MAX PLANCK INSTITUTE
FOR DEMOGRAPHIC RESEARCH

Konrad-Zuse-Strasse 1 · D-18057 Rostock · Germany · Tel +49 (0) 3 81 20 81 - 0 · Fax +49 (0) 3 81 20 81 - 202 · www.demogr.mpg.de

MPIDR Working Paper WP 2023-022 | May 2023
https://doi.org/10.4054/MPIDR-WP-2023-022

Revisiting the J-shape. Human Development and Fertility in the United States

Henrik-Alexander Schubert | schubert@demogr.mpg.de
Christian Dudel | dudel@demogr.mpg.de
Marina Kolobova | kolobova@demogr.mpg.de
Mikko Myrskylä | myrskyla@demogr.mpg.de

Revisiting the J-shape. Human Development and Fertility in the United States

Henrik-Alexander Schubert[1,2], Christian Dudel[1,3], Marina Kolobova[1], and Mikko Myrskylä[1,4,5]

[1]*Max Planck Institute for Demographic Research, Rostock, Germany*
[2]*University of Oxford, Nuffield College, Department of Sociology, England*
[3]*Federal Institute for Population Research, Wiesbaden, Germany*
[4]*University of Helsinki, Finland*
[5]*Max Planck – University of Helsinki Center for Social Inequalities in Population Health, Rostock, Germany and Helsinki, Finland*

Abstract

Economic and social development are closely linked with fertility. Several studies have shown that the relationship follows an inverse J-shape: at low and intermediate levels of development, the association is negative; and at high levels of development the association is reversed and becomes positive. However, more recent research building on subnational and U.S. data found only mixed evidence for the inverse J-shape. In this paper, we draw on subnational data on development and fertility in the U.S. states between 1969 and 2018 to examine the relationship between development and fertility. Using a longitudinal approach and addressing several criticisms of the fertility reversal hypothesis, our results support the inverse J-shaped pattern, reconciling trends observed in the U.S. with those in other high-income countries. We also discuss potential explanations for why studies might not detect the inverse J-shape. Moreover, our findings provide insights into the mechanisms that link development and fertility, showing that gender equality and economic uncertainty mediate the relationship between development and fertility.

1 Introduction

Are economic and social development and fertility negatively or positively associated? From a theoretical perspective, proponents of the demographic transition model have long argued that development increases the costs of having children, improves the means to control childbearing, and gives rise to life goals that are not compatible with fertility (Lesthaeghe and Van de Kaa, 1986; van de Kaa, 1987; Notestein, 1945; Davis, 1945). Thus, fertility and development should have a negative association. This theory accurately describes the lowest-low fertility observed in high-income countries, including the drop in fertility below the replacement level in the United States (Kohler and Ortega, 2002; Ruggles, 2015). However, this model was challenged when a study found reversals of fertility declines (Myrskylä et al., 2009). The association between fertility and development was shown to follow an inverse J-shaped pattern, with a negative association at low and medium levels of development, and a positive association at higher levels of development.

The initial evidence on the inverse J-shape and on reversals of fertility declines spawned a rich, partly critical body of literature that generated mixed evidence. Several studies replicated the original findings at the national and the subnational levels, and argued that gender attitudes, late childbearing, and family policies have been key contributors to recent fertility increases (Myrskylä et al., 2011; Luci-Greulich and Thévenon, 2014; Anderson and Kohler, 2015; Kolk, 2019; Mavropoulos and Panagiotidis, 2021; Fox et al., 2019). However, other studies failed to find an inverse J-shaped relationship between fertility and development (Ryabov, 2015; Harknett et al., 2014; Gaddy, 2021). For instance, Ryabov (2015) did not find a J-shaped relationship based on an analysis of cross-sectional data for the U.S. states. One potential explanation for why the inverse J-shape could be a spurious finding cites measurement errors. Fertility is often measured using the total fertility rate (TFR), which suffers from tempo distortions (Bongaarts and Sobotka, 2012); and development is captured through the Human Development Index (HDI), which is known to be imprecise (Ghislandi et al., 2019).

In this paper, we use data for the U.S. states and the District of Columbia covering the years 1969 to 2018 to re-examine the relationship between development and fertility. To address the criticisms raised in the literature, we use several measures of fertility and several measures of development, and we apply several different panel regression approaches. For instance, we test the inverse J-shape with three measures of fertility: the TFR, a tempo-adjusted TFR, and the TFR for men. The tempo-adjusted TFR removes distortions of fertility levels caused by postponement (Bongaarts and Watkins, 1996), while the TFR for men can differ substantially from the TFR for women because of birth squeezes caused by migration and cohort size (Dudel and Klüsener, 2019). We also provide insights into the potential mechanisms behind the association between development and fertility, including gender relations and economic uncertainty. The results are fully reproducible and all code is available online at `https://osf.io/mrzb5/?view_only=98d4065e951d4b8bb1d03198fa12ddd8`; the data can be obtained from National Bureau of Economic Research (NBER), the United States Mortality DataBase and the Global Data Lab.

Studying the relationship between development and fertility at the subnational level is crucial for the discussion of fertility decline reversals. There is considerable heterogeneity in terms of income, living standards, and well-being within countries (See for the United States Scherbov and Gietel-Basten, 2020; Porter and Purser, 2008). Moreover, within-country research designs are promising because they are robust to some common sources of error in cross-country research. Empirical investigations at the country level can be biased by unobserved heterogeneity due to cultural and institutional differences which are difficult to control for. In addition, cultural differences tend to be less pronounced and the institutional setup shows less variation within countries than between countries.

The United States is an interesting case for studying the relationship between development and fertility for several reasons. There is evidence that at the national level in the U.S., there has been a pronounced reversal of the fertility decline at a comparatively high level of fertility (Luci-Greulich and Thévenon, 2014), which makes the U.S. a somewhat special case among high-income countries. Furthermore, because there has been considerable variation in development and fertility trends at the subnational level and over time, it is ideally suited for conducting subnational analyses (Scherbov and Gietel-Basten, 2020). Finally, given that results from previous research on fertility decline reversals in the U.S. have been inconsistent, it is worthwhile to study the U.S. in more depth to help explain these inconsistencies (Ryabov, 2015; Porter, 2017).

This paper contributes to the literature in several ways. We provide the first longitudinal analysis of fertility decline reversals in the U.S. using data at the subnational level that cover a 50-year period and all U.S. states. Moreover, we address general criticisms of the reversal hypothesis raised in the literature by using several indicators of development and fertility, and by conducting several robustness checks. Our analyses reconcile inconsistent findings regarding fertility reversals at the subnational level, and provide new insights into potential drivers of reversals. Furthermore, we examine how the association between development and fertility has developed in recent years, and thus a period has not been covered by most existing papers. We find that there was no association between development and fertility during the post-recession period.

2 Background

2.1 Fertility and development at the national level

Several theoretical approaches argue that development and fertility are linked. In the following, development will be broadly understood as the material conditions, wealth, technological progress, social equality, and public support in a spatially bounded area that have an impact on the well-being of people (Sen, 1998). Thus, the concept highlights the importance of contextual characteristics for people's lives.

Demographic transition theory hypothesises a negative connection between fertility and development, starting with the observation that for much of history, fertility declined with increasing development. Proponents of the theory of the first demographic transition (Bryant, 2007; Notestein, 1945; Davis, 1945) have asserted that modernisation and the associated increases in wealth, the spread of education, and the improved survival are linked to reduced fertility. Based on the first demographic transition theory, it was argued that once the transition is completed, fertility would form a long-term equilibrium with mortality around replacement level (Casterline, 2003, p. 2011). [1]

Van de Kaa (1987) and Lesthaeghe (1986) suggested that the first demographic transition is followed by a second demographic transition, which is characterised by increasing non-marital cohabitation and the emergence of lowest-low fertility. The underlying driver of the second demographic transition is individualisation, which is itself related to development, because increases in wealth and changes in the occupational structure are assumed to spur value change (Beck, 1992; Inglehart, 1977). Individualisation leads to the emergence of competing life goals and the weakening of traditional institutions, which, in turn, lead to increased rates of non-marital cohabitation, reductions in fertility and high levels of childlessness. In its original formulation, the theory predicts that individualisation entrenches fertility at low levels (Lesthaeghe and Van de Kaa, 1986; van de Kaa, 1987).

Beyond the macro-level theories, the household economics framework by Becker (1981) provides a micro-level foundation that, among other things, offers an explanation for the negative relationship between development and fertility. This perspective assumes that development changes the structure of society by expanding educational participation and increasing wages. In response to increasing education and wage levels, the orientation shifts from the quantity of children to the quality of children, as they are able to invest more in each child (Becker and Lewis, 1973; Becker and Tomes, 1976). Thus, women are inclined to have fewer children, because of monetary constraints. Beyond describing the quality and quantity trade-off, Becker (1981) showed that as educational and employment levels of women increase, their probability of remaining childless also rise due to elevated opportunity costs. Therefore, as educational levels and wages increase, growing numbers of individuals are expected to opt out of forming a family or of having children altogether.

The authors of the fertility-trap hypothesis (Lutz et al., 2006) argued that once the fertility has fallen to lowest-low levels, fertility and development might be decoupled, and fertility would then remain at low levels. The key mechanism of this trap is the decreasing cohort size; i.e., if individuals grow up in an environment with low fertility and relatively few children, their fertility aspirations will be affected accordingly. Moreover, low fertility can put pressure on the welfare states through the accelerated ageing of the population. As income levels and welfare protections of younger cohorts decrease, fertility may become entrenched at low levels. In addition, the authors have argued that the detrimental effects of decreasing net income on fertility are reinforced by increasing economic aspirations, which result from past economic growth, as well as from small sibling numbers, as siblings can limit the amount of attention and resources each child receives.

While the fertility-trap hypothesis postulated that fertility could become entrenched at low levels, McDonald (2000), Goldschneider (2015) and Esping-Andersen (2015) argued that progress in gender development may lead to increases in fertility, observing that the gender revolution may offset the suppressing effect of work-family conflicts, thereby removing one of the mechanisms underlying the negative association between development

[1] It is important to note that neither Notestein nor Davis claimed that fertility will stay at around replacement level. However, the widely adapted interpretation of the framework postulates the emergence of a stable population before and after the first demographic transition with replacement level fertility.

and fertility. In the first stage of the gender revolution, the increasing participation of women in education and paid work reinforced the demographic transition, because it empowered women to make individual fertility decisions, while intensifying the conflict between career and family. However, in the second stage of the gender revolution, gender equity spread to the individual sphere, which led to a more equal distribution of power and of roles within the household, and facilitated the reconciliation of work and family. This framework essentially used the opportunity cost argument proposed by Becker (1981) to explain the first stage, and argued that these constraints could be mitigated by the institutional context.

Beyond the institutional context, development may spur fertility increases by transforming the economy into a more childbearing friendly environment. First, the modernisation of the economy shifts employment away from routine and manual tasks and towards service jobs, which may provide more flexible work arrangements that can help to ease the aforementioned work-family conflicts. For instance, having flexible working hours may enable parents to align their working schedule with childcare opening hours, while having the option to work from home may save parents commuting time or allows them to work while watching the children (Fox et al., 2019). Second, economic development plays a crucial role in the globalised market as it improves the competitive position of individuals, and thus their future prospects (Mills et al., 2006). Working in a competitive sector may provide individuals with the economic stability they require for making long-term commitments, such as raising children (Adsera, 2004; Hofmann and Hohmeyer, 2013). However, the claim that economic restructuring and flexibility have positive effects on fertility has been increasingly contested on several grounds. It has been argued that labour market flexibility may lead to higher levels of employment uncertainty, which can inhibit childbearing as couples could be inclined to postpone life-changing commitments if they see the future as unpredictable (Vignoli et al., 2020; Comolli, 2017, 2021). Moreover, the positive effects of globalised sectors have been called into question by scholars who have observed that the decline in manufacturing jobs has been associated with decreases in fertility in the U.S. (Seltzer, 2019).

Empirical evidence on the reversal of this association was provided by Myrskylä et al. (2009), who found that fertility declines tends to reverse at high levels of development. They examined the relationship between fertility and development using data from 140 countries on the TFR and the Human Development Index and uncovered an inverted J-shape relationship between development and fertility. In line with the theoretical perspectives discussed above, they observed that fertility fell steadily from high levels at low development stages to historical lows. However, they also observed that recent increases in development have been accompanied by increases in fertility. In line with the gender revolution theory (McDonald, 2000; Goldscheider et al., 2015; Esping-Andersen and Billari, 2015), they argued that this reversal is attributable to gender and social equality, to the introduction of more effective family policies, and to increases in living standards and labour market flexibility. These trends, which are associated with economic and societal development, have facilitated childbearing, and have thus made it easier for couples to achieve their childbearing intentions.

The findings of Myrskylä et al. (2009) were reproduced by several studies, which further examined the mechanisms behind the reversal of fertility declines (Myrskylä et al., 2011; Luci-Greulich and Thévenon, 2014; Mavropoulos and Panagiotidis, 2021). These studies found that changes in gender attitudes and family policies can indeed lead to higher fertility at highest-high levels of development (Myrskylä et al., 2011). However, they also showed that whether fertility declines are reversed depends on the labour market participation of women, which points to the importance of policies that support the reconciliation of work and family (Luci-Greulich and Thévenon, 2014). A recent study found that the existence of fertility decline reversals, as well as the conditions under which reversals occur, vary across countries, and thus highlighted the role of contextual factors in fertility, including women's employment and culture (Lacalle-Calderon et al., 2017).

