reproductive health (4), and decreased sperm count and quality (5).The most recent study in this strand of the literature, to the best of our knowledge, is that of Hajdu and Hajdu (6). The latter demonstrate that the channel driving the reduction in conception rate in the first few weeks following exposure to hot temperatures is the change in the number of induced abortions and spontaneous fetal losses. Hence, studies thus far have attributed the effect of temperature on fertility solely to biological reasons. Although many economists have investigated the implications of higher temperatures, they typically limit their investigation to economic aspects [Dell et al. (7) provides an informative literature review on climate change and its economic implications].

In this paper, we exploit empirical findings and fundamental theoretical aspects from the Climate-Economics and Economics-Demography literature to link temperature with fertility outcomes. Therefore, this study investigates the temperature-fertility nexus from an economic perspective. Particularly, we ask whether higher temperatures influence fertility outcomes through their impact on female labor supply and labor productivity. The direction of the effect cannot be theoretically predicted. As we demonstrate in subsubsection 3.2.1, it could also be conducive to fertility, apart from being detrimental. Hence, it is essentially an empirical question. The knowledge of the direction and size of the effect, as well as the specific groups of individuals most affected, would be a useful piece of information for policymakers to implement the appropriate policies and mitigate any undesirable fallout.

The intuition behind our approach is as follows. Initially, we draw from the *Climate-Economics literature*: high temperatures appear to have a negative impact on the number of working hours (8) and the level of labor productivity (9). Evidence also shows that labor productivity and female employment have been particularly significant in the recent fertility rebound (10), a fact that reveals their telling role in the contemporaneous evolution of fertility. According to the *Economics-Demography literature*: female labor force participation and female educational attainment have been steadily increasing in the developed world during the twentieth century, especially after the end of World War II (11). At the same time, women are still devoting more time than men to their children's upbringing (12), and hence, women face a continuously increasing opportunity cost, substitution and income effect on their fertility. Income has a positive impact on fertility, but the opportunity cost and substitution effect reduce it. Therefore, the outcome is vague. We end up with a synthesis of prior literature, *Climate-Economics-Demography*: labor supply and labor productivity are related to the opportunity cost, the substitution effect, and the income effect (explained in more detail in Subsection 2.2). Moreover, an extra hour of work weighs upon a worker's productivity even more at a higher level of working hours (13). That is, marginal labor productivity decreases at an increasing rate in higher levels of hours worked. And last, productivity deteriorates under the effect of higher temperatures (9). The combination of the above-mentioned evidence hints at an economic channel that links higher temperatures to fertility and merits our attention. The proposed economic channel is depicted in Figure 1.

Figure 1 A potential economic channel that links global warming with fertility.

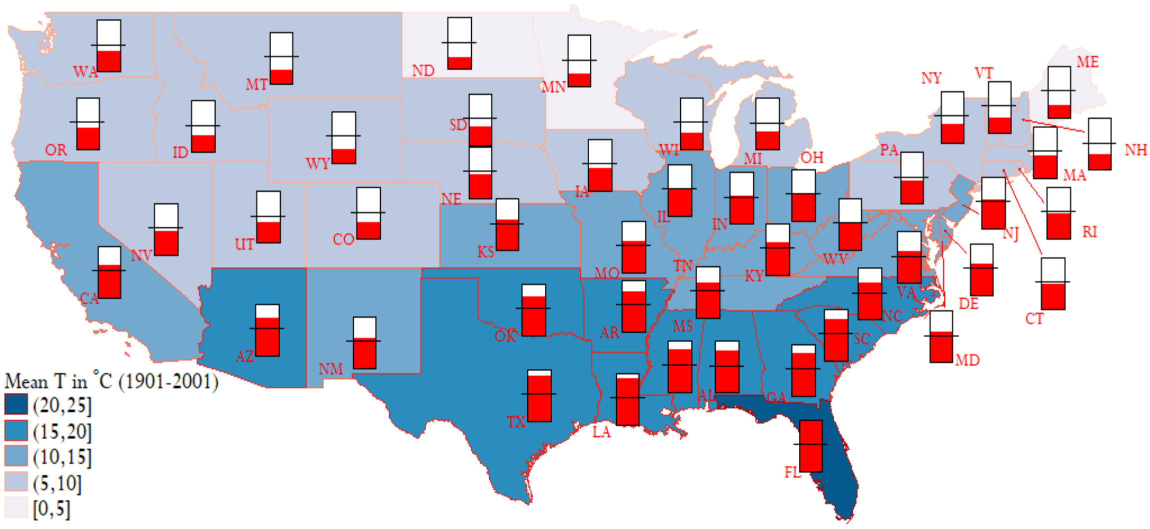


Evidence already demonstrates, and projections forewarn, that we anticipate higher temperatures to become more frequent and to last longer in the (not so distant) future. In this regard, temperature effects on fertility may be even more pivotal in the years to come. In addition to this, the persistence of low fertility rates in the developed world evokes concerns over many aspects of socioeconomic life, such as economic growth (14), the sustainability of pension systems (15), and CO2 emissions (16), to name a few. Furthermore, low fertility may be perceived as a problem in and of itself: the majority of couples in the developed world do not achieve their fertility goals [actual fertility has been found to be lower than desired fertility; see Beaujouan and Berghamme (17)]. Fertility intention failure is linked to lower levels of personal well-being (18). Consequently, there is an urge to better comprehend the interrelationship among climate change, the economy, and demography.

The present paper contributes to the related literature in several aspects. Firs, past literature has mainly focused on the impact of weather events on labor supply (19; 20; 21). Considering the importance of time regarding women's choice between working and child-care, which is often overlooked in the climate change literature, our study, to the best of our knowledge, is the first to investigate the role of women's labor supply (number of hours worked) on the relationship between temperatures and fertility. Second, our empirical framework takes into consideration time spent at work in terms of different employment statuses (full- or part-time), which is typically omitted in the literature but is a substantial part of women's daily life given that women are disproportionately shouldering the child-rearing. Third, to further explain fertility differences in response to increased temperatures, we classify occupations based on the flexibility of working time schedules. Fourth, our study is related to the literature on adaptation to climate change (adaptation hypothesis). Thus, we provide some evidence of whether the examined economic channel is subject to any adaptive behavior. Finally, this study has profound policy implications. This is because a better understanding of fertility differences among different groups due to changes in the female labor supply and labor productivity in the wake of higher temperatures could aid in the formulation of a more effective fertility policy.

We employ socio-economic and demographic individual-level data from the IPUMS-USA database that spans the period 2002-2019 and data on annual temperature (mean and maximum) per US state from the World Bank (1901-2001). Figure 2 shows the mean temperature over the previous century (1901-2001), along with the mean temperature over the last seventeen years (2002-2019). Since 1901, the average surface temperature across the contiguous 48 states has risen at an average rate of 0.16°F per decade. Eight of the top 10

Figure 2 The mean temperature per US state for the periods 1901-2001 and 2002-2019.

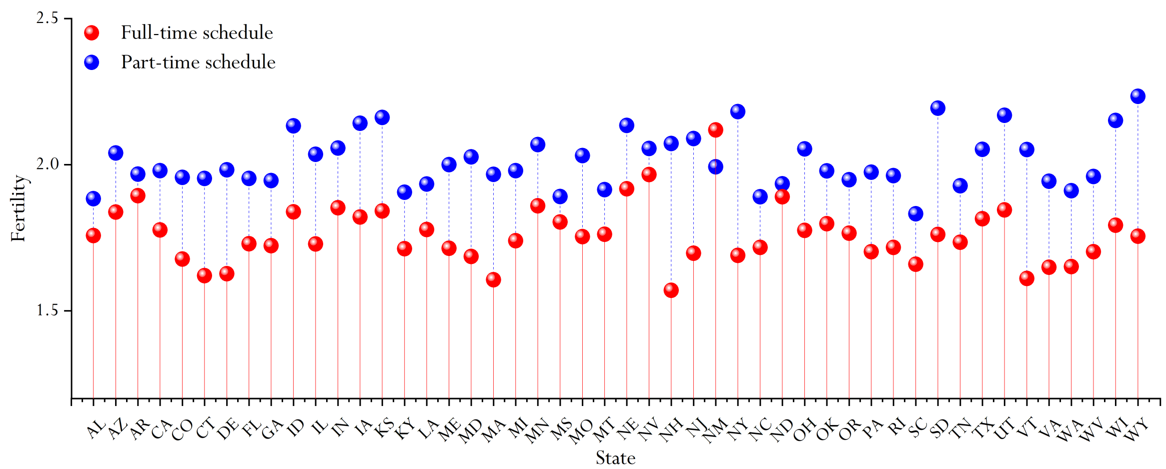


Notes: The map depicts the mean temperature between 1901 and 2001. The framed-rectangle charts represent the mean temperature between 2002 and 2019. Estimates were conducted by the authors. The two-digit state abbreviations are: Alabama: AL, Arizona: AZ, Arkansas: AR, California: CA, Colorado: CO, Connecticut: CT, Delaware: DE, Florida: FL, Georgia: GA, Idaho: ID, Illinois: IL, Indiana: IN, Iowa: IA, Kansas: KS, Kentucky: KY, Louisiana: LA, Maine: ME, Maryland: MD, Massachusetts: MA, Michigan: MI, Minnesota: MN, Mississippi: MS, Missouri: MO, Montana: MT, Nebraska: NE, Nevada: NV, New Hampshire: NH, New Jersey: NJ, New Mexico: NM, New York: NY, North Carolina: NC, North Dakota: ND, Ohio: OH, Oklahoma: OK, Oregon: OR, Pennsylvania: PA, Rhode Island: RI, South Carolina: SC, South Dakota: SD, Tennessee: TN, Texas: TX, Utah: UT, Vermont: VT, Virginia: VA, Washington: WA, West Virginia: WV, Wisconsin: WI, Wyoming: WY.
Source: IPUMS-USA and World Bank.

warmest years on record across all 48 states we examined have occurred since 1998; 2012 and 2016 have been the warmest years (source: U.S. EPA).