2.2 Fertility and development at the subnational level in the United States

The research findings on fertility decline reversals spurred a debate about the mechanisms that have contributed to recent fertility increases, and whether they are limited to nation states. It has, for example, been observed that development levels can vary considerably within countries, which may affect subnational fertility levels (for the United States, see Scherbov and Gietel-Basten, 2020; Porter and Purser, 2008). We discuss several mechanisms that might cause fertility levels to increase at high development levels in some subnational units, while remaining low in others. Given that regional differences in development levels can be large, this relationship is likely to be of interest to both policy-makers and academics.

In regions with lower levels of development, relatively large shares of the population are still employed in routine task-intensive activities, which face pressure from globalisation forces and technological change (Mills et al., 2006; Acemoglu and Autor, 2010). As a consequence, the working population may experience economic uncertainty, which could lead people to postpone or forego childbearing, as economic uncertainty is negatively related to fertility (Adsera, 2004; Hofmann and Hohmeyer, 2013). For instance, it has been that in the United States, state-level economic performance, as measured by the unemployment rate, is negatively related to non-marital childbearing among low-socioeconomic groups (Schneider and Hastings, 2015).

The aforementioned unequal spatial distribution of industries may contribute to fertility increases in highly developed regions dependent on the extent to which these industries allow to reconcile family and employment. Althoff et al. (2022) showed that in the U.S., the progress in workplace flexibility is not universal in the U.S.. Instead, they found that the share of remote work in each region depends on the region's economic structure and population density, and is particularly high in urban regions with a high proportion of jobs in the service sector. Workplace arrangements play an important role in fertility in the U.S., since having flexible working hours and the option to work from home may facilitate childbearing among working women, given the high costs of childcare (Fox et al., 2019). It hus appears that in contexts with high levels of development, eliminating an obstacle to childbearing has the potential to increase fertility.

Beyond these direct mechanisms, development may interact with migration in producing fertility increases. More developed areas are often urban and technological centres that attract large numbers of international migrants seeking employment opportunities (De Haas and Miller, 2020). For instance, in the U.S., states along the East and West coasts, and in the South - which are also among the leaders in terms of development levels - have larger shares of migrants than other states (Alexander et al., 2022). In the period immediately after their arrival, the fertility of international migrants tends to be higher if they are from a high-fertility sending country. Moreover, migrants often postpone childbearing until they have settled in the host country (Milweski, 2010; Lichter et al., 2012). Thus, the arrival of migrants may boost fertility levels in more developed areas.

There is empirical evidence of fertility decline reversals at the subnational level in Europe and the United States. Fox et al. (2019) analysed data at the NUTS-2 level for 20 European countries subdivided into 256 regions for the 1990-2012 period. They measured development using employee compensation, which is an indicator of household income; and they measured fertility using the TFR and the tempo-adjusted TFR. Based on these data, they concluded that fertility declines have reversed at the subnational level. Specifically, they found that between 1990 and 2012, the relationship between fertility and development became less negative or even positive in most of the 20 countries studied; except in Finland, West Germany, the United Kingdom, and France, where the relationship became more negative. These findings held even after accounting for tempo distortions by using the tempo-adjusted fertility rate.

For the U.S., empirical studies that investigated this relationship at the subnational level produced mixed results, which might be attributable to the cross-sectional approaches. Ryabov (2015) found no evidence of a fertility reversal among counties in the United States with very high development levels, and thus concluded that the combination of the second demographic transition and high levels of human development has resulted in persistent low fertility. By contrast, a study by Porter (2017) using county-level data reproduced the inverse J-shaped association. A potential explanations for these discrepancies are that they measured fertility and development with different measures and different models. Moreover, the cross-sectional approaches applied in these two studies relied on strong assumptions for assessing the causal relationship related to unobserved heterogeneity (Firebaugh, 2018; Wooldridge, 2002). Hence, the use of longitudinal data may help to resolve the inconsistencies in earlier research findings.

2.3 Critiques

The reversal hypothesis has stimulated a debate among scholars, some of whom have criticised its claims. In particular, the impact of tempo effects on fertility decline reversal has been raised. Bongaarts and Sobotka (2012) suggested that recent increases in fertility are attributable to cohort tempo fertility recuperation, rather than to an increase in the quantum of fertility caused by increasing development. Empirical support for this critique comes from two recent papers, which aimed to replicate the inverse J-shaped relationship, but found no evidence of fertility decline reversal in contexts with highest-high levels of development (Gaddy, 2021; Harttgen and Vollmer, 2014). Therefore, it was argued that the J-Shape hypothesis held only for a short period of time when fertility postponement came to an end.

Another critique of the reversal hypothesis has related the fertility decline reversals to Simpson's paradox (Lesthaeghe, 2020). Several studies have shown that even when an inverse J-shaped relationship between fertility and development is observed at the national level it might vanish when studied within country groups (Lesthaeghe and Permanyer, 2014; Rindfuss et al., 2016; Lesthaeghe, 2020). These authors suggested that national idiosyncrasies of the Nordic and the Anglo-Saxon countries - with the former having supportive social policies and the latter having flexible labour market - entirely explain the inverse J-shaped relationship, and thus that the positive association is a data artefact rather than a causal relationship.

Moreover, the Human Development Index, which was used in several studies as the indicator measuring development, has been criticised. The HDI is provided by the United Nations, and is itself based on four indicators: mean years of schooling, expected years of schooling, life expectancy at birth, and gross national income per capita. The main criticisms of the HDI are that it is only a crude indicator of development, and thus ignores many aspects relevant for development; that its components suffer from measurement error; that the estimation method has been revised repetitively; and that how the HDI combines the components is not well justified (Gaddy, 2021; Harttgen and Vollmer, 2014; Ghislandi et al., 2019; Scherbov and Gietel-Basten, 2020).

3 Data and methods

3.1 Overview

In this study, we aim to test the J-shape hypothesis in the U.S. states for the years 1969 to 2018. We examine the relationship between development and fertility using longitudinal data. As we seek to contribute to the ongoing debate, we take the critiques outlined above into account and run several robustness checks. We control for tempo distortions. Moreover, we account for measurement error by running several analyses using alternative indicators of fertility and of development. The indicators, their annual coverage, and their data sources are summarised in Table 1. Moreover, we apply several different regression techniques in our robustness checks to assess the model dependency of the findings.

3.2 Fertility indicators

As our main fertility indicator, we use the total fertility rate (TFR) for the 1969-2018 period for all 50 U.S. states and the District of Columbia. For the 1969-2004 period, the TFR is calculated from state-level birth register data provided by the National Bureau of Economic Research (2022), and from population counts provided by the NBER (2023). For the 2005-2018 period, we derive the state-level TFR from the annual birth collection that is published by the Centers for Disease Control and Prevention.

We use two alternative fertility indicators in robustness checks which will show to what extent the results might depend on the measurement of fertility. First, we calculate the tempo-adjusted TFR following Bongaarts and Feeney (1998, p. 278) in order to account for fertility postponement, which could distort the results as argued in the literature (Bongaarts and Sobotka, 2012). The adjusted TFR is calculated for the 1969-2004 period based on the data provided by the NBER (2023). The time series is shorter, because we lack access to state-level birth counts by parity for later years. We calculate adjusted rates of the second kind, and thus use the whole mid-year population as exposure for each parity, instead of the exposure for the exact parity, as this information is not available. We combine all parities higher than five into one category.

As a second alternative fertility indicator, we use the TFR of men. Specifically, we count births by the age of the father in the numerator, and we use the mid-year population for men instead of the exposure counterpart for women as the denominator. While the TFR for men is closely linked to the TFR for women, it is not necessarily the same, and it can differ from the female TFR [2] (Dudel et al., 2021; Schoumaker, 2019). These differences may be attributable to imbalances in the size of the population of men relative to size of the population of women, which can be caused by gender-selective migration or changing cohort sizes. Thus, results based on this indicator will show how sensitive the results are if the fertility indicator changes moderately. The male TFR is also based on the data provided by the NBER (also see Dudel and Klüsener, 2019).

3.3 Development indicators

Our main indicator for human development is the Human Life Indicator (HLI) (Ghislandi et al., 2019). It captures the average length of life as well as the lifespan distribution, and it is defined by the geometric average of the-age-at-death distribution. The HLI is more sensitive to lifespan inequalities than the traditional life expectancy. As it captures the inequality in the length of life, it has an inherent dimension of social equality. In contrast to the Human Development Index (HDI; see below), which is only available from 1990 onwards, the HLI can be calculated at the state-level from 1969 through 2018. This is the main reason why we use the HLI for our main analysis. Moreover, in contrast to the data used for the components of the HDI, the life table data used as input for the HLI is very reliable and robust (Ghislandi et al., 2019). The life tables were obtained from the United States mortality database (USMDB) (Barbieri and Wilmoth, 2022).

We use two alternative measures of development for which we present results alongside the results for our main indicator. Our motivation for doing so is to show whether the measurement of development affects the substantive findings. First, we use the Human Development Index (HDI), which is available at the level of U.S. states from the Global Data Lab for the years 1990 to 2018 (Smits and Permanyer, 2019). The HDI is one of the main measures of development cited in the literature and was used in the original publication on the J-shape hypothesis. The computation of the subnational HDI is identical to that of the country-level measure, and it consists of three dimensions: standard of living, knowledge, and long and healthy life. Standard of living is measured by gross domestic income (GDI) per capita, adjusted for inflation; knowledge is assessed by expected years

[2] In the remainder of the paper, TFR means the TFR for women, unless it is explicitly stated that the TFR is for men.

of schooling and mean of years of schooling; and long and healthy life is measured by life-expectancy.

Second, we use life expectancy (LE) as an indicator for human development. Life expectancy is as a good indicator for human development, because it reflects not just living standard as measured by GDP, but captures also education, medical provision, and health insurance services (Sen, 1998). The data were obtained from the USMDB. For the periods in which the HDI and LE overlap, they are highly correlated (Pearson's R = 0.792). This is also the case for the HLI and LE (Pearson's R = 0.9733). As mentioned earlier, the data underlying the LE are of high quality. These properties make LE a readily available and well-understood alternative to the other indicators.

3.4 Further control variables

In our main analysis, only development and fertility are included in the regression models. However, trends in fertility might be driven by factors other than development, or by factors that mediate the impact of development. To account for these mechanisms, we conduct robustness checks that include additional control variables. First, in some analyses we include the proportion of jobs in the service sector, which accounts for structural economic change (Ruggles, 2015; Seltzer, 2019). Furthermore, in some instances, we include the annual state unemployment rate, which accounts for economic conditions and shocks, such as the financial crisis 2007/2008, which might have driven some of the observed fertility trends (Comolli, 2021; Schneider and Hastings, 2015). The results may also be confounded by heterogeneous trends in gender equality, as suggested by the gender revolution theory, which were described in section 2.1 (McDonald, 2000; Esping-Andersen and Billari, 2015). Hence, we include a proxy for gender equality in norms and household roles: namely, the mean age difference between parents. The parental age difference is a good indicator for gender equality in the domestic sphere, because it affects the bargaining power within the relationship (Presser, 1975; Carmichael, 2011).

As was stated in section 2.3 on the critiques of the reversal hypothesis, tempo-distortions of the TFR are a major threat to the identification of the effect of development on fertility. Beyond using the tempo-adjusted TFR, which is only available for the years 1969-2004, we expand the time-series to 2018 by using the mean age of childbearing as control variable in a set of further robustness checks. Guided by the models presented in the literature, we use the specification following Myrskylä et al. (2011) and include the first and second differences of the mean age of childbearing as controls. An alternative specification suggested by Luci-Greulich and Thévenon (2014) is also estimated, including the (undifferentiated) mean age of childbearing as a linear and as a squared term, as postponement might have non-linear effects on the total fertility rate.

A description of the data is displayed in Table 1. For each variable, it shows the total number of state-year observations, the years covered, and the minimum and the maximum value, the latter with an indication for which state the value refers to.

Table 1: Summary statistics of the data. The first block contains the three fertility indicators: TFR for women, TFR for men and the tempo-adjusted TFR following Bongaarts and Feeney (1998). The second block displays the three development indicators Human Life Indicator (HLI), Human Development Index (HDI), and life expectancy at birth (LE). The last block consists of the three control variables which are used to disentangle the mechanisms. The abbreviation of the state name is written in parentheses behind the value of the minima and maxima **Note:** The time-series length differs across indicators due to data availability.

Statistic	Years	N	Min	Max	Source
Female TFR	1969-2018	2,550	1.346 (DC)	3.186 (UT)	NBER/CDC
Male TFR	1969-2004	1,836	1.552 (RI)	3.647 (UT)	NBER
Tempo-adjusted TFR	1969-2004	1,836	1.514 (DC)	3.513 (UT)	NBER
HLI	1969-2018	2,550	51.881 (DC)	77.528 (HI)	USMD
HDI	1990-2018	1,479	0.820 (MS)	0.956 (MA)	GDL
LE	1969-2018	2,550	69.58 (DC)	84.47 (HI)	USMD
Unemployment rate	1976-2018	2,193	2.108 (CT)	17.233 (WV)	BEA
% in service	1980-2018	2,193	0.449 (NC)	0.951 (DC)	BEA
Parental age difference	1969-2004	1,836	2.092 (NH)	4.703 (DC)	NBER
Mean age of childbearing	1969-2018	2550	24.2 (OK)	31.3 (DC)	NBER

State abbreviations: CT = Connecticut; DC = District of Columbia ; HI = Hawaii; MA = Massachusetts; MS = Mississippi; NH = New Hampshire; NC = North Carolina; OK = Oklahoma; RI = Rhode Island; UT = Utah; WV = West Virginia
Source abbreviations: NBER = National Bureau of Economic research, CDC = Center for Disease Control, USMD = US Mortality Database, GDL = Global Data Lab, BEA = Buereau of Economic Analysis

3.5 Methods

For our main analysis, we use a fixed effects individual slope regression model (FEIS), which accounts for unobserved heterogeneous trends across states in addition to unobserved time-constant and state-specific heterogeneity (Rüttenauer and Ludwig, 2020; Wooldridge, 2002). This approach is more flexible than the FE or two-way FE approach, and makes less restrictive assumptions. However, as the model effectively reduces the number of observations, it imposes greater demands on the data and often produces larger standard errors. As our dependent variable we use the TFR in state i in year t. As our explanatory variables, we use a development indicator in state i in the previous year $t-1$, as well as the square of the development indicator. For the HLI the regression equation on the looks as follows:

$$TFR_{i,t} = \beta_1 HLI_{i,t-1} + \beta_2 HLI_{i,t-1}^2 + \mu_i t + \lambda_i + \gamma_t + \varepsilon_{i,t} \quad (1)$$

where μ_i is the state-specific slope, λ_i is the individual fixed effect, γ_t is the year fixed effect, and $\varepsilon_{i,t}$ is the idiosyncratic error. The coefficients in the equation above are estimated after taking first differences and then demeaning; because of this, μ_i, λ_i, and γ_t are not estimated explicitly, as would be the case for λ_i and γ_t in a standard one-way or two-way FE model.

For fertility decline reversals, the coefficient β_1 has to be negative, while β_2 has to be positive; if either or both coefficients have the opposite sign, the data do not follow an inverse J-shape. The point at which the association between the TFR and development switches from negative to positive, i.e., the inversion point I, can be calculated as $I = \frac{-\beta_1}{2\beta_2}$. The standard error of I can be easily calculated from the standard errors of β_1 and β_2 (see section A in the Supplementary Materials).

In our robustness checks, we use several other modelling approaches to account for model dependence. We apply two-way fixed effects regression, which only removes the additive contribution of state and year effects (Imai and Kim, 2021). We apply models with state fixed effects (FEs), which removes less variance from the outcome variable and which usually has lower standard errors than FEIS. In addition, we re-run the analysis using two-way random effects (RE). This approach requires stronger assumptions than the FE approaches, namely that unobserved heterogeneity is not correlated with the development indicator; but if this assumption holds it is statistically more efficient, meaning that its standard errors will be smaller than those of the FE approaches.

We also conducted further robustness checks. First, as was discussed earlier, is is long-term development changes, rather than short-term fluctuations, that ultimately determine fertility. To remove short-term fluctuations from the data, we smooth both the fertility and the development time-series using locally-weighted scatterplot smoothing (LOESS). After generating the smoothed time series, we proceed as described above. Second, accounting for the spatial structure of the U.S. states, the state-level FEs are replaced by FEs structured by Census divisions. This allows us to account for the fact that states that are close to each other are often relatively similar, leading to a high spatial correlation of state-level TFRs. Third, as another alternative regression method, we use quantile regression (Koenker, 2004), as previously applied in a related study by Lacalle-Calderon et al. (2017). This approach allows us to assess the association between development and fertility at different levels of fertility, and thus to measure the potential heterogeneity in the association.

4 Results

4.1 Descriptive results

Figure 1 shows the TFR trends in the top left panel (blue lines) for all states (semi-transparent lines), as well as the TFR trend at the national level (thick line). Over the 1969-2018 period, the national-level TFR fell from 2.7 to a historical low of 1.8. Beyond indicating the overall trend, the graph reveals three phases: a strong decline around the year 1970 related to the baby bust that followed the baby boom, a gradual recovery between 1977 and 2008, and a strong decline following 2008. While these phases roughly apply to most states, we also see considerable heterogeneity in fertility levels. For instance, in 2018, the state-level TFR ranged from 1.3 in the District of Columbia to 2.1 in South Dakota. Moreover, we also find that the trends in some states deviated from the country-level trends.

The time-series of our three development indicators are presented in Figure 1 (top right and bottom panels), and show clear improvement in development in the United States over the analysed period, with all development measures increasing between 1969 and 2018. However, we also find that this trend stalled somewhat in the most recent years, as in the 2020s, both LE and the HLI decreased, and the HDI increased at a slower pace. The decline in LE and the HLI, which are measures based on life tables, is reflects either stagnating or even increasing mortality, which has been attributed to the drug overdose crises and to cardiovascular diseases (Jalal et al., 2018; Mehta et al., 2020).

Figure 2 provides a first look at the association between development and fertility. Each line represents one of the states, while each point indicates the average level of the development indicator and the average TFR during each decade (1960s, 1970s, ...). LE and HLI show a similar pattern, which resembles a J-shape, with fertility decreasing at lower values, and increasing again at a life expectancy of 75. Yet, the middle panel presents a different pattern, with the relationship between the HDI and the TFR showing increases and decreases at different times and at different levels across regions.

4.2 Main results

The results of the FEIS model using the TFR as the fertility measure are shown for different development indicators in the columns in Table 2. The signs of the coefficients for the HLI and LE are in line with the fertility decline reversal hypothesis, while the results for the HDI (discussed below) contradict it. For the HLI and LE, the association between development and fertility is negative at lower levels of development, as the linear term has a negative sign; and the association becomes positive at higher levels of development, as the positive coefficient of the quadratic term starts to dominate. Based on these coefficients, we calculate that the female TFR starts to increase when a state has reached a HLI value above 74.2 (95% confidence interval 72.9 - 75.5) or a LE of 116.71 years or higher (95% confidence interval 104.02 - 129.4). The turning point for the HLI lies within the observed value range, while the turning point for LE exceeds the maximal observed value, indicating that states have not yet reached the turning point.

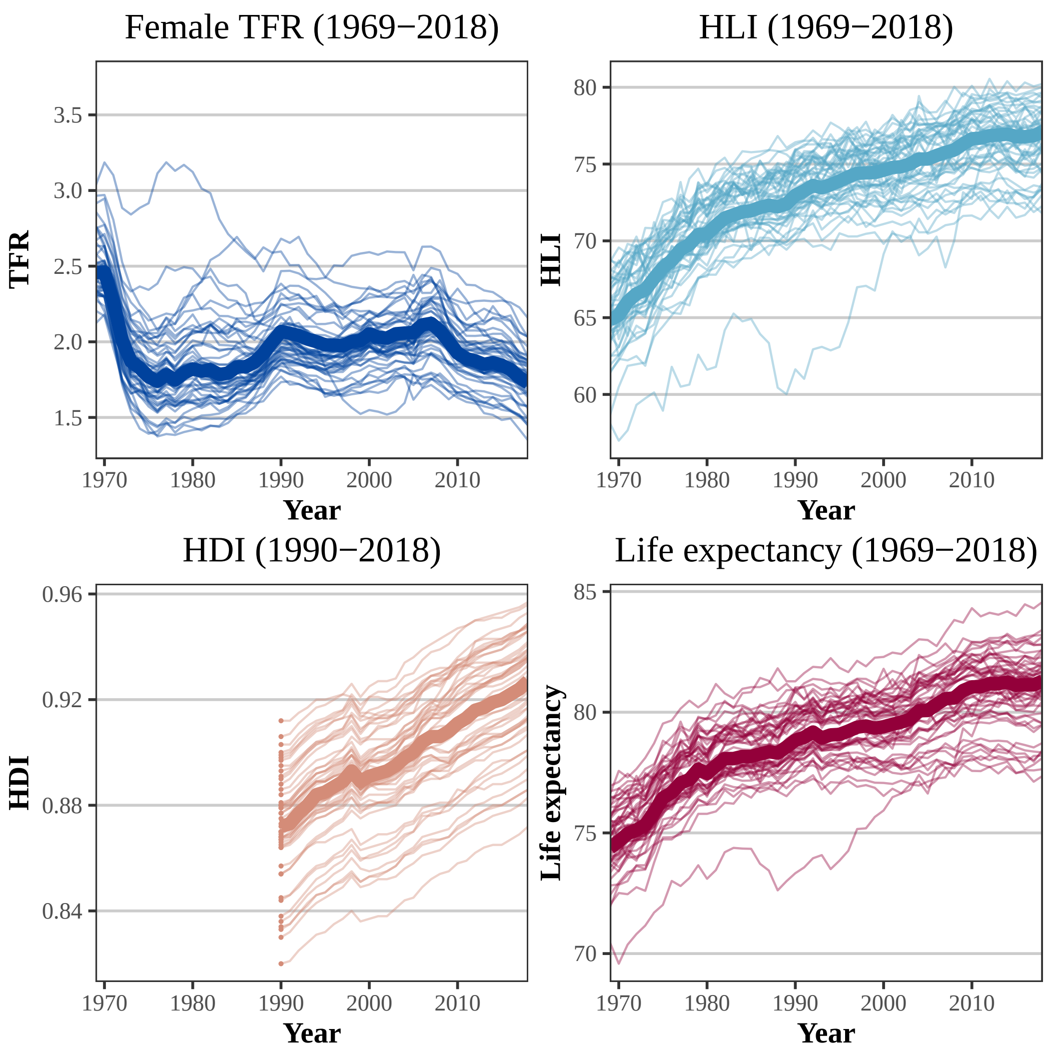

Figure 1: Time-series of fertility and the three development variables. The semi-transparent lines represent the data values for the states. The thick lines are the values of the indicator at the country level for the US.

The results based on the HDI as a development indicator, which are also shown in Table 2, do not provide evidence for fertility reversals. The linear term is positive, while the squared terms is negative, indicating a positive impact of development that reverses at higher levels. These findings not only contradict the J-shape hypothesis, they also do not match demographic transition theory. The descriptive results presented in Figure 2 point to some potential explanation for these results. The time-series is shorter than that for the HLI and LE, and is only observed for relatively high values of development, with little variance. In line with this explanation are findings from our robustness checks for the HLI and LE, which suggests that omitting several years at the beginning of the time series changes the results drastically. More generally, the results obtained using the HDI indicate

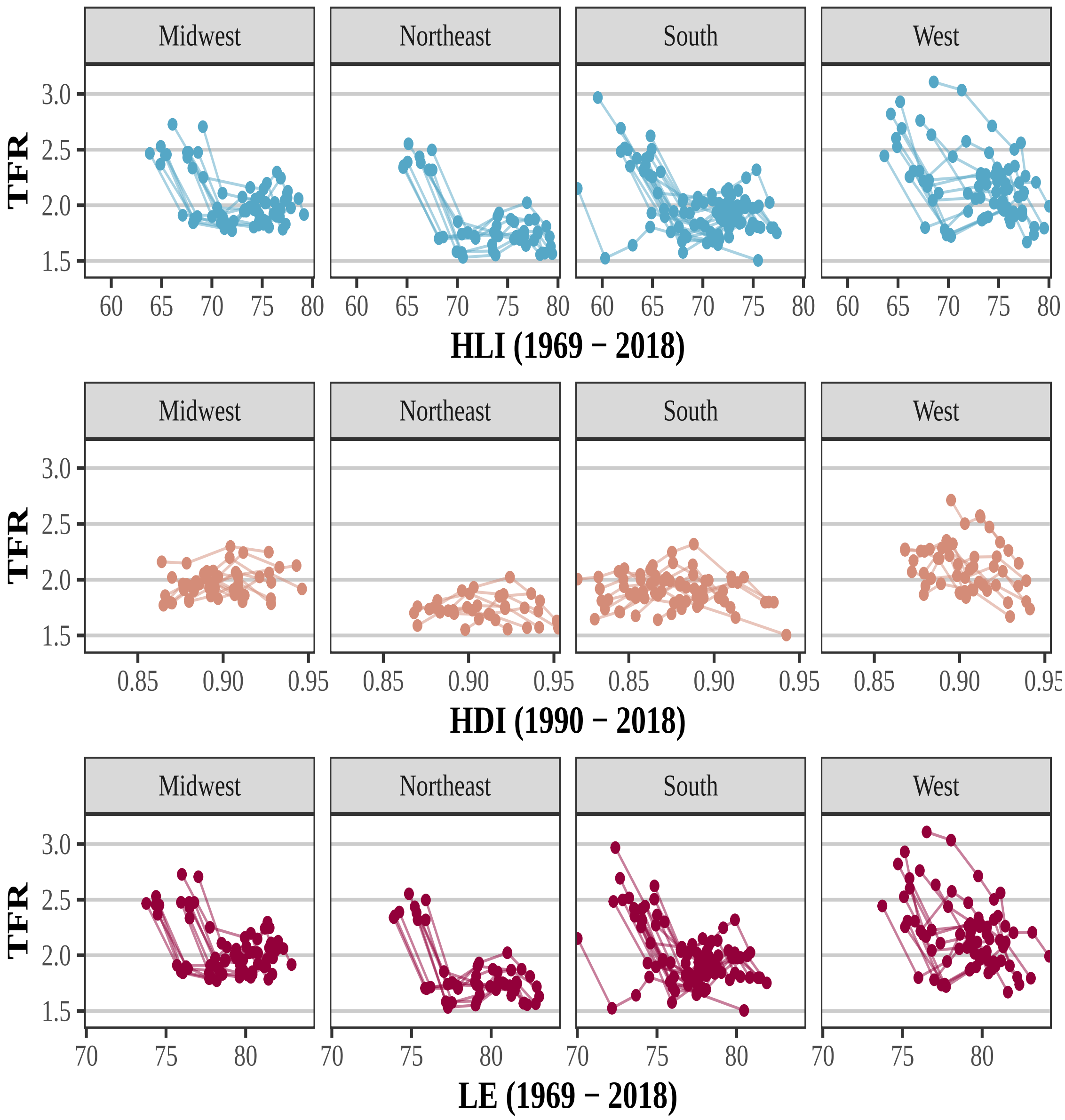

Figure 2: The relationship between development indicators (x-axis) and female TFR (y-axis) using decade averages. The vertical grid dimensions reflect the different development indicators. The horizontal grid dimensions represent different census divisions in order to improve readability. **Note:** The x-axis and the y-axis differ between the rows, because of different data lengths.

that the conclusions are sensitive to the choice of development indicator and its availability over time; the robustness checks discussed below confirm this conclusion.