We conduct repeated cross-section regression analysis at the individual level. We begin with an estimate of the impact of the mean temperature and the number of working hours on fertility. As shown in Figure 3, the fertility of the women working full-time is lower than that of those working part-time in all US states over the last seventeen years, except for New Mexico (NM). Subsequently, we distinguish between women working part-time (PT henceforth) and full-time (FT henceforth) in order to explore the effect of temperature on fertility within flexible working regimes. Next, we focus on the interaction effect between temperature and female working hours on fertility. We further divide women into two groups according to their type of occupation. As we explain in Subsection 2.2, because the influence of higher temperatures on the type of occupation and the number of working hours possibly wreaks opposing effects on fertility, this extra division of women into their occupations allows us to disentangle between them. Last, we examine the adaptation hypothesis. According to the latter, we expect the fertility patterns of individuals who are accustomed to warmer climates to be less vulnerable to the observed upsurge in annual mean temperatures.

Figure 3 Fertility according to women's work schedule per US state.



Notes: Estimates were conducted by the authors. Period: 2002-2019. The two-digit state abbreviations as in Figure 2. *Source*: IPUMS-USA.

In a nutshell, we found that higher temperatures affect mainly the category of women who work full-time in jobs with lower educational demands. We found this effect even though the vast majority of the occupations considered are "indoor". An attempt to interpret the obtained results has been based on the graphical analysis concerning the movements of the opportunity cost, the substitution and income effects. We demonstrate that the direction of the temperature impact depends on the specific point at which each woman is placed across the concave curve that is shaped between the female wage and her number of hours worked. It also depends on her type of occupation (and hence - as we show - her educational level). Finally, we provide some evidence in favor of the adaptation hypothesis.

The remaining of the paper is organised as follows: Section 2 describes the data and the empirical methodology. Section 3 presents the empirical results. Section 4 concludes.

2 Data and methodology

2.1 Data sources and details

The empirical analysis has been based on individual-level data from the IPUMS-USA database (22). The extracted data spans annually from 2002 to 2010 and also the years 2014, 2015, and 2019. The missing years of 2011, 2012, 2013, 2016, 2017, and 2018 have not been intentionally excluded. This occurred because each family (household) in the IPUMS-USA database appears more than once, but it is not followed over all the years. Therefore, we had to remove duplicates so that each couple appears only once in the sample in order to perform the repeated cross-section analysis.

We removed Alaska, the District of Columbia, and Hawaii in accordance with Kearney and Wilson (23). Thus, individuals in the sample come from the other 48 US states. We kept only heterosexual married couples with both spouses present in the household. In addition, our sample consists only of couples in which the "head" of the household is male. The latter occurred due to data availability. Subsequently, the "wife" is always female. In the remainder of the paper, we use the words "wives", "women" and "females" interchangeably. Couples in which the wife is out of the labor market have been removed from the sample. This is because we are interested in the temperature effect solely through its impact on the number of female working hours and productivity. In this respect, the inclusion of a woman out of labor market would be of no meaning. We further kept women aged between 18 and 49 because this is the period that corresponds, on average, to the reproductive years. Ages below 18 have been left out because they are usually considered non-normative (24). Before the restrictions that we present in the following paragraphs, the original sample consists of 438,120 married couples. To obtain nationally representative statistics, we have employed sample weights at the household-level (variable: "hhwt"; see https://usa.ipums.org/usa-action/variables/HHWT#description_section).

Dependent variable

Fertility represents the dependent variable in our model. We approach a couple's fertility by using the IPUMS-USA variable "nchild", which gives the number of own children in the household. However, this leads to children of any age, which is obviously unrelated to current fertility. In order to precisely approach fertility, we confine the sample to married couples with children, who, irrespective of their number of children, have experienced a birth during the last year, or have no children at all. This process took place by employing the “yngch” variable. Thus, with the latter restriction, we ensure that the birth occurred at most during the last year at the time of the interview.

Independent variables

Data on the annual mean and maximum temperatures by US state and year comes from the World Bank database for the period 1901-2001 (`worldbank.org`). The rest of the variables employed have been retrieved from the IPUMS-USA database. The number of weekly working hours for the husband and his wife is a two-digit numeric variable (“uhrswork”). Wages for both spouses represent their total pre-tax wage and salary income for the previous year. To make comparisons across years meaningful, we have converted wages into constant 1999 dollars (see Table 1 in `https://usa.ipums.org/usa/cpi99.shtml`). Next, we estimate the mean income by the state as the mean of the total pre-tax income earned by one’s family from all sources in the previous year (“ftotinc”). The latter has also been converted into constant 1999 dollars. To estimate the interaction effect of temperature and female working hours on fertility (explained further in the following Subsection), we create a dummy for the mean temperature (T_{mean}) that includes half (24) of the US states with the highest calculated mean temperature between 2002 and 2019. We repeat this process to create the dummy for maximum temperature (T_{max}) in order to include the 24 states that displayed the biggest annual maximum temperature deviation from their mean during the same period.[1]

Control variables

The variable “age” reports the age of the individual in years. We controlled for education by using the variable “educ” for each spouse, which includes 44 categories (detailed codes in: `https://usa.ipums.org/usa-action/variables/EDUC#codes_sec`

[1] We should underline that the latter group of states has been created irrespective of their rank on the mean temperature scale. As a result, states included in the T_{max} dummy may, or may not, have one of the highest mean temperatures in the US.

tion). To control for changes across different populations, we incorporated the variable "race" which consists of 9 categories. Hispanic identity has also been taken into consideration with the respective IPUMS-USA variable ("hispan"; 5 categories). The occupation for each spouse has been added according to the "occ2010" variable (484 occupations under the general titles of management, business, science, and the arts). Finally, to control for state effects, we used the variable "statefip".

2.2 Methodology

The empirical analysis evolves in five steps. In the first step, we estimate the temperature effect on fertility. In the second step, we focus on the effect of the number of working hours and their interaction with temperature on fertility. A separation in the working time schedule between part-time (PT henceforth) and full-time (FT henceforth) female workers and their respective effects on fertility takes place in the third step. In the fourth step, we further distinguish wives into two groups according to their working time schedule (PT or FT) and their type of occupation. Step five tests the adaptation hypothesis.

More thoroughly, we depart from the general impact of temperature on fertility. The fertility of each wife is regressed on the estimated average of the annual mean temperature for the period between 2002 and 2019 by the US state. We repeat the analysis employing the estimated average of the annual maximum temperature for the same period. The specification for the first step is as follows:

$$\begin{aligned} fert_i = a_0 + a_1 * temp_i + a_2 * wwh_i + a_3 * hwh_i + a_4 * X_i^{'} + a_5 * Year + a_6 * State \\ + a_7 * Year * State + u_i \qquad (1) \end{aligned}$$

where i denotes individuals (wives); $fert_i$ is the number of own child/children (if any), given that at least one of them is of age $\leqslant 1$; $temp_i$ is the average of the annual mean (maximum) temperature by US state and year for the period 2002-2019; wwh_i and hwh_i refer to the number of weekly working hours for wives and husbands, respectively; $X_i^{'}$ is a vector of control variables including: age of the husband and its square; age of the wife and its square; wage of the husband and its square; wage of the wife and its square; educational attainment of the husband and his wife (in years of schooling); occupation of the husband and his wife;

the mean total family income by state; a dummy for race and a dummy for Hispanics. $Year$ is a dummy for years; $State$ is a dummy to clean out time-invariant effects between states; the interaction $Year$*$State$ captures for state-specific trends. Lastly, u_i is the error term. All variables, apart from the dummies, have been transformed in logarithmic form.

In the second step, we explore the effect of the female number of working hours and its interaction with temperature on fertility. We focus on women's rather than men's working hours due to the opportunity cost and substitution effect that mainly women face regarding fertility. Regression results in Section 3 confirm our choice: the number of males' hours worked has not been found to have a significant effect on fertility in any of the models considered. Next, we ranked states by their annual mean temperature and created a dummy with the 24 warmest states (out of the 48) for the period 2002-2019. We also developed a dummy to include the 24 states with the highest annual maximum deviation from the mean temperature during the same period. The calculated deviation equals the annual maximum temperature minus the annual mean temperature by US state. We use the annual maximum deviation instead of the annual maximum temperature because states that display the highest annual maximum and mean temperature are identified. The latter leads to a dummy that includes the same states. The developed temperature dummies help us find out whether the number of female working hours differentiates its impact on fertility in states with higher mean temperatures, or in states exposing the greatest deviation from their usual mean temperatures (independently of the temperature level). The specifications can be presented in the following forms:

$$\begin{aligned} fert_i = a_0 + a_1 * wwh_i + a_2 * (wwh_i * T_{mean}) + a_3 * hwh_i + a_4 * X_i^{'} + a_5 * Year \\ + a_6 * State + a_7 * Year * State + u_i \end{aligned} \tag{2}$$

$$\begin{aligned} fert_i = a_0 + a_1 * wwh_i + a_2 * (wwh_i * T_{max}) + a_3 * hwh_i + a_4 * X_i^{'} + a_5 * Year \\ + a_6 * State + a_7 * Year * State + u_i \end{aligned} \tag{3}$$

where T_{mean} is a dummy (binary) that takes the value 1 for each state ranked in the top 24 warmest states according to their annual mean temperature recorded during the period

2002-2019 and 0 otherwise. T_{max} is a dummy that takes the value 1 for each state ranked in the top 24 states with the highest maximum deviation from the mean temperature for the aforementioned period and 0 otherwise. Thus, the interaction term $wwh*T_{mean}$ indicates whether the impact of female working hours differentiates statistically in states that have displayed a higher mean temperature than the rest during the investigated period (2002-2019). The interaction $wwh*T_{max}$ shows the potential variation in states with the greatest maximum deviation. Because T_{max} does not always refer to the warmest states, we interact the latter with the T_{mean} to create the $wwh*T_{max}*T_{mean}$ interaction term with the aim of exploring further the impact in states with the highest maximum deviation and the highest mean temperature. The rest of the notations are the same as in equation 1.