In order to evaluate the effect size of development on fertility, we estimate the marginal effect of a one-point increase in the HLI on the female TFR from the model parameters at the 25% quantiles (HLI = 56.99, 70.76, 75.79, 80.73). At the lowest value of human development that is, a HLI of 56.99, a one unit increase in the HLI is expected to reduce

Table 2: Fixed effects individual slope regression (FEIS) on TFR of females.

	lag.HLI	lag.HDI	lag.LE
Linear	-0.033^{*}	1.744	-0.036
	(0.017)	(21.352)	(0.080)
Squared	0.0002^{*}	1.734	0.0002
	(0.0001)	(11.778)	(0.001)
State fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
Years	1969 - 2018	1969 - 2018	1969 - 2018
Observations	2,499	1,377	2,499
R^2	0.001	0.041	0.003
J shape	Yes	No	Yes
Turning point	76.82	-0.5	116.71
Confidence interval	(75.4 , 78.24)	(-0.93 , -0.08)	(104.02 , 129.4)

Note: *p<0.1; **p<0.05; ***p<0.01

the TFR by 0.0084 (CI: -0.0016 and -0.0152). This value corresponds to a decrease of 0.8 % in the TFR sample mean. While an increase at the maximum value of the HLI, which is 80.73, corresponds to an increase of 0.0016 (CI: -0.003 and 0.006) in the TFR, which is equivalent to 0.16 % of the total mean TFR of the sample. Overall, the pattern of the marginal effects is in line with the J-shape hypothesis.

4.3 Robustness checks

Our results are summarised in Figure 3, which displays the turning points across indicators and model specifications. Overall, the graph shows that the majority of points lie in the observed value range of the development indicator (shaded area), which supports the hypothesis that there have been fertility decline reversals in the United States. However, some results contradict the hypothesis. There is variation across model specifications displayed on the y-axis, whereas the two-way fixed effects and random effects models contradict the J-shape hypothesis, as the turning points lie outside of the observed value range. Moreover, the middle column shows fewer points than the other columns, which to different signs in the regression coefficients for the HDI indicator, and thus contradicts the J-shape hypothesis.

4.3.1 Fertility indicators

To account for potential tempo distortions of the TFR, we use the tempo-adjusted TFR (Bongaarts and Feeney, 1998, p. 278). The results are displayed in Tables S1 and S2 in the supplementary materials. The coefficients have the same signs as in the the analysis with

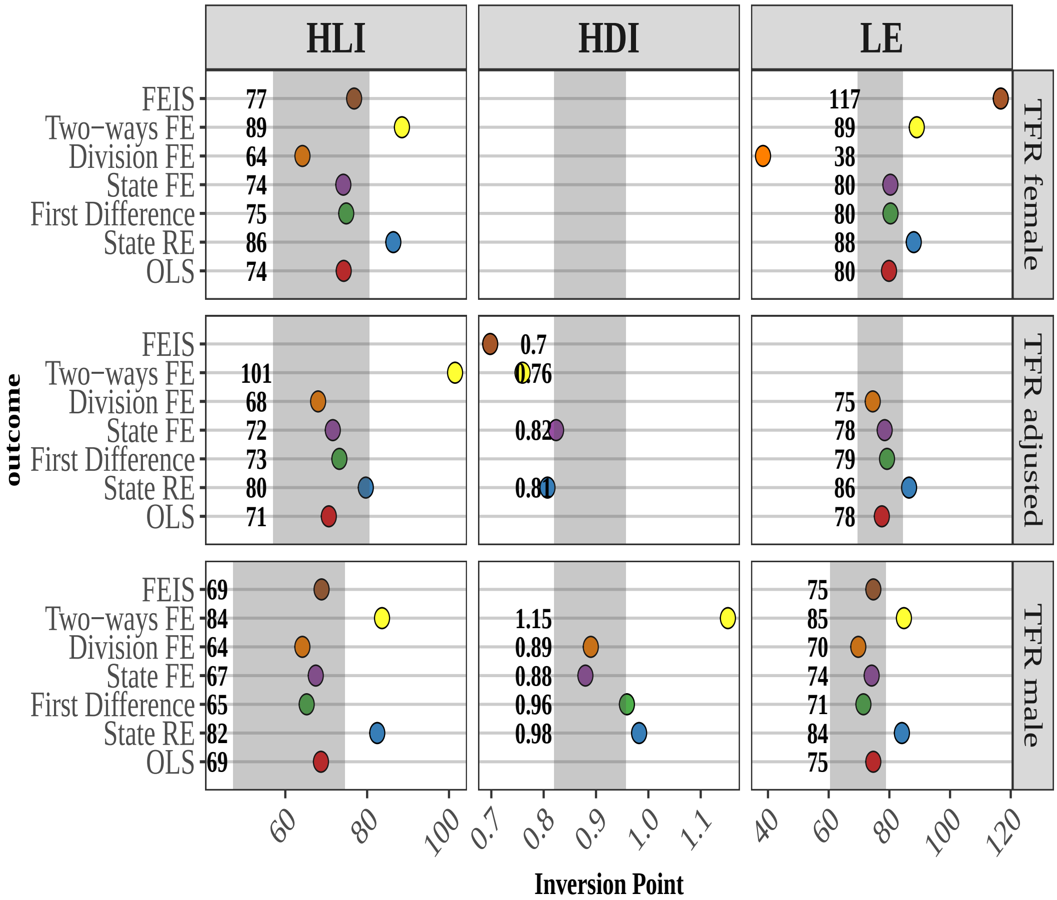

Figure 3: The sensitivity of the turning point in relation to the model selection and the selected variables. The shaded area indicates the observed value range over the entire observation period. If a line does not show a point estimate, then the relationship was not convex but concave. The numbers inside the plot indicate the value of the turning point for the model.

the unadjusted TFR, and they are consistent with the J-shaped association and the fertility decline reversals. These findings give us further confidence to conclude that the J-shaped pattern was not caused by fertility recuperation, as was argued by Bongaarts and Sobotka (2012).

Table S3 presents the results based on the male TFR, which lead to very similar conclusions, and have turning points similar to that in the main model. According to the two-way fixed effects regression, the male TFR starts increasing at a HLI of 83.64 or respectively at a life expectancy of 84.8, while the location of the turning point of the HDI lies at 1.15 and therefore outside the range of observed and even possible values. However, the data for the HDI model consists only of 14 years of observations, and is thus less robust than the other estimates.

4.3.2 Adding control variables

In Section 2.2, we discussed the role of gender equality and economic uncertainty in the development-fertility nexus. We introduce controls for the state-level unemployment rate, the state-level percentage of jobs in the service sector, and the average age gap between parents, and test whether the results remain similar. Furthermore, the inclusion of time-varying controls allow us to better account for heterogeneous trends in economic conditions and gender equality. The results displayed in Table S4 in the supplementary materials show patterns that correspond to arguments presented in the theoretical section. Controlling for unemployment or gender equality absorbs the J-shaped relationship between development and fertility. This indicates that the association between development and fertility net of economic conditions and gender equality is likely small, and that these two factors are key drivers of the overall association.

The results for the tempo-adjusted TFR are confirmed by the models with controls for the mean age of childbearing and the first and second difference time-series of the indicator, which are shown in Table S5. The model estimates show a convex relationship and give reasonable turning points.

4.3.3 Different regression methods

To assess to what extent our findings are dependent on model assumptions, we used several alternative regression models. We use two-way fixed effects models to account for the fact that the FEIS models may absorb some of the variance in the outcomes that are the result of developmental processes. As hypothesised, the linear term is negative, while the quadratic term is positive, yielding a convex relationship. The results point into a similar direction, as can be seen in Table 3, however, the turning points occur at a higher value of the development variable and outside the observed value range. We conclude, that the selection on trends may not be captured in the two-way fixed effects model, despite giving significant results for the squared term.

As another alternative to two-way FE models, we also calculate a two-way random effects model. This has stronger assumptions regarding the relationship between the error term and the regressors, but the standard errors are expected to be lower. The results are in

Table 3: Two-way fixed effects regression on TFR of females with different development indicators.

	lag.HLI	lag.HDI	lag.LE
Linear	-0.075^{***}	44.862^{***}	-0.172^{***}
	(0.019)	(5.944)	(0.065)
Squared	0.0004^{***}	-21.614^{***}	0.001^{**}
	(0.0001)	(3.237)	(0.0004)
State fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
Years	1969 - 2018	1990 - 2018	1969 - 2018
Observations	2,550	1,428	2,550
R^2	0.051	0.598	0.034
J shape	Yes	No	Yes
Turning point	88.5	1.04	89.03
Confidence interval	(87.57 , 89.43)	(1.03 , 1.05)	(87.79 , 90.27)
Note:		*p<0.1; **p<0.05; ***p<0.01	

line with the J-shape hypothesis, as can be seen in Table S6 and S7, and present additional support for the existence of a J-shape.

We have modelled the relationship between development and fertility using smoothed time-series data. This approach should yield further evidence on the contribution of the impact of long-term effects of developments beyond short-term fluctuations, which are removed from the data using LOESS. The results displayed in Tables S9 and S10 point to the impact of long-term development on fertility. Therefore, we conclude, that it is the overall trend in development, rather than short-term fluctuations in development, that has an effect on fertility.

We have also accounted for the problem of spatial auto-correlation, which became apparent in Figure 2 from the within-census division similarities, by replacing state fixed effects with Census division fixed effects. The results, displayed in Table S11, are in line with the hypothesis. The inversion of fertility decline occurs within the range of observed values. Nevertheless, the significance of the estimates and the R^2 is low, which points to considerable variation around the expected values.

Finally, we have calculated a longitudinal quantile regression following the suggestion by Lacalle-Calderon et al. (2017). In this regression model, we find that the reversal of fertility does only occur for states with high levels of fertility, while low-fertility regimes experience almost no influence of development. This result reinforces previous findings indicating that contextual idiosyncrasies, such as factors related to culture and institutions, can affect fertility decline reversals. This observation gives additional weight to the results from the state-level trend models (FEIS) presented in Table 2.

4.3.4 Further robustness checks

In order to test the sensitivity of the results to single observations, we calculate two-way fixed effects regression with the TFR and the human life indicator for subsamples, after removing single year or state observation. The results are displayed in Figure S5, and are in line with the previous results. Two important observations can be made. First, when omitting observations from the years 1971, 1972, and 1973 from the sample, we observe that the linear term increases in effect size, while the squared term decreases in size. This shows that the decline in fertility between 1969 and 1975, which is visible in Figure 2, and has been labelled the baby bust, drives the negative relationship between development and fertility at lower levels. Second, Mississippi and Utah have some important effects on the model results, as the lower panel of Figure S8 shows. Omitting Mississippi yields a fully negative relationship between development and fertility. In contrast, when Utah is omitted, the J-shaped relationship is more pronounced.

Two competing explanations may account for the diverging results across indicators: 1) the time-series length and 2) the different dimensions of development. We re-estimate the two-way fixed effects regression model for the same time-series, the years 1990 to 2018. This neutralises, the impact of the first explanation. The results have changed drastically, providing evidence of the relevance of the time-series length. The J-shape for the life expectancy indicator in the main model has faded completely; while for the HLI, the estimated turning point has increased to a HLI level of 180.04. Thus, the unexpected result for the HDI is mainly attributable to the short-time series. However, substantial differences remain across the three indicators, which provides evidence that the indicators capture different dimensions of development.

5 Discussion

In this paper, we examined whether the J-shape hypothesis proposed by Myrskylä et al. (2009) holds for the United States at the subnational level. Leveraging state-level data covering the years 1969 to 2018, we found that the association between development and fertility followed an inverse J-shape, and that this association was robust across many sensitivity checks. Thus, our findings lend support to the validity of the reversal hypothesis proposed by Myrskylä et al. (2009) for the U.S. at the subnational level. The results were found to be sensitive to the choice of indicator; however, further analysis showed that the time-series length accounts for most of the differences across indicators. Nevertheless, in its original formulation based on the HDI, the hypothesis could not be confirmed, which calls the usage of the HDI into question. While adjusting for tempo effects indicated that these factors might have played some role in the fertility decline reversals, our main finding persisted. Moreover, we found that good economic prospects as well as high levels of gender equality were prerequisites for the reversal of the relationship. These results correspond to the findings of previous studies by Myrskylä et al. (2011) and Luci-Greulich and Thévenon (2014).

Moreover, our results are in line with those of the study by Porter (2017) on the relationship between the HDI and fertility across U.S. counties, but contradict the findings of Ryabov (2015), who found no evidence of fertility decline reversals. Two factors may account for the discrepancies between our findings and those of the latter study: first, as our study was based on longitudinal data rather than the cross-sectional design used by Ryabov, we could control for unobserved differences; and, second, the geographic scales differed, as Ryabov (2015) averaged fertility values at the county level instead of the state level.

The finding of an inverse J-shape relationship has theoretical implications, as it stands in contrast to the demographic transition theory and the low-fertility trap hypothesis. The results point to the existence of factors that can relax and even reverse the negative association between development and fertility posited by demographic transition theory (Lesthaeghe and Van de Kaa, 1986; Lesthaeghe, 2020; Notestein, 1945; Davis, 1945). As was outlined in Section 2.1, levels of gender inequality and economic uncertainty may be reduced by increasing development, which can lead to higher fertility. Furthermore, increasing fertility contradicts the low-fertility trap hypothesis (Lutz et al., 2006). We found no sign of entrenchment at low levels, which leads us to question whether low fertility is indeed self-reinforcing.

Consistent with existing research, we showed that the results vary depending on the choice of the development indicator (Gaddy, 2021; Harttgen and Vollmer, 2014); in particular, no inverse J-shape association was found when using the Human Development Index (HDI), while the inverse J-shape was observed when using life expectancy and the HLI. These findings appear to support Gaddy (2021) and Harttgen and Vollmer (2014), who criticised the indicators used in the original publication. However, additional analyses showed that these results were mainly attributable to the shortness of the HDI time-series, which varied little over time, except in the years of the financial crisis. This issue corresponds in graphical terms to failing to recognise the letter "J" after removing the stroke of the J.

A key contribution of this study is that we addressed the major criticism of the J-shape hypothesis. First, we conducted several sensitivity checks that accounted for the potential impact of postponement, including the tempo-adjusted TFR, and using the mean age at childbirth as a control variable. All of these robustness checks still yielded an inverse J-shaped pattern. Thus, in contrast to findings of other studies (Bongaarts and Sobotka, 2012), we conclude that at least for the U.S., postponement does not seem to be a major driver of the association between development and fertility. Second, by changing the research design into a subnational longitudinal setup, which rules out unobserved cultural and institutional factors, we were able to address the concern raised by Lesthaeghe (2020) that national idiosyncrasies my be driving the J-shaped pattern.Finally, we took the critique regarding measurement error into account by using different indicators. We found that the general results depended more on the time-series length than on the indicator itself.

In line with previous studies, we found that economic and gender factors play a crucial role in the development-fertility nexus (Esping-Andersen and Billari, 2015; Goldscheider et al., 2015; Kolk, 2019; Luci-Greulich and Thévenon, 2014). First, it appears that the fertility decline reversals were conditional on positive employment prospects. This evidence points to the role of economic uncertainty, as argued by Schneider and Hastings (2015) and Comolli (2017; 2021). Second, we found that the effect was moderated by household gender equality (Luci-Greulich and Thévenon, 2014). Theoretical arguments emphasize the role of the reconciliation of family and work, but also women's opportunities to achieve their personal career goals (Goldscheider et al., 2015). Therefore, the gender dimension seems to play a crucial role in fertility in highly developed states, with fertility increasing as development progresses.

It is also noteworthy that we found a particular pronounced and robust J-shaped pattern when measuring fertility using the TFR for men. This provides evidence of the existence of birth squeezes in the United States, which have been observed elsewhere (Dudel and Klüsener, 2019). Figure S7 shows that the male-female TFR ratio was negatively associated with development, which suggests that the demographic behaviours of women and men responded differently to development (the relationship at the national level is described and explained in Schoumaker, 2019). Among the potential explanations for this gender difference are female-dominated migration to the more developed regions, which may have led to female-skewed populations that deflated the TFR for women.

5.1 Methodological considerations

When interpreting our results, it is important to keep in mind that they show the association between development and fertility at the macro level, and do not allow us to infer individual responses to development. Our results yield evidence only on contextual factors, which, in our analysis, might also be specific to the United States. Moreover, while the association between development and fertility we found was strong, development was only one of many determinants of fertility, as highlighted by some of our additional analyses. Some of these other determinants might be mediators or moderators of the impact of development, which calls for further research into the mechanisms linking development and fertility.

Moreover, in interpretation our results, it is also important to bear in mind that it is difficult to predict whether the associations we found will hold in the future. In recent years, U.S. fertility has been volatile and sensitive to external shocks. The TFR started falling between 2008 and 2010 following the Great Recession, and did not rebound thereafter (Schneider and Hastings, 2015; Cherlin et al., 2013). Thus, fertility decline reversals might be stalled, or even be undone. Moreover, it is important to keep in mind that in comparison to other countries, the United States stands out because its development increases have levelled off, and no large improvements in development have been reported in the U.S. in recent years.

This study makes a leap forward by using a wide array of robustness checks, most of which showed the existence of fertility reversals in the United States. Thus, our results confirm the existence of fertility decline reversals at higher levels of development.

References

Acemoglu, D. and Autor, D. (2010). Skills, Tasks and Technologies: Implications for Employment and Earnings.

Adsera, A. (2004). Changing fertility rates in developed countries. The impact of labor market institutions. *Journal of Population Economics*, 17(1):17–43.

Alexander, M., Polimis, K., and Zagheni, E. (2022). Combining Social Media and Survey Data to Nowcast Migrant Stocks in the United States. *Population Research and Policy Review*, 41(1):1–28.

Althoff, L., Eckert, Ganapati, S., and Walsh, C. (2022). The Geography of Remote Work. *Regional Science and Urban Economics*, 93(3).

Anderson, T. and Kohler, H.-P. (2015). Low Fertility, Socioeconomic Development, and Gender Equity. *Population and Development Review*, 41(3):381–407.

Barbieri, M. and Wilmoth, J. (2022). United States Mortality DataBase. https://usa.mortality.org/.

Beck, U. (1992). *Risk Society. Towards a New Modernity*. SAGE Publications Ltd, London.

Becker, G. S. (1981). *A Treatise on the Family*. University of Chidcago Press, Chicago.

Becker, G. S. and Lewis, H. G. (1973). On the Interaction between the Quantity and Quality of Children. *Journal of Political Economy*, 81(2):S279–S288.

Becker, G. S. and Tomes, N. (1976). Child Endowments and the Quantity and Quality of Children. *Journal of Political Economy*, 84(4):S143–S162.

Bongaarts, J. and Feeney, G. (1998). On the Quantum and Tempo of Fertility. *Population and Development Review*, 24(2):271–291.

Bongaarts, J. and Sobotka, T. (2012). A Demographic Explanation for the Recent Rise in European Fertility. *Population and Development Review*, 38(1):83–120.

Bongaarts, J. and Watkins, S. C. (1996). Social Interactions and Contemporary Fertility Transitions. *Population and Development Review*, 22(4):639.

Bryant, J. (2007). Theories of Fertility Decline and the Evidence from Development Indicators. *Population and Development Review*, 33(1):101–127.

Carmichael, S. (2011). Marriage and power: Age at first marriage and spousal age gap in lesser developed countries. *The History of the Family*, 16(4):416–436.

Casterline, J. B. (2003). *Demographic Transition*, pages 210–216. Macmillan Reference, USA.

Centers for Disease Control and Prevention. Natality public-use data 2003-2006. Technical report.

Cherlin, A., Cumberworth, E., Morgan, S. P., and Wimer, C. (2013). The Effects of the Great Recession on Family Structure and Fertility. *The ANNALS of the American Academy of Political and Social Science*, 650(1):214–231.

Comolli, C. L. (2017). The fertility response to the Great Recession in Europe and the United States: Structural economic conditions and perceived economic uncertainty. *Demographic Research*, 36:1549–1600.

Comolli, C. L. (2021). Resources, aspirations and first births during the Great Recession. *Advances in Life Course Research*, 48:100405.

Davis, K. (1945). The World Demographic Transition. *The ANNALS of the American Academy of Political and Social Science*, 237(1):1–11.

De Haas, H. and Miller, M. (2020). *The Age of Migration*. Guilford Press.

Dudel, C. and Klüsener, S. (2019). Estimating men's fertility from vital registration data with missing values. *Population Studies*, 73(3):439–449.

Dudel, C., Klüsener, S., Loichinger, E., Myrskylä, M., and Sulak, H. (2021). The extension of late working life in Germany: Trends, inequalities, and the East-West divide. Technical Report WP-2021-018, Max Planck Institute for Demographic Research, Rostock.

Esping-Andersen, G. and Billari, F. C. (2015). Re-theorizing Family Demographics. *Population and Development Review*, 41(1):1–31.

Firebaugh, G. (2018). *7 Rules for Social Research*. Princeton University Press, NJ, Princeton.

Fox, J., Klüsener, S., and Myrskylä, M. (2019). Is a Positive Relationship Between Fertility and Economic Development Emerging at the Sub-National Regional Level? Theoretical Considerations and Evidence from Europe. *European Journal of Population*, 35(3):487–518.

Gaddy, H. G. (2021). A decade of TFR declines suggests no relationship between development and sub-replacement fertility rebounds. *Demographic Research*, 44:125–142.

Ghislandi, S., Sanderson, W. C., and Scherbov, S. (2019). A Simple Measure of Human Development: The Human Life Indicator. *Population and Development Review*, 45(1):219–233.

Goldscheider, F., Bernhardt, E., and Lappegård, T. (2015). The Gender Revolution: A Framework for Understanding Changing Family and Demographic Behavior. *Population and Development Review*, 41(2):207–239.

Harknett, K., Billari, F. C., and Medalia, C. (2014). Do Family Support Environments Influence Fertility? Evidence from 20 European Countries. *European Journal of Population*, 30(1):1–33.

Harttgen, K. and Vollmer, S. (2014). A Reversal in the Relationship of Human Development With Fertility? *Demography*, 51(1):173–184.

Hofmann, B. and Hohmeyer, K. (2013). Perceived Economic Uncertainty and Fertility: Evidence From a Labor Market Reform. *Journal of Marriage and Family*, 75(2):503–521.

Imai, K. and Kim, I. S. (2021). On the Use of Two-Way Fixed Effects Regression Models for Causal Inference with Panel Data. *Political Analysis*, 29(3):405–415.

Inglehart, R. (1977). *The Silent Revolution. Changing Values and Political Styles Among Western Publics*. Princeton University Press, Princeton.

Jalal, H., Buchanich, J. M., Roberts, M. S., Balmert, L. C., Zhang, K., and Burke, D. S. (2018). Changing dynamics of the drug overdose epidemic in the United States from 1979 through 2016. *Science*, 361(6408):eaau1184.

Koenker, R. (2004). Quantile regression for longitudinal data. *Journal of Multivariate Analysis*, 91(1):74–89.

Kohler, H.-P. and Ortega, J. A. (2002). Tempo-Adjusted Period Parity Progression Measures, Fertility Postponement and Completed Cohort Fertility. *Demographic Research*, 6:91–144.

Kolk, M. (2019). Weak support for a U-shaped pattern between societal gender equality and fertility when comparing societies across tim. *Demographic Research*, 40:27–48.

Lacalle-Calderon, M., Perez-Trujillo, M., and Neira, I. (2017). Fertility and Economic Development: Quantile Regression Evidence on the Inverse J-shaped Pattern. *European Journal of Population*, 33(1):1–31.

Lesthaeghe, R. (2020). The second demographic transition, 1986–2020: Sub-replacement fertility and rising cohabitation—a global update. *Genus*, 76(1):10.

Lesthaeghe, R. and Permanyer, I. (2014). European Sub-Replacement Fertility: Trapped or Recovering?

Lesthaeghe, R. and Van de Kaa, D. (1986). Twee demografische transities? *Bevolking: groei of krimp*, pages 9–24.

Lichter, D. T., Johnson, K. M., Turner, R. N., and Churilla, A. (2012). Hispanic Assimilation and Fertility in New U.S. Destinations. *International Migration Review*, 46(4):767–791.

Luci-Greulich, A. and Thévenon, O. (2014). Does Economic Advancement 'Cause' a Re-increase in Fertility? An Empirical Analysis for OECD Countries (1960–2007). *European Journal of Population*, 30(2):187–221.

Lutz, W., Skirbekk, V., and Testa, M. R. (2006). The Low-Fertility Trap Hypothesis: Forces that May Lead to Further Postponement and Fewer Births in Europe. *Vienna Yearbook of Population Research*, 4:167–192.

Mavropoulos, G. and Panagiotidis, T. (2021). On the drivers of the fertility rebound. *Economic Change and Restructuring*, 54(3):821–845.

McDonald, P. (2000). Gender Equity in Theories of Fertility Transition. *Population and Development Review*, 26(3):427–439.

Mehta, N. K., Abrams, L. R., and Myrskylä, M. (2020). US life expectancy stalls due to cardiovascular disease, not drug deaths. *Proceedings of the National Academy of Sciences*, 117(13):6998–7000.

Mills, M., Johnston, A. D., and DiPrete, T. A. (2006). Globalization and men's job mobility in the United States. In *Globalization, Uncertainty and Men's Careers*, pages 328–364. Edward Elgar Publishing.

Milweski, N. (2010). *Fertility of Immigrants: A Two-Generational Approach in Germany*. Springer, Berlin, Heidelberg.