In step three, our goal is to delve more into the interrelationship among temperature, the number of female working hours, and the fertility outcome. To this end, we separate wives in our sample according to their working time schedule (PT or FT). The effect of temperature on fertility via the number of hours worked may differ between women who work in a PT schedule and women who work in a FT schedule. The intuition behind the latter is the following. As already mentioned, an extra hour of work weighs even more upon a worker's productivity at a higher level of working hours (13). That is, marginal labor productivity decreases at an increasing rate in higher levels of hours worked. Moreover, the productivity reduction could deteriorate in warmer places under the effect of higher temperatures (9). In this respect, one may expect to observe a greater temperature-working hours interaction effect on fertility for women in FT schedules relative to women in PT schedules. We examine the latter hypothesis by running the specifications in equations 2 and 3 two times. Initially, we keep in our sample only wives who worked PT, and subsequently, only wives who worked FT. The PT schedule corresponds to a number of weekly working hours less than 40 (< 40), whereas that of the FT corresponds to a number of weekly working hours equal to or more than 40 ($\geqslant 40$).

In step four, we impose an additional distinction that helps us disentangle potential opposite effects that confound the results obtained in the previous steps. Hence, the sample is split into women who work PT but in "FT jobs", and women who work FT but in "PT jobs". First, let us clarify what we mean by the expressions "PT jobs" and "FT jobs", and next, let

Table 1: Most common part-time and full-time occupations for women according to the IPUMS-USA database.

Part-time			Full-time		
Occupation	Frequency	% of participation	Occupation	Frequency	% of participation
Licensed Practical and Licensed Vocational Nurses*	4352	1.02	Cashiers	7333	1
Dental Assistants*	4437	1.04	Education Administrators**	7909	1.08
Other Teachers and Instructors*	4987	1.17	Retail Salespersons	7997	1.09
Medical Assistants and Other Healthcare*	4997	1.17	Managers in Marketing, Advertising, and		
Janitors and Building Cleaners*	5077	1.19	Public relations	8311	1.13
Post secondary Teachers*	5285	1.24	Social Workers**	8326	1.13
Hairdressers, Hairstylists, and Cosmetologists*	5832	1.37	Receptionists and Information Clerks	8480	1.16
Office Clerks, General	5843	1.37	Secondary School Teachers**	9315	1.27
First-Line Supervisors of Sales Workers	5944	1.4	Office Clerks, General	9405	1.28
Accountants and Auditors	6310	1.48	Nursing, Psychiatric, and Home Health Aides	10492	1.43
Maids and Housekeeping Cleaners*	6588	1.55	Financial Managers	10520	1.43
Receptionists and Information Clerks	6818	1.6	Human Resources, Training,		
Customer Service Representatives	7213	1.69	and Labor Relations Specialists**	10564	1.44
Preschool and Kindergarten Teachers*	7466	1.75	Bookkeeping, Accounting, and Auditing Clerks	14870	2.03
Chefs and Cooks*	8238	1.93	First-Line Supervisors of Office		
Bookkeeping, Accounting, and Auditing Clerks	8732	2.05	and Administrative Support Workers	15585	2.12
Childcare Workers*	9088	2.13	Customer Service Representatives	15773	2.15
Nursing, Psychiatric, and Home Health A	10202	2.4	Managers, nec (including Postmasters)**	17716	2.41
Waiters and Waitresses*	10511	2.47	Accountants and Auditors	20119	2.74
Retail Salespersons	12796	3.01	First-Line Supervisors of Sales Workers	22071	3.01
Cashiers	15492	3.64	Registered Nurses	27209	3.71
Teacher Assistants*	16134	3.79	Secretaries and Administrative Assistants	41786	5.69
Elementary and Middle School Teachers	19686	4.62	Elementary and Middle School Teachers	57335	7.81
Secretaries and Administrative Assistant	25606	6.01			
Registered Nurses	29336	6.89			

Notes: *Refers to occupations that appear only in PT schedules where the female participation percentage is higher than 1% relative to the rest in our sample. **Refers to occupations that appear only in FT schedules where the female participation percentage is higher than 1% relative to the rest in our sample. The rest of the occupations appear in both work schedules. The frequency denotes the number of women. *Source*: IPUMS-USA.

us explicate the intuition behind this extra division.

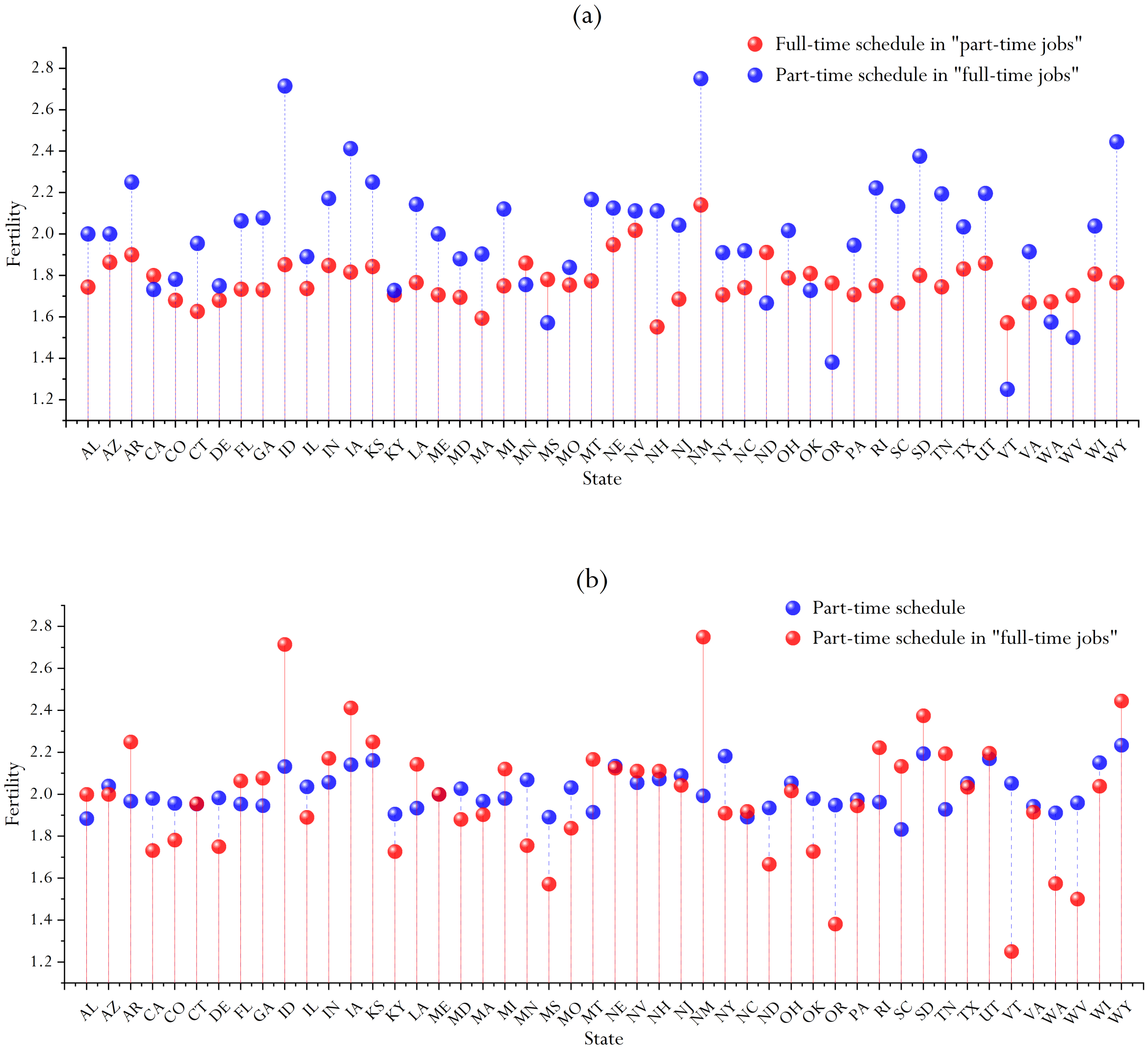
The expression "work PT in "FT jobs" " pertains to women who worked PT the previous year, but their job (occupation) is usually met by women who worked FT according to the data in the IPUMS-USA database (the inverse applies to the expression "FT in "PT jobs" "). This implies that there are specific jobs in which most women usually work on PT schedules and specific jobs in which most women usually work on FT schedules. This is shown in Table 1, where we have categorized occupations that appear in our sample based on the percentage of women's participation who worked either PT or FT in them. For instance, the "Full-time" schedule in Table 1 includes 7,909 women, who worked as "Education Administrators", and assigns to the 1.08% of all women in our sample. We kept occupations that correspond at least to the 1%. This is because of the great distribution of women in various occupations, which leads to a rather low maximum percentage of 6.89% ("PT jobs") and 7.81% ("FT jobs"), respectively (Table 1). By excluding occupations that appear with a percentage less than 1%, we gain in terms of precision. Hence, the selected occupations are more representative of women's participation in the labor market than the ones left out of the analysis.[2]