Myrskylä, M., Kohler, H.-P., and Billari, F. C. (2009). Advances in development reverse fertility declines. *Nature*, 460(7256):741–743.

Myrskylä, M., Kohler, H.-P., and Billari, F. C. (2011). High development and fertility: Fertility at older reproductive ages and gender equality explain the positive link. Technical Report WP-2011-017, Max Planck Institute for Demographic Research, Rostock.

National Bureau of Economic Reseach (2022). Vital Statistics Natality Birth Data. https://www.nber.org/research/data/vital-statistics-natality-birth-data.

National Bureau of Economic Reseach (2023). SEER Population Data - United States Filees at State and/or County Level. https://www.nber.org/research/data/survey-epidemiology-and-end-results-seer-us-state-and-county-population-data-age-race-sex-hispanic.

Notestein, F. D. (1945). Population - The Long View. In *Food for the World*, pages 36–57. University of Chidcago Press.

Porter, J. R. (2017). Human Development and the Fertility Reversal: A Spatially Centered Sub-national Examination in the US. *Spatial Demography*, 5(1):43–72.

Porter, J. R. and Purser, C. W. (2008). Measuring relative sub-national human development: An application of the United Nation's Human Development Index using geographic information systems. *Journal of Economic and Social Measurement*, 33(4):253–269.

Presser, H. B. (1975). Age Differences Between Spouses: Trends, Patterns, and Social Implications. *American Behavioral Scientist*, 19(2):190–205.

Rindfuss, R. R., Choe, M. K., and Brauner-Otto, S. R. (2016). The Emergence of Two Distinct Fertility Regimes in Economically Advanced Countries. *Population Research and Policy Review*, 35(3):287–304.

Ruggles, S. (2015). Patriarchy, Power, and Pay: The Transformation of American Families, 1800–2015. *Demography*, 52(6):1797–1823.

Rüttenauer, T. and Ludwig, V. (2020). Fixed Effects Individual Slopes: Accounting and Testing for Heterogeneous Effects in Panel Data or Other Multilevel Models. *Sociological Methods & Research*, page 004912412092621.

Ryabov, I. (2015). On the Relationship between Development and Fertility: The Case of the United States. *Comparative Population Studies*, 40(4).

Scherbov, S. and Gietel-Basten, S. (2020). Measuring inequalities of development at the sub-national level: From the human development index to the human life indicator. *PLOS ONE*, 15(4):e0232014.

Schneider, D. and Hastings, O. P. (2015). Socioeconomic Variation in the Effect of Economic Conditions on Marriage and Nonmarital Fertility in the United States: Evidence From the Great Recession. *Demography*, 52(6):1893–1915.

Schoumaker, B. (2019). Male Fertility Around the World and Over Time: How Different is it from Female Fertility? *Population and Development Review*, 45(3):459–487.

Seltzer, J. A. (2019). Family Change and Changing Family Demography. *Demography*, 56(2):405–426.

Sen, A. (1998). Mortality as an Indicator of Economic Success and Failure. *The Economic Journal*, 108(446):1–25.

Smits, J. and Permanyer, I. (2019). The Subnational Human Development Database. *Scientific Data*, 6(1):190038.

van de Kaa, D. (1987). Europe's Second Demographic Transition. *Population Bulletin*, 42(1).

Vignoli, D., Bazzani, G., Guetto, R., Minello, A., and Pirani, E. (2020). Uncertainty and Narrative of the Future: A Theoretical Framework for Contemporary Fertility. In Schoen, R., editor, *Analyzing Contemporary Fertility*, volume 51 of *The Springer Series on Demographic Methods and Population Analysis*. Springer International Publishing, Cham.

Wooldridge, J. M. (2002). *Econometric Analysis of Cross Section and Panel Data*. MIT Press.

Revisiting the J-shape. Human Development and Fertility in the United States: Online Appendix

CONTENTS

A. VARIANCE ESTIMATION FOR THE INVERSION POINT

Formula for the inversion point:

$$I = \frac{-\beta_1}{2\beta_2} \tag{S1}$$

Delta method:

$$\text{Var}(I) = \frac{\delta I}{\delta \beta'} \text{Var}(\beta) \frac{\delta I}{\delta \beta'} \tag{S2}$$

$$= \left(\frac{\delta I}{\delta \beta_1} \right)^2 \text{Var}(\beta_1) + \left(\frac{\delta I}{\delta \beta_2} \right)^2 \text{Var}(\beta_2) + 2 \frac{\delta I}{\delta \beta_1} \frac{\delta I}{\delta \beta_2} \text{Cov}(\beta_1, \beta_2) \tag{S3}$$

with

$$\frac{\delta I}{\delta \beta_1} = -\frac{1}{2\beta_2} \tag{S4}$$

and

$$\frac{\delta I}{\delta \beta_2} = \frac{2\beta_1}{4\beta_2^2} \tag{S5}$$

which can be evaluated at parameter estimates. Using the $Var(I)$ estimate and the estimated turning point, the 95%-confidence interval was estimated in the following way:

$$ci_{95}(I) = I \pm 1.96 * \frac{Var(I)}{\sqrt{n}}$$

B. EQUATIONS

Estimation of tempo-adjusted TFR

$$TFR_{tempo-adjusted} = \sum_{parity=1} \frac{TFR_{parity}}{(1-r)} \tag{S6}$$

with

$$r = 0.5 * [MAB(t+1, parity) - MAB(t-1, parity)] \tag{S7}$$

Estimation of the Human Life indicator

$$\text{Human Life indicator} = \prod_{i=1}^{N} (age_i + a_i)^{d_i} \tag{S8}$$

C. ADDITIONAL TABLES

Treatment	Outcome	Model	State FE	Year FE	Controls	inv. J-shape?	Turning point
HLI	TFR	Std.	Yes	No	No	Yes	71.6
HLI	TFR	Std.	Yes	Yes	No	Yes	88.5
HLI	TFR	FEIS	Yes	Yes	No	Yes	76.82
HLI	TFR	RE	No	No	No	Yes	86.4
HLI	TFR	Census	No	No	Yes	Yes	64.19
HLI	TFR	Smooth	Yes	Yes	No	Yes	102.36
HLI	aTFR	Std.	Yes	Yes	No	Yes	101.49
HLI	mTFR	Std.	Yes	Yes	No	Yes	83.64
HLI	TFR	Std.	Yes	Yes	Unemp.	No	75.8
HLI	TFR	Std.	Yes	Yes	Service	Yes	58.61
HLI	TFR	Std.	Yes	Yes	Age diff.	No	74.84
HLI	TFR	Std.	Yes	Yes	Rec.	Yes	79.18
HLI	TFR	Std.	Yes	No	ΔMAB	Yes	72.63
HLI	TFR	Std.	Yes	Yes	ΔMAB	Yes	88.23
HLI	TFR	Std.	Yes	No	MAB	Yes	76.48
HLI	TFR	Std.	Yes	Yes	MAB	Yes	104.21
HDI	TFR	Std.	Yes	No	No	No	0.82
HDI	TFR	Std.	Yes	Yes	No	No	1.04
HDI	TFR	FEIS	Yes	Yes	No	No	-0.5
HDI	TFR	RE	No	No	No	No	0.96
HDI	TFR	Census	No	No	No	No	0.92
HDI	TFR	Smooth	Yes	Yes	No	No	1.03
HDI	aTFR	Std.	Yes	Yes	No	Yes	0.76
HDI	mTFR	Std.	Yes	Yes	No	Yes	1.15
HDI	TFR	Std.	Yes	Yes	Rec.	No	1
LE	TFR	Std.	Yes	No	No	Yes	78.46
LE	TFR	Std.	Yes	Yes	No	Yes	89.03
LE	TFR	FEIS	Yes	Yes	No	Yes	116.71
LE	TFR	RE	No	No	No	Yes	88.04
LE	TFR	Census	No	No	No	Yes	38.37
LE	TFR	Smooth	Yes	Yes	No	Yes	94.2
LE	aTFR	Std.	Yes	Yes	No	No	62.42
LE	mTFR	Std.	Yes	Yes	No	No	84.8
LE	TFR	Std.	Yes	Yes	Rec.	Yes	84.51

Tempo-adjusted TFR

Table S1. State fixed effects regression on tempo-adjusted TFR using lagged values of the Human Life indicator (HLI), Human Development Index (HDI) and life expectancy (LE).

	lag.HLI	lag.HDI	lag.LE
Linear	-0.708^{***}	-44.092^{**}	-2.140^{***}
	(0.040)	(21.577)	(0.145)
Squared	0.005^{***}	26.764^{**}	0.014^{***}
	(0.0003)	(12.227)	(0.001)
State fixed effects	Yes	Yes	Yes
Year fixed effects	No	No	No
Years	1969 - 2004	1990 - 2004	1969 - 2004
Observations	1,836	714	1,836
R^2	0.142	0.114	0.123
J shape	Yes	Yes	Yes
Turning point	71.6	0.82	78.46
Confidence interval	(71.45 , 71.76)	(0.79 , 0.86)	(78.25 , 78.66)
Note:			*p<0.1; **p<0.05; ***p<0.01

Table S2. Two-way fixed effects regression on tempo-adjusted TFR using lagged values of the Human Life indicator (HLI), Human Development Index (HDI) and life expectancy (LE).

	lag.HLI	lag.HDI	lag.LE
Linear	−0.025	−39.756**	0.026
	(0.031)	(18.318)	(0.108)
Squared	0.0001	26.168**	−0.0002
	(0.0002)	(10.325)	(0.001)
State fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
Years	1969 - 2004	1990 - 2004	1969 - 2004
Observations	1,836	714	1,836
R^2	0.011	0.476	0.002
J shape	Yes	Yes	No
Turning point	101.49	0.76	62.42
Confidence interval	(94.46 , 108.51)	(0.73 , 0.79)	(54.34 , 70.49)
Note:			$^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

Table S3. Two-way fixed effects regression on male TFR using lagged values of the Human Life indicator (HLI), Human Development Index (HDI) and life expectancy (LE).

	lag.HLI	lag.HDI	lag.LE
Linear	-0.108^{***}	-6.844	-0.243^{***}
	(0.015)	(12.787)	(0.042)
Squared	0.001^{***}	2.970	0.001^{***}
	(0.0001)	(7.208)	(0.0003)
State fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
Years	1969 - 2004	1990 - 2004	1969 - 2004
Observations	1,836	1,428	1,836
R^2	0.184	0.621	0.158
J shape	Yes	Yes	Yes
Turning point	83.64	1.15	84.8
Confidence interval	(83.02 , 84.25)	(0.92 , 1.38)	(84.11 , 85.48)
Note:			*p<0.1; **p<0.05; ***p<0.01

The effect of state-level controls

Table S4. Two-way fixed effects regression with controls of female TFR on lagged values of the Human Life indicator (HLI), Human Development Index (HDI) and life expectancy (LE).

	(1)	(2)	(3)
HLI	0.213^{***}	-0.131^{***}	0.235^{***}
	(0.033)	(0.046)	(0.034)
HLI ^{2}	-0.001^{***}	0.001^{***}	-0.002^{***}
	(0.0002)	(0.0003)	(0.0002)
Unemployment Rate	-0.011^{***}		
	(0.002)		
% in Service		-0.012	
		(0.016)	
Age Difference			0.181^{**}
			(0.086)
State fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
Observations	2,193	1,479	2,193
Years	1976 - 2018	1976 - 2018	1976 - 2004
J shape	No	Yes	No
Turning point	75.8	58.61	74.84
Confidence interval	(75.37 , 76.23)	(57.88 , 59.34)	(74.44 , 75.24)

Note: *p$<$0.1; **p$<$0.05; ***p$<$0.01

A.Controlling for fertility postponement

Table S5. State fixed effects regression of female TFR on lagged values of the Human Life indicator (HLI), Human Development Index (HDI) and life expectancy (LE).