With respect to the intuition behind the described process. A more careful look at Table 1, reveals that most (not all) of the occupations denoted with an asterisk and appearing in the "Part-time" schedule are of relatively low specialization (lower education demands), such as "Maids and Housekeeping Cleaners" and "Childcare Workers". On the other hand, the occupations denoted with a double asterisk that appears in the "Full-time" schedule are those with higher specialization (higher education demands), such as "First-Line Supervisors of Office" and "Administrative Support Workers and Education Administrators". This is also confirmed in terms of education. That is, we estimated the mean female educational attainment by category, as shown in Table 1, and we found that women in "PT occupations" are less educated than their peers in "FT occupations" (7.2 versus 8.9 mean years of schooling, respectively). This observation suggests that in estimating the effect of temperature on fertility through the number of working hours, one should be cautious enough to consider the "nature" of the job apart from the level of working hours already mentioned. This is crucial because women in high-skilled occupations may be less affected by temperature [see (25):339]. Most importantly, with the term "nature" we do not refer to the distinction between "outdoor" and "indoor" jobs, which is a popular one in this strand of the literature (26). One may confirm that the vast majority (if not all) of the occupations listed in Table 1 belong to the "indoor" category. Therefore, although one may expect an extra hour of work in the PT schedule to be less effective on fertility due to the low number of working hours, if, on the other hand, occupations that are usually met on PT schedules are more vulnerable to higher temperatures, it may counteract the latter effect. As a result, the final outcome becomes ambiguous due to these two potential opposing effects. Hence, the distinction between working time schedules and occupations is intended to clarify this issue: it separates the opposing effects.

The model specification repeats the ones in equations 2 and 3. Again, we create and apply two distinguished samples. In the first, we keep and explore the effect only for women who worked PT but whose occupation is typically met on "FT jobs". In the second sample, we only keep and examine the relationship for women who worked FT in the previous year

[2] One may notice that the higher the percentage by each category (PT or FT), the higher the precision of the empirical analysis. However, a higher threshold (e.g., 3%) than the one we set (1%), it would reduce the number of observations and possibly question the regression results. The satisfaction of both conditions (precision and number of observations) warrants our preference on the level of the imposed threshold (1%).

Figure 4 Married couple's fertility level by US state, weekly hours of work, and type of employment for females.



Notes: Estimates were conducted by the authors. The two-digit state abbreviations as in Figure 2. *Source*: IPUMS-USA.

but whose job is typically met on "PT jobs". Figure 4 compares the levels of fertility in the developed groups of women. In panel (a), we see that women who are employed on PT schedules but in "FT jobs" show, on average, a higher level of fertility than the other group. This is aligned with Figure 2, where we observed that the fertility of the PT female workers surpasses that of their FT peers. However, notice that the distinction regarding their occupation, imposed in Figure 3 relative to Figure 2, increases further the fertility discrepancy between PT and FT schedules. We depict the difference between the two PT regimes in panel (b). It is interesting to observe in the latter that in most states, women in PT schedules with "FT jobs" have, on average, higher fertility than women in PT schedules. There are, however, considerable exceptions (e.g., Idaho and New Mexico).

Finally, our last step tests the adaptation hypothesis. The latter supports the idea that states which more frequently experience a specific weather event - higher temperatures in our case (e.g. in Florida or in Louisiana) - their habitats are expected to be less influenced by it (27). Heutel et al. (28), for instance, provide some evidence that the mortality effects of temperature vary across the US states given their climates. Particularly, they found that hot days cause fewer deaths in warm places, and vice versa, cold days are less deadly in cool places, which implies that humans tend to adapt to external conditions. Regarding the relationship under investigation, we anticipate the effect of temperature on fertility, through the number of hours worked, to be lower in traditionally warmer places because individuals are better accustomed to heightened temperatures. We estimate the annual mean temperature by US state from 1901 to 2001 to find the half of the states that have historically been the warmest in the US with the goal of creating the dummy for adaptation ($T_{\textit{ad-mean}}$). Unsurprisingly, we found that these are the same 24 states that also displayed the highest mean temperature during the last years (2002-2019). Thus, the simplest method of testing for adaptation cannot be used because both dummies ($T_{\textit{mean}}$ and $T_{\textit{ad-mean}}$) would consist of the same states. The latter would not allow us to disentangle the temperature effect from the adaptation effect. To address this issue, we kept in the sample only the states included in $T_{\textit{mean}}$ (24 warmest), and for each state within the latter dummy, we estimated the difference in its annual mean temperature between the recent period 2002-2019 and the historical one between 1901 and 2001. Hence, the new variable $T_{\textit{ad-mean}}$ consists of 12 states (out of the 24 warmest) with the smallest difference in mean temperatures between these two periods. Our assumption is that individuals in states that show the least increase (difference) in mean temperature between their historical and most recent years should be less influenced by higher temperatures since they are relatively more accustomed to them. Hence, the developed dummy for adaptation ($T_{\textit{ad-mean}}$) satisfies two desired conditions: (1) it refers to a group that consists of the warmest states in the US, and (2) it includes states only from the latter group that has displayed the lowest increase in mean temperature between the periods 1901-2001 and 2002-2019. Some caution is needed here. One may call into question our approach because if individuals in the sample do not reside and work in the state where they were born, the adaptation hypothesis as formulated may be violated. To fulfill the latter requirement, we have also used, as a robustness check, the variable for the state of birth ("bpl") in order to find and keep only individuals who are currently working in the state they were born. The results we derived are qualitatively the same as the ones we present in the next Section. They are available upon request.

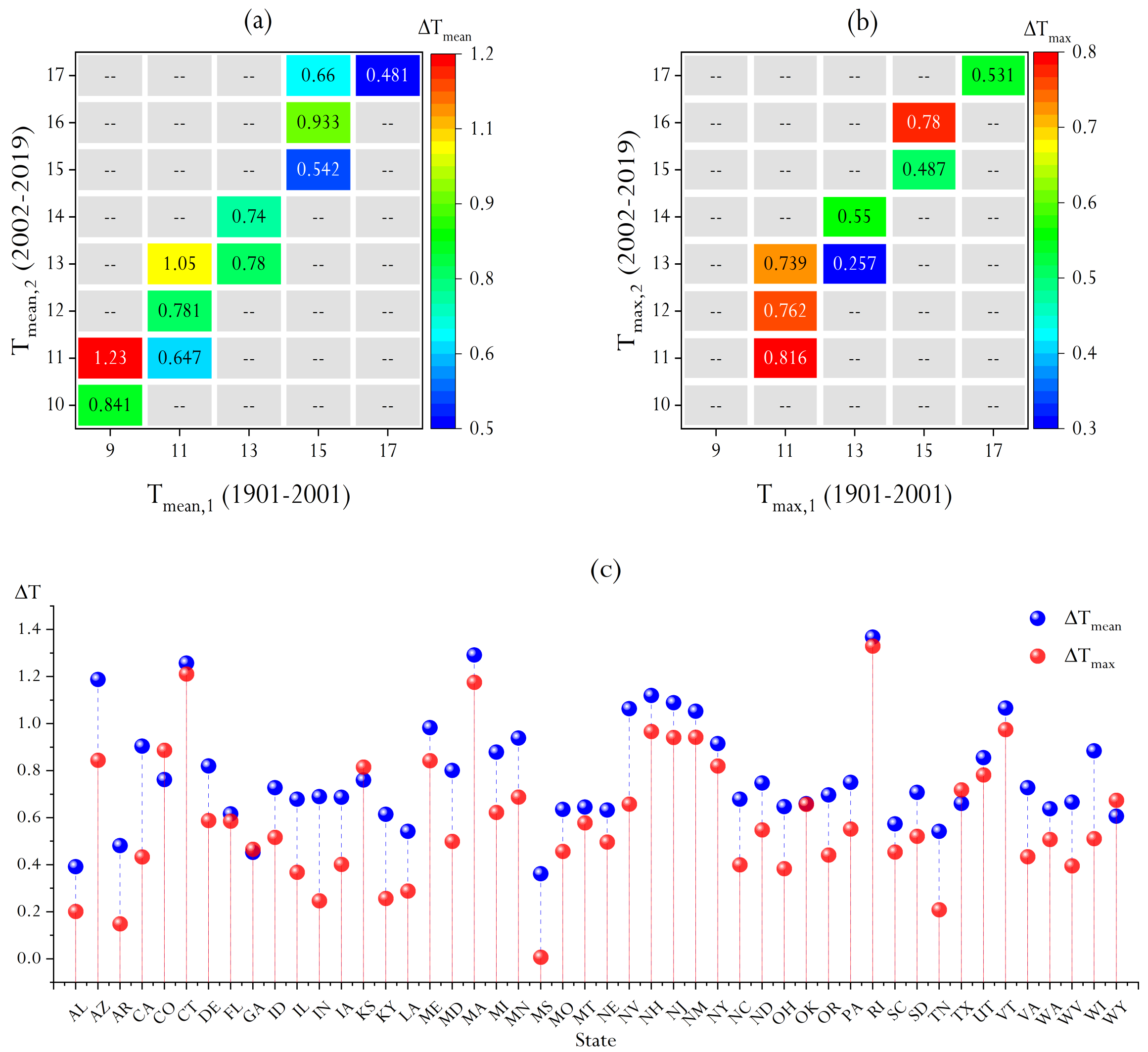
To carry out the adaptation hypothesis regarding the maximum temperature deviation, we construct a dummy for adaptation ($T_{ad\text{-}max}$) based on the difference in the average of the annual maximum temperatures between the two aforementioned periods for each state. T_{max}, like the $T_{ad\text{-}max}$ dummy, may include states with a low mean temperature from 2002 to 2019. The latter allows us to examine the effect of the maximum deviation independently of a specific temperature scale. However, because we are primarily interested mostly in exploring the temperature effect on fertility via working hours in warmer climates, we also interact the $T_{ad\text{-}max}$ dummy with the T_{mean}.