	TFR female			
	Myrskylä 1	Myrskylä 2	Greulisch 1	Greulisch 2
lag.HLI	-0.327^{***}	-0.076^{***}	-0.415^{***}	-0.081^{***}
	(0.025)	(0.020)	(0.029)	(0.022)
lag.HLI^2	0.002^{***}	0.0004^{***}	0.003^{***}	0.0004^{**}
	(0.0002)	(0.0001)	(0.0002)	(0.0002)
Δ MAB	-0.503^{***}	0.026		
	(0.046)	(0.042)		
ΔΔ MAB	-0.215^{***}	0.027		
	(0.035)	(0.028)		
MAB			1.871^{***}	0.369^{***}
			(0.097)	(0.090)
MAB^2			-0.034^{***}	-0.005^{***}
			(0.002)	(0.002)
State fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	No	Yes	No	Yes
Years	1969 - 2018	1969 - 2018	1969 - 2018	1969 - 2018
Observations	2,550	2,550	2,550	2,550
R^2	0.09	0.049	0.165	0.101
J shape	Yes	Yes	Yes	Yes
Turning point	72.63	88.23	76.48	104.21
Confidence bands	(72.44 , 72.81)	(87.31 , 89.15)	(76.29 , 76.67)	(102.84 , 105.58)
Note:				*p<0.1; **p<0.05; ***p<0.01

B.Random effects models

Table S6. State random effects regression of female TFR on lagged values of the Human Life indicator (HLI), Human Development Index (HDI) and life expectancy (LE).

	lag.HLI	lag.HDI	lag.LE
Linear	-0.335^{***}	49.369^{***}	-0.908^{***}
	(0.025)	(6.425)	(0.081)
Squared	0.002^{***}	-28.862^{***}	0.006^{***}
	(0.0002)	(3.578)	(0.001)
Constant	14.354^{***}	-19.076^{***}	38.489^{***}
	(0.885)	(2.884)	(3.162)
State random effects	Yes	Yes	Yes
Year random effects	No	No	No
Observations	2,550	1,428	2,550
Years	1969 - 2018	1990 - 2018	1969 - 2018
R^2	0.078	0.107	0.076
J shape	Yes	No	Yes
Turning point	74.34	0.86	80.55
Confidence bands	(64.79 , 83.89)	(0.57 , 1.14)	(68.3 , 92.79)
Note:			$^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

Table S7. Two-way random effects regression of female TFR on lagged values of the Human Life indicator (HLI), Human Development Index (HDI) and life expectancy (LE).

	lag.HLI	lag.HDI	lag.LE
Linear	-0.079^{***}	34.196^{***}	-0.184^{***}
	(0.019)	(6.080)	(0.065)
Squared	0.0005^{***}	-17.766^{***}	0.001^{**}
	(0.0001)	(3.343)	(0.0004)
	(0.697)	(2.774)	(2.552)
Constant	5.290^{***}	-14.405^{***}	9.954^{***}
State random effects	Yes	Yes	Yes
Year random effects	Yes	Yes	Yes
Observations	2,550	1,428	2,550
Years	1969 - 2018	1990 - 2018	1969 - 2018
R^2	0.046	0.094	0.032
J shape	Yes	No	Yes
Turning point	86.4	0.96	88.04
Confidence interval	(85.56 , 87.24)	(0.95 , 0.97)	(86.9 , 89.17)

Note: $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

Table S8. State fixed effects regression with smoothed time-series of lagged values of the Human Life indicator (HLI), Human Development Index (HDI) and life expectancy (LE).

	Smoothed female TFR		
	(1)	(2)	(3)
HLI.smooth	-0.240^{***}		
	(0.018)		
HLI.smooth^2	0.002^{***}		
	(0.0001)		
HDI.smooth		212.042^{***}	
		(11.684)	
HDI.smooth^2		-116.906^{***}	
		(6.375)	
LE.smooth			-0.631^{***}
			(0.060)
LE.smooth^2			0.004^{***}
			(0.0004)
Year fixed effects	No	No	No
State fixed effects	Yes	Yes	Yes
Years	1969 - 2018	1990 - 2018	1969 - 2018
Observations	2,550	1,428	2,550
R^2	0.221	0.520	0.221
J shape	Yes	Yes	Yes
Turning point	76.28	0.91	82.12
Confidence interval	(76.07 , 76.48)	(0.9 , 0.91)	(81.85 , 82.39)

Note: $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

Table S9. Two-way fixed effects regression with smoothed time-series.

	Dependent variable:		
	Smoothed female TFR		
	(1)	(2)	(3)
HLI.smooth	-0.053^{***}		
	(0.017)		
HLI.smooth^2	0.0003^{**}		
	(0.0001)		
HDI.smooth		45.519^{***}	
		(4.828)	
HDI.smooth^2		-22.139^{***}	
		(2.628)	
LE.smooth			-0.103^{*}
			(0.057)
LE.smooth^2			0.001
			(0.0004)
Year fixed effects	Yes	Yes	Yes
State fixed effects	Yes	Yes	Yes
Years	1969 - 2018	1990 - 2018	1969 - 2018
Observations	2,550	1,428	2,550
R^2	0.021	0.133	0.010
J shape	Yes	No	Yes
Turning point	102.36	1.03	94.2
Confidence interval	(100.8 , 103.91)	(1.02 , 1.04)	(92.17 , 96.23)
Note:			$^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

Table S10. Census-division fixed effects regression of female TFR on lagged values of development indicators.

Dependent Variable:		TFR female	
Model:	(1)	(2)	(3)
lag.HLI	-0.0419		
	(0.0385)		
lag.HLI^2	0.0003		
	(0.0003)		
lag.HDI		23.01**	
		(9.226)	
lag.HDI^2		-12.53**	
		(5.157)	
lag.LE			-0.0127
			(0.0963)
lag.LE^2			0.0002
			(0.0006)
Census division	Yes	Yes	Yes
Year	Yes	Yes	Yes
Years	1969 - 2018	1990 - 2018	1969 - 2018
Observations	2,550	1,428	2,550
R^2	0.68597	0.67502	0.68718
Within R^2	0.00215	0.00684	0.00598
J shape	Yes	No	No
Turning point	64.19	0.9200	38.37
Confidence bands	(62.44 , 65.93)	(0.89 , 0.94)	(33.69 , 43.05)

Clustered (census Division-Year) standard-errors in parentheses

*Signif. Codes: ***: 0.01, **: 0.05, *: 0.1*

Table S11. The effect of the great recession period on the fertility-development nexus.

	Female TFR		
lag.HLI	-0.116^{***}		
	(0.023)		
lag.HLI^2	0.001^{***}		
	(0.0002)		
lag.HLI:Recession	0.113		
	(0.133)		
lag.HLI^2 $\times$ Recession	-0.001		
	(0.001)		
lag.HDI		56.684^{***}	
		(11.261)	
lag.HDI^2		-28.395^{***}	
		(6.306)	
lag.HDI $\times$ Recession		-30.491^{**}	
		(12.747)	
lag.HDI^2:Recession		17.019^{**}	
		(7.069)	
lag.LE			-0.238^{***}
			(0.080)
lag.LE^2			0.001^{***}
			(0.001)
lag.LE:Recession			-0.021
			(0.296)
lag.LE^2 $\times$ Recession			0.0001
			(0.002)
State fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
Observations	2,550	1,428	2,550
Years	1969-2018	1990-2018	1969-2018
J shape	Yes	No	Yes
Turning point	79.18	1	84.51
Confidence bands	(78.59 , 79.76)	(0.98 , 1.01)	(83.49 , 85.52)
Note:		$^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$	

Table S12. State fixed effects regression on female TFR using Several Development Indicators.

	lag.HLI	lag.HDI	lag.LE
Linear	-0.349^{***}	56.896^{***}	-0.983^{***}
	(0.025)	(7.762)	(0.083)
Squared	0.002^{***}	-33.309^{***}	0.006^{***}
	(0.0002)	(4.313)	(0.001)
State fixed effects	Yes	Yes	Yes
Year fixed effects	No	No	No
Years	1969 - 2018	1990 - 2018	1969 - 2018
Observations	2,550	1,428	2,550
R^2	0.081	0.133	0.079
J shape	Yes	No	Yes
Turning point	74.18	0.85	80.33
Confidence interval	(74 , 74.36)	(0.85 , 0.86)	(80.1 , 80.56)
Note:			*p<0.1; **p<0.05; ***p<0.01

D. ADDITIONAL FIGURES

A. The role of postponement

When looking at fertility developments using the tempo-adjusted TFR, the j-shape pattern remains visible. However, the weakening relationship points at interfering tempo distortions of the normal TFR, because the measure is biased by tempo-distortions. The initial drop in fertility was partially driven by postponement, as well as the subsequent recovery. We cannot make any statements about the impact of tempo distortions in the last phase because of data limitations. Yet, previous studies have shown that the decline resulted from decreasing childbearing intensity of teenagers and young adolescences, while fertility above age 30 remained roughly at the same level, which is visible in our data as well. Although this is not the ultimate evidence for tempo-distortions resulting from fertility postponement, it provides some preliminary support. Yet to be shown is whether the people that did not receive children between 2008 and 2018, have they only postponed or forewent childbearing altogether.

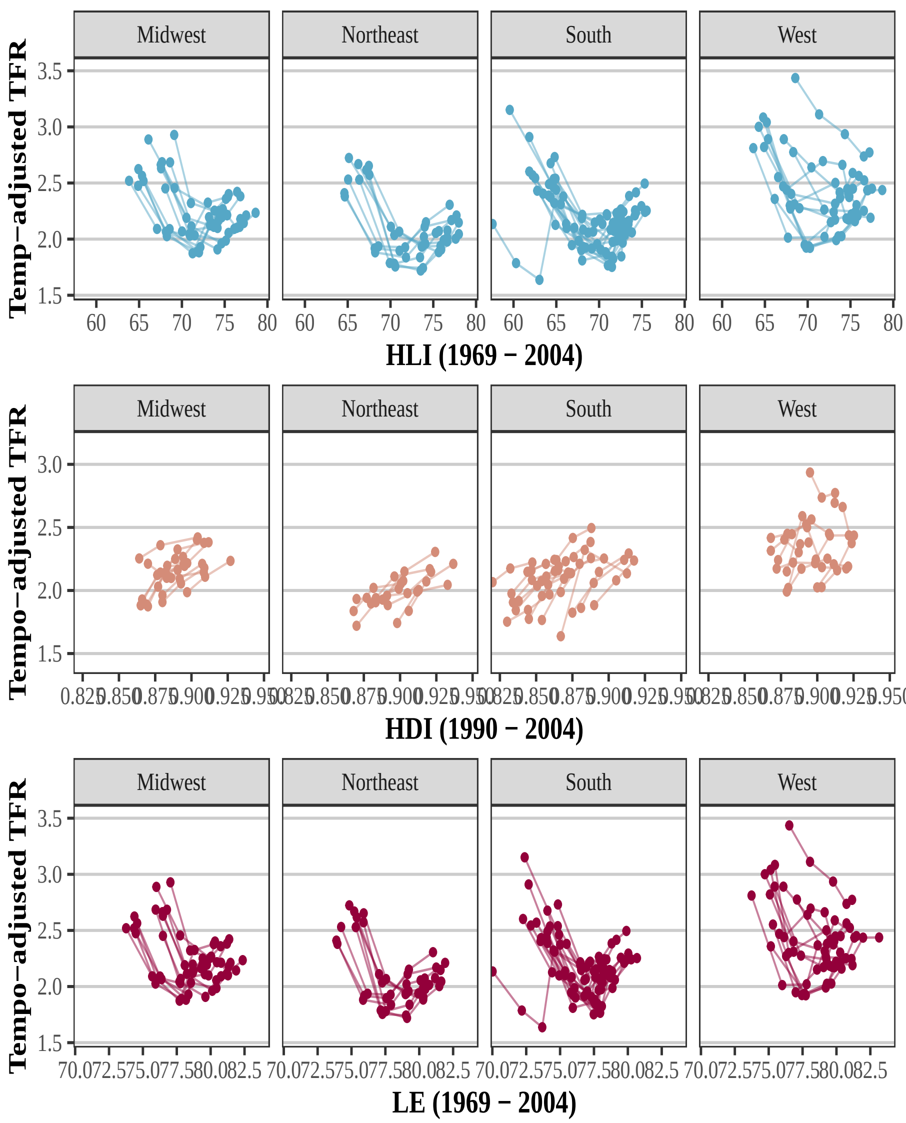

Fig. S1. Decade averages of development and fertility in the United States between 1990 and 2018

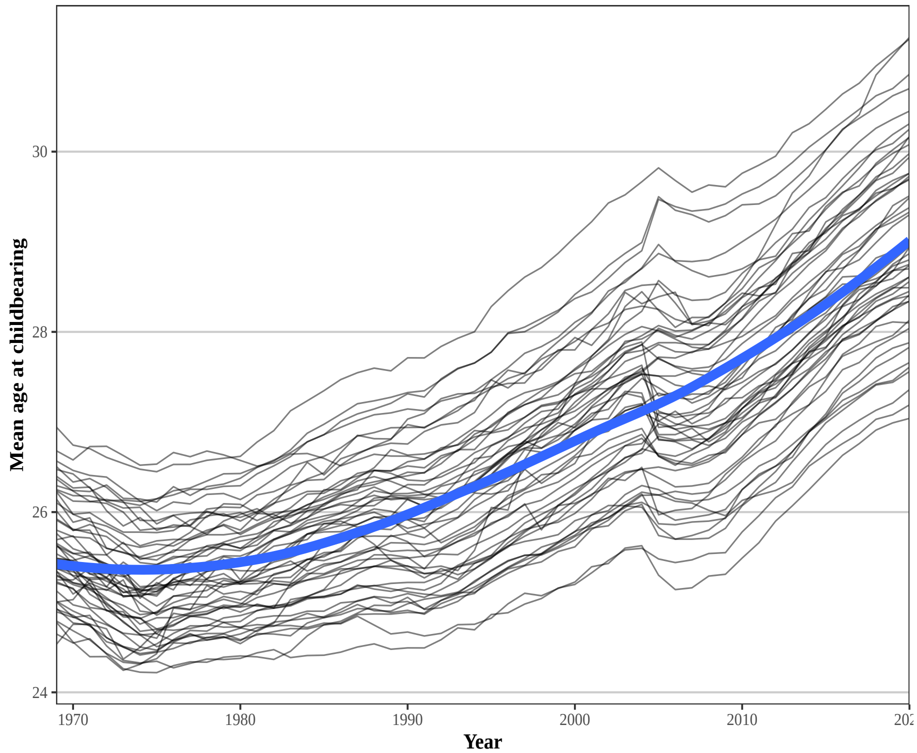

Fig. S2. The development of mean age of childbearing at the state-level between 1969 and 2020 in the U.S.