Figure 5 depicts the estimated differences. Notice an interesting feature that is mainly depicted in the mean temperature shift (ΔT_{mean}) in panel (a): most of the biggest increases took place in states with relatively lower mean temperatures. For example, the red window (1.23) is placed in the lowest temperature distribution (coords: 11, 9). The same picture is repeated in panel (b). This evidence suggests that in places where the temperature is already high, it usually exhibits a moderate increment. That may be encouraging for the warmer states, but it should raise concerns in relatively colder locations. Panel (c) compares the estimated differences by US state. It reveals that increases in the mean temperature are, in most states, greater than those in the maximum temperature. The latter suggests that warming in the US is more of a permanent phenomenon than a temporary shock.

According to the preceding analysis, the model specifications for adaptation may be written in the following ways:

$$fert_i = a_0 + a_1 * wwh_i + a_2 * (wwh_i * T_{ad-mean}) + a_3 * hwh_i + a_4 * X_i^{'} + a_5 * Year + a_6 * State + a_7 * Year * State + u_i \quad (4)$$

Figure 5: The estimated differences for T_{mean} and T_{max} between the periods 1901-2001 and 2002-2019.



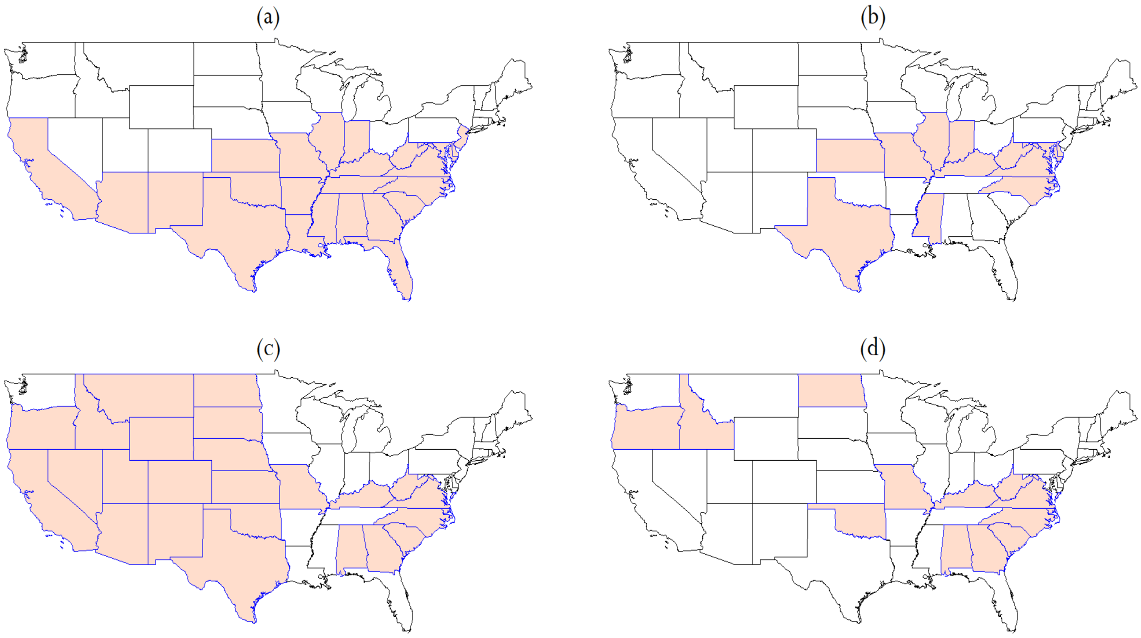
Notes: ΔT_{mean}= $T_{mean,\,2}$ - $T_{mean,\,1}$ and T_{max}= $T_{max,\,2}$ - $T_{max,\,1}$. T_{mean}: the average of the annual mean temperature for each period estimated. T_{max}: the average of the annual maximum temperature for each period estimated. Estimates were conducted by the authors. The two-digit state abbreviations as in Figure 2. *Source*: World Bank.

$$fert_i = a_0 + a_1 * wwh_i + a_2 * (wwh_i * T_{ad-max}) + a_3 * hwh_i + a_4 * X_i' + a_5 * Year + a_6 * State + a_7 * Year * State + u_i \tag{5}$$

$$fert_i = a_0 + a_1 * wwh_i + a_2 * (wwh_i * T_{ad-max} * T_{ad-mean}) + a_3 * hwh_i + a_4 * X_i' + a_5 * Year + a_6 * State + a_7 * Year * State + u_i \tag{6}$$

where $T_{ad\text{-}mean}$ is the dummy that aims to test adaptation using the mean temperature approach. It takes the value 1 for the 12 states with the lowest difference in the mean temperatures between the periods 2002-2019 and 1901-2001, out of the 24 warmest states in the US during the period 2002-2019; it takes the value 0 otherwise. The dummy $T_{ad\text{-}max}$ is used to test the adaptation effect in the maximum deviation approach. It takes the value 1 for the 12 states with the lowest difference (increase) in the mean of their maximum temperatures between 2002-2019 and 1901-2001, out of the 24 states in the US with the highest deviation in 2002-2019; otherwise, it is set to 0. For the T_{mean} and T_{max} dummies, see the explanation below equations 2 and 3. For the rest see equation 1. Figure 6 depicts each state on the US maps that have been included in the constructed dummies (T_{mean}, $T_{ad\text{-}mean}$, T_{max}, $T_{ad\text{-}max}$).

Figure 6: States included in each of the temperature dummies developed.



Notes: Panels (a), (b), (c), and (d) refer to the states included in the T_{mean}, $T_{ad\text{-}mean}$, T_{max}, and $T_{ad\text{-}max}$ dummy, respectively. Estimates were conducted by the authors. *Source*: World Bank.

Finally, one might question the perceived cross-sectional approach in the sense that we may face endogeneity issues and specifically the existence of reverse causality. That is, women who decide to give birth would probably choose to reduce their number of working hours. The latter would obtain a spurious negative correlation between fertility and the number of working hours. By splitting the sample into women with FT and PT schedules, we think that we have dealt to a great extent with this issue.

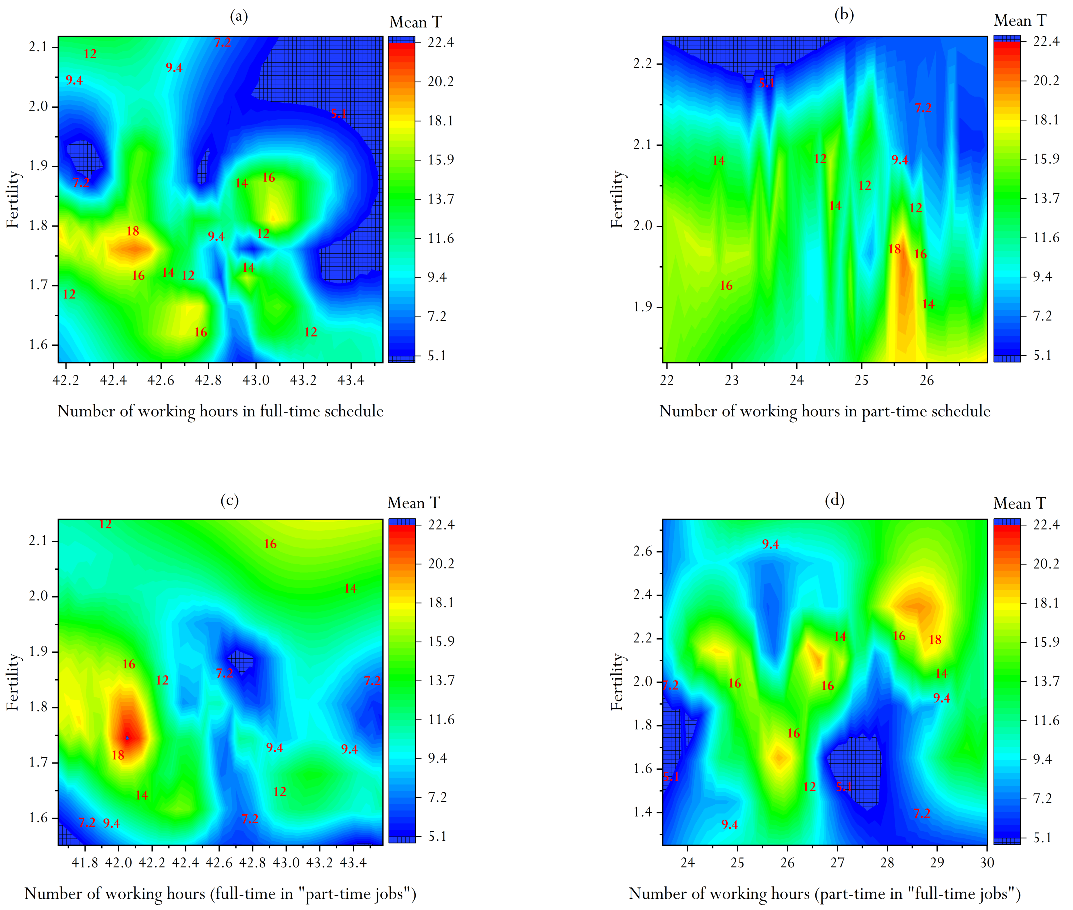
3 Results

3.1 Contour panels

Contour panels in Figure 7 have the advantage of exhibiting the correlation among three variables at the same time. Panel (a) indicates that higher levels of fertility are mostly associated with lower temperatures for wives who work FT (blue region). The red region of higher temperature (18 $^{\circ}C$) is met on the lower segment of the working hours distribution ($<$42.6) and for fertility less than 1.8. Thus, panel (a) suggests that high temperatures are not conducive to either a higher number of working hours or fertility. In panel (b), we consider the PT schedule. The red region is placed in the higher segment of the distribution of working hours ($>$25), which is opposed to the pattern derived in panel (a). However, in line with the latter, the red region concurs with relatively lower fertility ($\leq$ 2). Another interesting feature is the expansion of the blue region (low temperatures) with the increase in working hours, which is also observed in panel (a). This evidence suggests that women in warmer states tend to work fewer hours.

In panel (c), we take the group of wives who work FT in jobs usually referred to as "PT" ones. The picture is similar to panel (a). The red region has the same levels of working hours and fertility as the latter. There are some differences though. Here, we see that the green color dominates at the higher fertility level ($>$2). Hence, moderate temperatures seem advantageous for this group. Lastly, panel (d) displays the case of wives who work PT in "FT jobs". It reveals a great dispersion of the red regions; we note four different red hot spots. The largest one is located at the top right of the panel, which corresponds to high fertility ($>$ 2.1) and working hours ($>$ 28). This is important because it shows that the group of PT in "FT jobs" is the only one among the four examined groups, for which fertility as well as the number of hours worked remain relatively unaffected by higher temperatures.

Figure 7: Contour plots among fertility, temperature, and the work schedule for wives.



Notes: Regions of vertical and horizontal black lines within plots denote "no data". Numbers within plots refer to the mean temperature (T_{mean}) at the respective point. Estimates were conducted by the authors. Period: 2002-2019. *Source*: IPUMS-USA and World Bank.

3.2 Regression results

3.2.1 The case of the mean temperature

We start with the investigation of the effect of the annual mean temperature on fertility. In Table 2, the mean temperature has a statistically significant ($p<.05$) negative effect on a couple's fertility (col. 1), which aligns with findings in Barreca et al. (1). In col. 1 and 2, the number of wives' working hours (wwh) is negatively correlated to fertility. The latter reflects the substitution effect of women (29). That is, an extra hour at work translates into an extra hour less for childcare - assuming zero childcare purchases. In col. 2, the interaction with temperature (wwh $*T_{mean}$) has a positive effect, implying that the substitution effect is reduced in states with higher mean temperatures. The husband's number of working hours (hwh) shows only a tiny and insignificant effect on fertility (.009). This is repeated across all columns. His wage has a convex impact on fertility, whereas that of his wife has a concave one. Both were found to be statistically significant ($p<.01$).

To better explore the investigated interrelationship among temperature, the number of female working hours, and fertility, we separated our sample between PT and FT working wives (col. 3 and 4, respectively) for reasons delineated in step three. The statistical significance and signs for wwh, and the interaction with the mean temperature, remain the same in the PT schedule (< 40). In the FT schedule ($\geqslant 40$) the effect of wwh becomes positive though insignificant. Only in the PT schedule does the temperature interaction effect become significant ($p< 0.01$). It is still positive and has slightly increased. Before we further examine the temperature effect, we focus on the interpretation of the obtained results on the wwh and wages (*wife wage* and *husb. wage*) hitherto. The comprehension of the latter is crucial to understanding the direction of the temperature influence we see next.

The obtained coefficient for the *husb. wage* could be attributed to the quality-quantity trade-off (30). Thus, at lower levels of wages, a wage increase causes couples to reduce the number of children (quantity) in order to invest more in their children's education (quality). This behavior is driven by the rise in human capital returns. Once the level of wage is high enough, couples are probably more able to provide their children with the desired level of education and at the same time fulfill their fertility preferences. Thus, there is a turning point that reverses the negative correlation between wages and fertility into a positive. This mech-

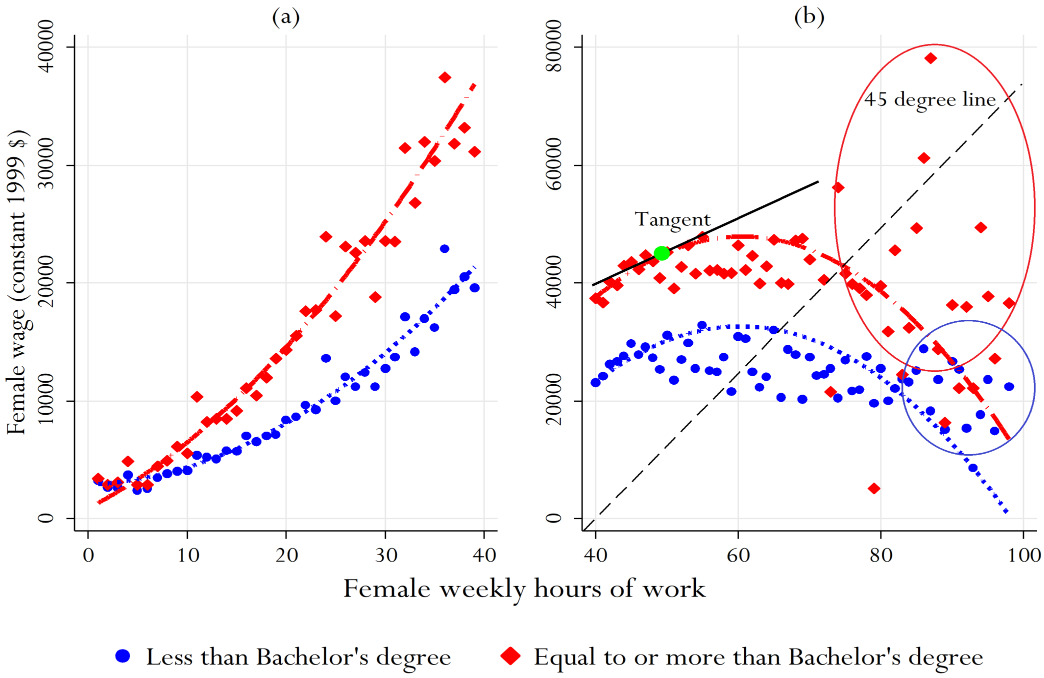
Table 2 Regression results for the mean temperature.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Hours worked:	Any	Any	<40	⩾ 40	<40 in "FT jobs"	⩾ 40 in "PT jobs"	Assess adaptation[a]	Assess adaptation[b]
ln(T)	-.132**							
	(.059)							
ln(wwh)	-.088***	-.108***	-.095***	.023	-.108***	.258***	-.115***	.162**
	(.003)	(.005)	(.006)	(.027)	(.032)	(.096)	(.025)	(.072)
ln(wwh)*T_{mean}		.034***	.036***	-.039	.003	-.296**		
		(.005)	(.007)	(.034)	(.034)	(.121)		
ln(wwh)*$T_{ad\text{-}mean}$							.031	-.270**
							(.034)	(.134)
ln(hwh)	.009	.009	.005	.002	.010	-.021	.011	.022
	(.007)	(.007)	(.011)	(.009)	(.043)	(.029)	(.044)	(.029)
ln(husb. wage)	-.123***	-.123***	-.077***	-.130***	-.005	-.020	-.005	-.024
	(.020)	(.020)	(.024)	(.029)	(.098)	(.100)	(.098)	(.099)
ln(husb. wage)^2	.005***	.005***	.003***	.006***	.0007	.001	.001	.001
	(.001)	(.001)	(.001)	(.001)	(.004)	(.005)	(.004)	(.005)
ln(wife wage)	.041***	.041***	.088***	-.118***	.076	.064	.073	.007
	(.011)	(.011)	(.015)	(.024)	(.086)	(.064)	(.085)	(.064)
ln(wife wage)^2	-.003***	-.003***	-.006***	.005***	-.004	-.002	-.004	-.002
	(.0006)	(.0006)	(.0009)	(.001)	(.004)	(.003)	(.004)	(.003)
ln(state income)	-.542	-4.56***	-4.44**	-.314	4.51	8.65	4.65	-7.74***
	(.80)	(1.17)	(1.84)	(2.52)	(3.24)	(7.20)	(2.87)	(2.55)
R^2	0.210	0.210	0.233	0.210	0.463	0.385	0.463	0.385
Number of obs.	146,738	146,738	59,792	86,946	3,206	7,019	3,206	7,019

Notes: Dependent variable: number of own child/children (if any) of age $\leqslant$ 1. FT: full-time; PT: part-time. [a]We test the adaptation hypothesis for wives who work less than 40 hours per week in "FT jobs". [b]We test the adaptation hypothesis for wives who work equal to or more than 40 hours per week in "PT jobs". And other control variables have been included. Robust s.e. in parentheses. *** p-value$<$ 0.01, ** p-value$<$ 0.05, * p-value$<$ 0.1.

anism does not seem to apply with respect to the earnings of the wife, as we see in col. 1 and 2. The female wage presents the inverse behavior: its impact increases with fertility at lower levels of wage, it reaches a peak, and begins to fall from a point on. This is, perhaps, the result of the opportunity cost and the substitution effect (whereas in men we have only the income effect). It is important to draw a subtle and crucial distinction between the opportunity cost and the substitution effect regarding fertility. The substitution effect imposes a direct cost (more time devoted to work means less disposable time for childcare). The opportunity cost implies an indirect cost (*potential* foregone earnings). Hence, the opportunity cost has a key role in fertility before employment. Once a woman decides to work (the decision *per se* is important in this context because it shows that the dilemma has been overcome), and before she starts working, her opportunity cost becomes null. Once she is hired, the substitution effect arises along with the income effect (from her earned wage). From this point on, the substitution effect competes with the income effect. By bearing this analysis in mind, we turn to the interpretation of the *wwh* and *wife wage* results.