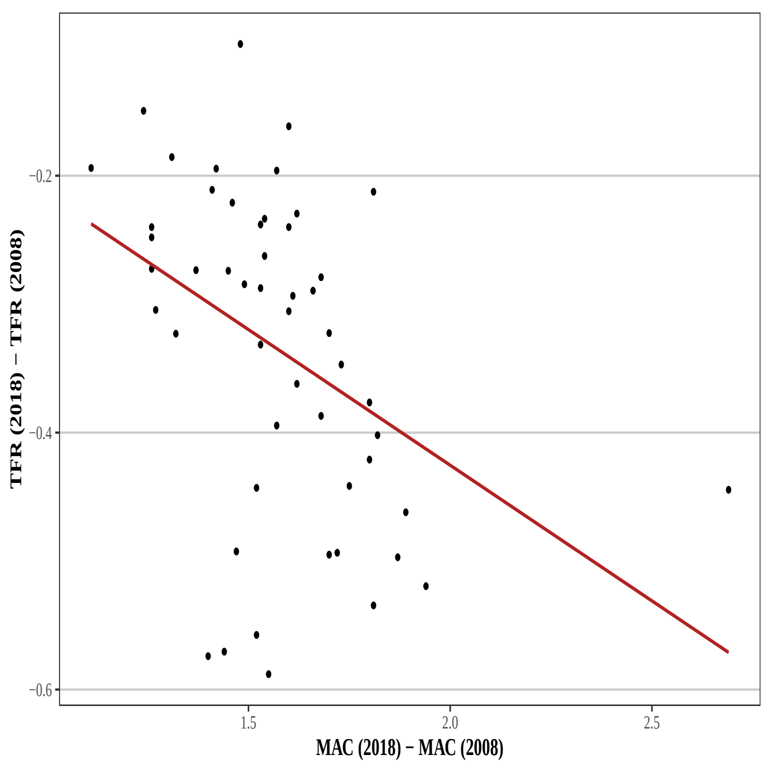

Fig. S3. The change in mean age of childbearing and the change of TFR between 2008 and 2018 at the subnational level in the U.S.

Model dependency

In the main model, the inversion point was calculated at a Human Life indicator of 77 and a life expectancy of 117 years. Yet, when calculating the models with different indicators and different specifications, the inversion point may shift slightly due to differences in the dimension of development as well as varying model assumptions, as displayed in Figure S4. Thus, to reveal the distribution of turning points, we have calculated the point for random-effects, fixed effects, state-specific slope and OLS regression models using the different indicators, removed the values which showed a concave relationship and assembled the results in the Figure S4. The inversion point for the HDI and life expectancy is more clear cut than for the HLI. The mean for the HLI is at 74 (HDI = 0.92, LE = 89), while the 25%- quantile is at 68 (HDI = 0.84, LE = 74) and the 75%-quantile is at 79 (HDI = 0.98, LE = 83). This shows, that the inversion point lies within the observed value range.

Yet, one result is inconsistent with our proposed hypothesis. For the HDI and the LE we see several observations that are at the far right end of the distribution. These values are strong outliers and belong to the models using the tempo-adjusted fertility rate and two-way fixed effects. We direct the reader to the section on tempo-effects.

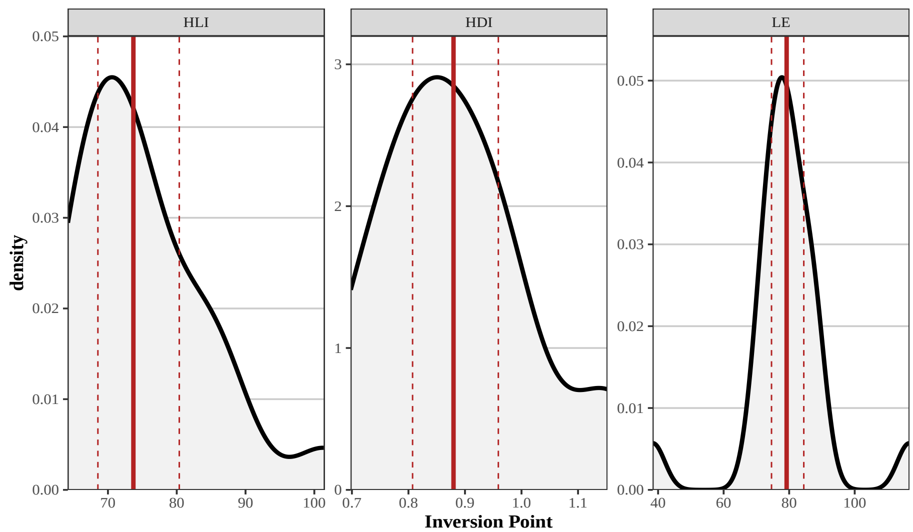

Fig. S4. The graph displays the distribution of turning points of the OLS, state FE, first-differenced, state random, two-ways random, two-way fixed effects models that show a convex relationship. Out of 63 models show 49 a convex relationship and 14 do not show the convex relationship. The thick line is the median of the turning points, and the dashed lines are the 25%quantiles.

Sensititvity

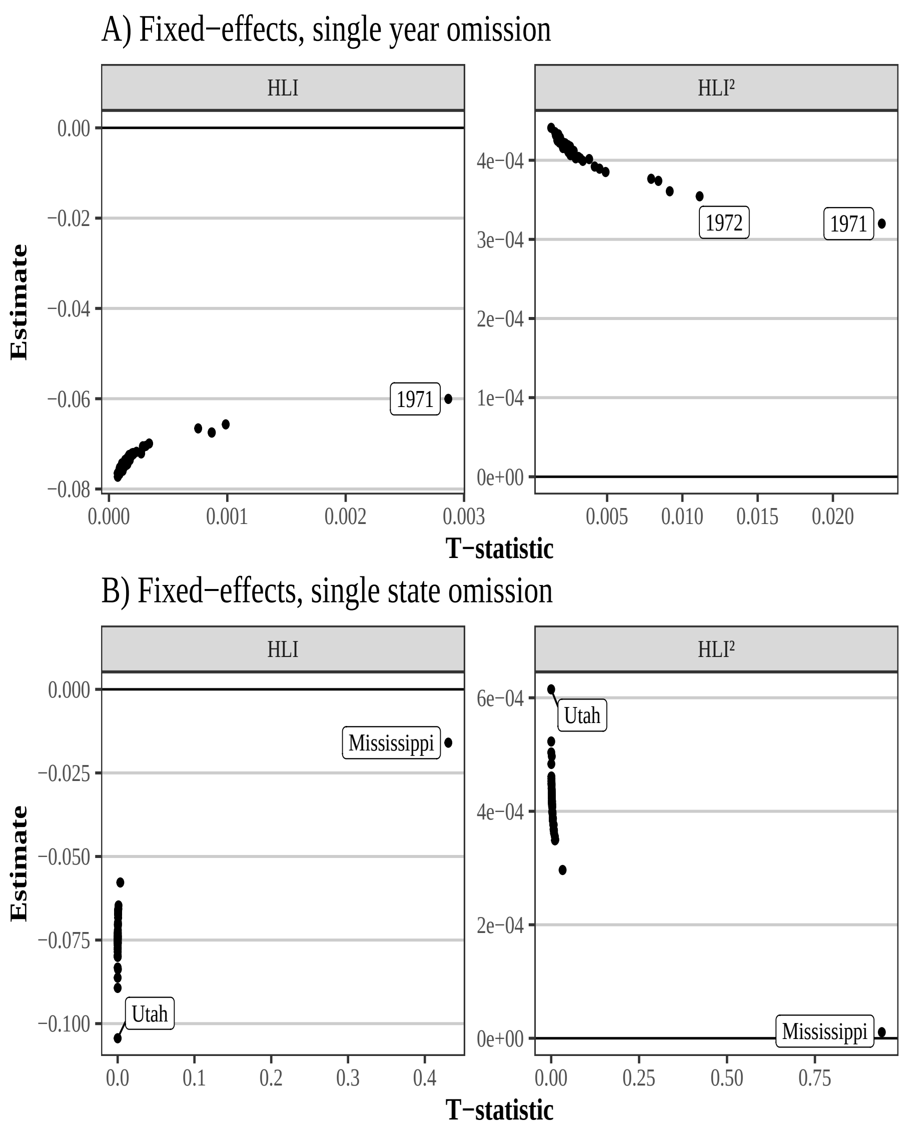

Fig. S5. This figures illustrates the coefficients and the T-statistic for HLI and HLI^2 across several two-way fixed effects regression models for different subsamples, after removing single years or single states. **Interpretation:** The results remain largely robust after removing single cases. However, omitting early years from the sample results in weaker J-shaped pattern. After removing Mississippi from the data, the relationship between development and fertility is largely flat, while the J-shape becomes more pronounced when removing Utah.

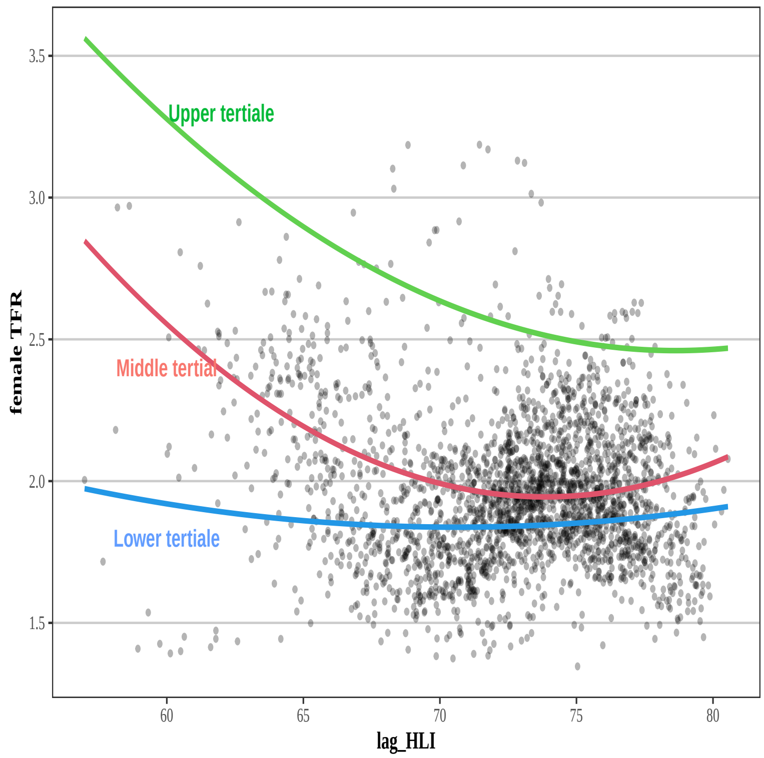

Fig. S6. Quantile regression with 33% quantiles.

B. Development and the male-female TFR ratio

When looking at the ratio of TFR of men to TFR of women in relation to development indicators, we see a strong negative relationship. The higher the development the lower the value for men compared to the female equivalent. The negative relationship holds within and between states. This observation for the subnational level corresponds to results from previous research at the national level, which shows a cross-over of male and female fertility during the demographic transition. Additionally, Dudel and colleagues (2020) have shown for the U.S, that the decline of the male to female TFR ratio is exaggerated by declining cohort size, which is framed as birth squeeze. Yet, there are some outliers in the most recent years, as Massachusetts as well as New York have a male-to-female TFR ratio that is higher than 1, although they belong to the most developed states.

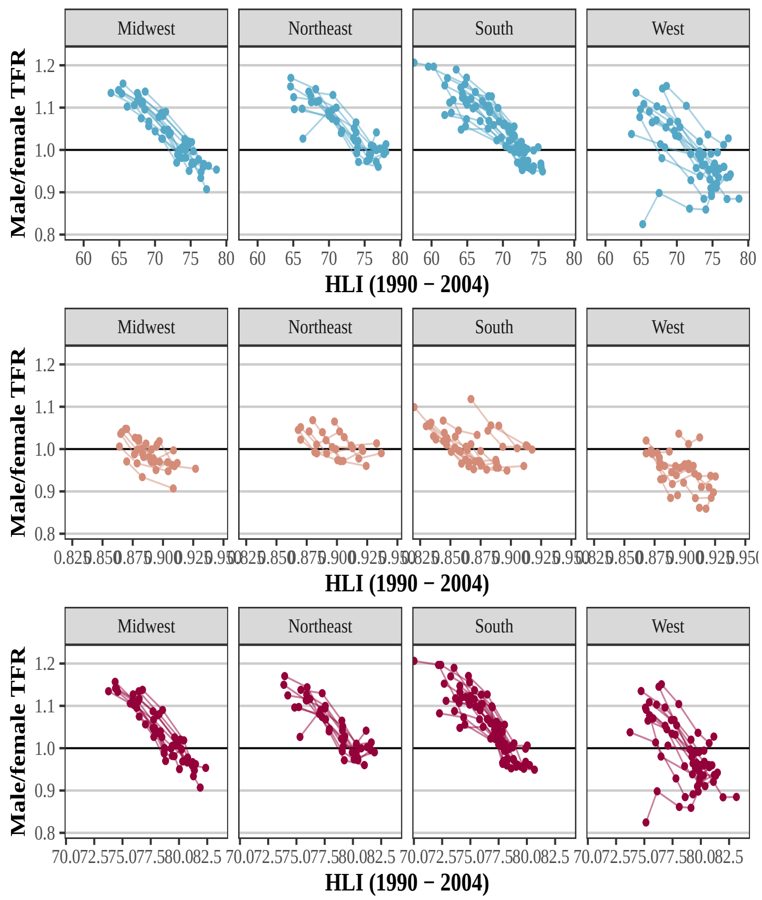

Fig. S7. Decade averages of development and male fertility in the United States between 1990 and 2018