Figure 8: The relationship between female wage and weekly hours of work by level of education.



Notes: The lines represent the fit of each correlation. The diagonal dashed line represents the 45° degree line. The solid line in (b) is the tangent of the upward segment of the curve. Estimates were conducted by the authors. *Source*: IPUMS-USA.

Figure 8 helps us further with the interpretation. It depicts the relationship between the female wage and hours worked for two educational groups according to their work schedules. Panels (a) and (b) refer to the women that work less, and equal to or more than 40 hours per week, respectively. Figure 8 reveals that the female number of hours worked displays a concave relationship with earnings.[3] We observe that in the PT schedule (panel a), the female wage augments in both educational groups at a positive pace. This implies that the income effect (I) from the female wage increase prevails over the substitution effect (S) from an increase in working hours: $dI/dS > 1$. Hence, women in this segment of the curve face a growing opportunity cost and a decreasing substitution effect relative to the income effect for each additional hour of work. The slope difference between the two educational groups confirms that the highly-skilled women face a higher opportunity cost (31). At the same time, the earned wage remains insufficient (<40000) to fully compensate for the additional work-

[3]Panels (a) and (b) together constitute the concave relationship we refer to. We present it divided for reasons of analysis.

ing hour taken from childcare (depending on the relative childcare price). Consequently, the prevalence of the increasing opportunity cost against the gains from the decreasing substitution effect across the PT curve explains why fertility falls with wwh (col. 3: -.095***), although women in PT schedules experience on average higher fertility than those in FT schedules (Figure 3). Also, the income effect on fertility surpasses that of the substitution effect, which is why fertility has been found initially to increase and then to fall with the *wife wage* (col.3 : .088*** and -.006***).

The inverse holds true for women who work FT ($\geqslant 40$). In this segment of the curve (plot b), we observe that the female wage initially increases with a decreasing rate ($0 < dI/dS < 1$), it stagnates ($dI/dS = 0$) and then falls ($dI/dS < 0$). Hence, women on FT schedules face a declining opportunity cost with an extra hour of work ($dI/dS1$) in the best-case scenario (compare the slope of the tangent of the highly educated wives with that of the 45-degree dashed line).[4] The high level of wage, however, may allow this group of women to substitute their increased working hours with childcare purchases (32) – especially for the well-educated (notice where the circle with the most outliers of each group lies). Hence, the decreasing or zero opportunity cost explicates the fertility increase with wwh (col. 4: .023). The change in the relationship between the income effect and the substitution effect (now it is: income<substitution) warrants the convex correlation with the *wife wage*.[5]

As we discussed in Subsection 2.2, an extra hour of work in the PT schedule may be less detrimental to fertility than in the FT schedule due to the lower level of working hours, which implies less losses on labor productivity under the effect of higher temperatures. However, if women in occupations that are met on PT schedules are more vulnerable to hot weather, the effect of the moderate loss in productivity may be concealed. Hence, disentangling the potential opposing effects is essential to highlight the real temperature impact on fertility through the number of working hours and productivity. For this purpose, we have further separated our sample into wives who work PT but in "FT jobs" (col. 5), and wives who work

[4]We consider the tangent on the curve of the most educated women because they face a higher opportunity cost (slope), and thus, it makes our claim applicable to the other group as well.

[5]Only in col. 4 does the *wife wage* have a significant convex effect on fertility. The derived result we see later on in col. 6 indicates that the latter arises from wives who work FT in "FT jobs". This aligns with the analysis presented since these women earn higher wages than those in FT schedules but in "PT jobs" (col. 6), and thus, they have a better chance to purchase childcare. However, we did not consider this group of wives because our primary goal was to highlight and disentangle the confounding effects with respect to temperature. The distinction we present is, in our view, sufficient for this purpose.

FT but in "PT jobs" (col. 6). We found that the negative wwh effect in col. 5 augments to -.108***, which reaffirms the substitution effect hypothesis. Interestingly enough, the interaction effect (wwh*T_{mean}) diminishes and also becomes positive and insignificant (.003). Previously, in col. 3, where the type of occupation had not been taken into account, the effect was bigger and significant (.036***). In col. 6, the effect of wwh was found to be positive, significant, and greater (.258***) than the negative one in col. 5 (-.108***). In addition, the interaction with the mean temperature becomes negative (-.296**). Thus, the obtained results provide some evidence that the type of job, as well as the type of employment (PT or FT), have a distinguished role regarding the effect of temperature, through the number of working hours, on fertility.

From the results presented thus far, a crucial question is posed: why does temperature have a positive effect on fertility for the women who work PT in "FT jobs" and a negative one for those who work FT but in "PT jobs"? In col. 5 (PT in "FT jobs") we saw that, although women who work PT give more births (Figure 2), an extra hour of work declines their fertility because of the prevalence of their increasing opportunity cost against their decreasing substitution effect, as we explained with the help of Figure 8. A potential channel through which temperature acts in this instance could be the labor supply, because higher temperatures reduce the number of hours worked. Jiao et al. (33) found that on days with extremely high temperatures, women reduce their labor supply by about one hour. Thus, if temperature does reduce the number of working hours, the opportunity cost that women face is also reduced in col. 5 [which assigns to a movement to the left along the curve in Figure 8(a)]. The opportunity cost reduction could in turn increase fertility levels - given stable fertility preferences. This mechanism may explain the positive wwh*T_{mean} effect we see. However, this effect is small and insignificant (.003). The latter may be expected for two reasons. First, higher temperatures should harm labor productivity more in FT rather than PT workers as we already explained in step three (Subsection 2.2). And second, we have provided evidence that women in this category (PT in "FT jobs") are more educated and are occupied in jobs of higher quality, and therefore, they are probably less affected by higher temperature (25). Thus, there are two potential effects that operate in the same direction: fewer hours of work and jobs of better quality. On the other hand, taking the same channel of labor supply (opportunity cost) for the other group of women in col. 6, we see that temperature exerts a negative and statistically significant impact on them (-.296**). This is because the reduction in working hours, as a result of higher temperatures, increases the opportunity cost in this category [movement to the left along the curve in Figure 8(b)] and subsequently leads to fertility decline. Thus, the explanation remains the same. Only the direction changes.

Lastly, we carry out the adaptation hypothesis. In col. 7 and 8, we test for adaptation in the samples that consist of wives working PT in "FT jobs" and wives who work FT in "PT jobs", respectively. The effect of wwh in both cases aligns with the previous ones (-.115*** and .162**). The variable wwh*$T_{\textit{ad-mean}}$ in col. 7 aims to estimate the temperature interaction effect in states with the smallest temperature difference between the periods 1901-2001 and 2002-2019. It exerts a positive, relatively small, and insignificant effect on fertility (.031). When we compare the derived coefficient to the one in col. 5, we get: .031>.003. This outcome denotes the absence of any adaptive behavior. However, notice that the small size of the effect (.031) and its insignificance, may suggest that there is no need for adaptation in this group of women, because the temperature interaction effect has been found negligible (.003). On the contrary, for the women in FT schedules but in "PT jobs" in col. 8, the effect is substantial and less negative (-.270**) than previously in col. 6 (-.296**). The observed reduction of the interaction effect in the states that display the smallest mean temperature difference between 1901-2001 and 2002-2019 demonstrates adaptive behavior. The discrepancy between the two coefficients reveals the size of adaptation: .026.

3.2.2 The case of the maximum deviation from the mean temperature

We present the respective results for the maximum deviation from the mean temperature in Table 3. This takes place as a kind of robustness check. We see no considerable differences from the results obtained with the mean temperature apart, from the adaptation hypothesis test. The interpretation remains essentially the same.

In step 4, we described the derivation of the T_{max} dummy. There we noted that T_{max} does not necessarily include states that have also experienced the highest annual mean temperature (T_{mean}). Thus, to check the fertility behavior in the latter as well, we interacted the T_{max}

Table 3 Regression results for the maximum deviation temperature.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Hours worked:	Any	Any	<40	⩾ 40	<40 in "FT jobs"	⩾ 40 in "PT jobs"	Assess adaptation[a]	Assess adaptation[b]
ln(T)	-8.06**							
	(3. 64)							
ln(wwh)	-.088***	-.106***	-.088***	.012	-.101***	.361***	-.106***	.305***
	(.003)	(.005)	(.007)	(.031)	(.035)	(.108)	(.033)	(.100)
ln(wwh)*T_{max}		-.007	-.029**	.057	-.041	-.534***		
		(.009)	(.012)	(.066)	(.070)	(.205)		
ln(wwh)*T_{max}*T_{mean}		.040***	.034***	-.027	.016	-.316**		
		(.006)	(.009)	(.041)	(.039)	(.144)		
ln(wwh)*$T_{ad\text{-}max}$							-.017	-.544**
							(.106)	(.263)
ln(wwh)*T_{max}*T_{mean}							.078	-.381**
							(.049)	(.191)
ln(hwh)	.009	.008	.005	.002	.009	-.022	.009	-.022
	(.007)	(.007)	(.011)	(.009)	(.043)	(.029)	(.044)	(.029)
ln(husb. wage)	-.123***	-.123***	-.077***	-.130***	-.002	-.018	-.004	-.012
	(.020)	(.020)	(.024)	(.029)	(.097)	(.100)	(.098)	(.101)
ln(husb. wage)^2	.005***	.005***	.003***	.006***	.001	.001	.001	.001
	(.001)	(.001)	(.001)	(.001)	(.004)	(.005)	(.004)	(.005)
ln(wife wage)	.039***	.040***	.088***	-.118***	.076	.007	.060	.006
	(.011)	(.011)	(.015)	(.024)	(.085)	(.064)	(.088)	(.064)
ln(wife wage)^2	-.003***	-.003***	-.006***	.005***	-.004	-.002	-.003	-.002
	(.001)	(.001)	(.001)	(.001)	(.004)	(.003)	(.004)	(.003)
ln(state income)	-30.07**	-5.36***	-5.70***	2.22	2.13	-19.91	1.24	13.31
	(13.19)	(1.26)	(1.90)	(4.06)	(4.10)	(11.52)	(3.49)	(10.89)
R^2	0.210	0.211	0.233	0.210	0.464	0.386	0.464	0.386
Number of obs.	146,738	146,738	59,792	86,946	3,206	7,019	3,206	7,019

Notes: Dependent variable: number of own child/children (if any) of age $\leqslant$ 1. FT: full-time; PT: part-time. [a]We test the adaptation hypothesis for wives who work less than 40 hours per week in "FT jobs". [b]We test the adaptation hypothesis for wives who work equal to or more than 40 hours per week in "PT jobs". Other control variables have been included. Robust s.e. in parentheses. *** p-value$<$ 0.01, ** p-value$<$ 0.05, * p-value$<$ 0.1.

dummy with the T_{mean} dummy. As in the previous subsection, the effect in col. 1 is negative and significant (-8.06**). The effect of wwh, before any classification in work schedules, was found to be negative and significant (cols 1 and 2). The wage variables display qualitatively the same behavior we observed in Table 2.

The effect of wwh when interacted with the T_{max} dummy is quite interesting. It is negative and statistically significant (-.029**) in the PT schedule (col. 3), whereas it was found to be positive and significant (.036***) with the T_{mean}. A potential explanation for the sign differentiation could be the absence of many of the highest mean temperature states within the T_{max} dummy. That is, in the wwh*T_{max} interaction effect we see the result only for states that have experienced an upward deviation from their mean annual temperature. The latter could be beneficial rather than harmful for labor productivity in states with colder climates. It may indicate the presence of a threshold in the lower temperature distribution, which once crossed, fosters female labor participation.[6] In this regard, the negative coefficient raises the opportunity cost even further, possibly by increasing the number of hours worked. We found a positive effect (.034***) when we multiplied the T_{mean} to develop the wwh*T_{max}*T_{mean} interaction and checked the behavior for the maximum deviation in warmer states (a higher T_{mean}), as shown in Table 3. The shift to a positive sign lends further support to the proposed interpretation. However, this is not supported by the findings in col. 5 and 6. The effect of wwh*T_{max} becomes insignificant in col. 5, whereas it has been found to be negative, significant, and sizeable (-.534***) for women working FT in "PT jobs" (col. 6). Thus, the interaction with the maximum deviation reduces the positive wwh effect on fertility even in states with lower mean temperature. Moreover, we observe that the negative sign persists in the $wwh * T_{max} * T_{mean}$ interaction, albeit attenuated to -.316**. The observed reduction may be ascribed to the fact that most of the states included in the T_{mean} dummy that was multiplied, appear to be the ones with the lowest maximum deviation (see Figure 6).

Finally, regarding the adaptation hypothesis, we re-investigate the examined relationship for states with the lowest increase in maximum deviation between 1901-2001 and 2002-2019 ($T_{ad\text{-}max}$). The effect we obtained for the PT in "FT jobs" in col. 7 is negative but small and insignificant (-.017). With the same sign but of greater magnitude than the latter has been derived the effect for women in FT schedule of "PT jobs" (-.546**). This is greater than that of T_{max} (-.534***). The latter refutes the adaptation hypothesis. The same is true for the states that also have the highest mean temperature (T_{mean}). In particular, we obtained a coefficient of -.381**, which is greater than the respective effect excluding adaptation: -.316**. Again, this finding does not provide sufficient support for the adaptation hypothesis.

4 Conclusions

In this study, we employed individual-level data from the IPUMS-USA database (2002-2019), and annual temperature data at the state level from the World Bank (1901-2001), to solicit the effect of higher temperatures on the fertility of married couples through labor supply and productivity. To our knowledge, this is the first endeavor to explore the role of female hours of work and productivity regarding the effect of temperature on fertility.

[6]Closely to this finding is the work of Cai et al. (34). Cai and his colleagues found an inverted U-shaped relationship between temperature and labor productivity.

We separated our sample into women who work either part-time (PT) or full-time (FT). We found that an extra hour of work in the PT schedule reduces births, whereas an extra hour of work in the FT schedule increases births. We attempted to demonstrate that the obtained result is linked to changes in the opportunity cost, substitution, and income effects. The opportunity cost moves in different directions depending on the number of working hours. Because of the concave relationship between female wage and hours worked, an increase in the latter raises the opportunity cost in the PT schedule more than a decrease in the substitution effect. In this instance, the income is not enough to compensate for the latter, and thus fertility falls. On the contrary, the opportunity cost is declining in the FT schedule with an extra hour of work, and following the same set of arguments as in the PT (but in the opposite direction), it increases fertility. The interaction effect of temperature with the number of female hours worked changes accordingly. Thus, in the developed dummy that includes the 24 states with the highest mean temperature from the total of 48 considered in this study, we found that the effect on fertility is positive and significant in the PT schedule but negative and negligible in the FT one.

To scrutinize further the examined relationship, we separated the sample into women who work PT but in "FT jobs" and those who work FT in "PT jobs". By the notion of "PT" or "FT jobs", we referred to occupations that are most common among women who work PT or FT, respectively, according to records in the IPUMS-USA database. We should highlight the fact that the vast majority of the occupations included in the analysis are regarded as "indoor". The results revealed that the temperature-working hours' interaction effect is negligible in the group of women who worked PT in an "FT job". The respective impact for the group of FT schedules in "PT jobs" is negative, more sizeable, and significant. We have interpreted these outcomes through the lens of the number of working hours. That is, the group of FT in "PT jobs" faces a greater loss in labor productivity due to heightened temperatures (in turn due to the increased level of working hours), which acts negatively on fertility. In the FT employment status, the opportunity cost was found to decrease with hours of work, which implies, inversely, that the opportunity cost increases as the number of working hours dwindle. The latter causes a decline in fertility. The same applies to the other group, but the other way around. Thus, we observed that in the PT group of women, who work in

"FT jobs", the temperature interaction effect is positive. However, the effect emerged as insignificant. This has been explained by the fact that "FT jobs" in the IPUMS-USA are occupations with relatively higher educational demands than the "PT" ones. Indeed, with the data at hand, we corroborated that women in "PT jobs" are, on average, of lower educational attainment. Thus, women who work PT in "FT jobs" are probably better protected from the effect of higher temperatures on fertility because they face a lower productivity loss and they are also benefited more from the better quality of their job. A robustness analysis has been conducted by creating a dummy with the 24 states with the highest maximum annual temperature deviation from the mean. Results did not deviate a lot from the ones with the mean temperature dummy. Inferences remain the same.

Finally, we found some evidence for the adaptation hypothesis only in the group of women who work FT in "PT jobs", as one would expect given the negligible effect of temperature on the other group (which entails no need for any kind of adaptation). In particular, we created a dummy ($T_{ad\text{-}mean}$) that includes 12 states, out of the 24 with the highest mean temperatures (T_{mean}), which have shown the least increase in their mean temperature between the historical period 1901-2001 and the most recent years 2002-2019. The intuition is that individuals in these states are better accustomed to their warmer local climate, and hence, they should be less affected by a modest temperature increase relative to the rest of the warmest states that exhibited a greater increase. The comparison between the coefficients of T_{mean} and $T_{ad\text{-}mean}$ reveals a discrepancy of .026. This evidence supports the adaptation hypothesis.

To conclude, this paper aligns with studies on climate change showing that global warming is going to affect the most vulnerable individuals (35; 36; 37). In the same vein, our results suggest that higher temperatures affect more the women, who work long hours and are employed in occupations of lower educational demands. Knowing this latter fact and identifying the specific channels that are in place may be a fruitful way to tackle the fertility implications of global warming.

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