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ORIGINAL PAPER

Long-term barriers to global fertility convergence

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Abstract
After WWII, the demographic transition exhibited features of convergence between developing countries and the forerunner countries with low fertility. Although today fertility is low in the majority of countries, significant differences persist. In this article, I study club convergence of fertility in 190 countries over the period 1950 to 2018. First, I apply a novel econometric method for convergence analysis and club clustering. I find no evidence of global fertility convergence, and I classify the 190 countries into four clubs. I further classify countries into two clubs at the beginning of the period and identify a club of countries transitioning from high to low fertility. Second, I interpret fertility convergence clubs as a feature of the long-term process of economic development and estimate an ordered probit model of the probability that a country enters one of three clubs characterized by high, medium, and low barriers to global fertility convergence. Here, the focus is on ancestral fundamental factors of diversity in economic development. Estimates show a statistically significant inverted U-shaped relationship between interpersonal population diversity and the probability of lower barriers, consistent with the literature on diversity and development. Estimates also highlight that genetic distance to the USA and years since the Neolithic transition to agriculture cause higher barriers to fertility decline.

Keywords Fertility decline · Population diversity · Neolithic transition · International convergence · *Logt* convergence test · Ordered probit

JEL Classification J11 · J13 · O15

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1 Introduction

Over the past two centuries, the decline in fertility has been central to the transition of societies from an epoch of stagnation to an era of sustained economic growth, fostering human capital formation, technological progress, and economic growth. While developed countries experienced this transition predominantly during the second half of the nineteenth century, fertility rates started to decline across developing counties towards the second half of the twentieth century, contributing to an apparent convergence in fertility rates across the globe.

This study analyzes the patterns of convergence in fertility rates across 190 countries over the period 1950 to 2018. It explores whether the fertility rates have been converging globally or whether the deep historical factors that have contributed to the persistent gap in the wealth of nations have led to the emergence of convergence clubs in fertility rates.

Unified growth theory (UGT) suggests that reinforcing interaction between the rate of technological progress and the size and composition of the population in the course of human history accelerated the pace of technological progress beyond a tipping point, where rudimentary education became essential for the ability of individuals to adapt to the rapidly changing technological environment. Fertility rates started to decline and the growth in living standards was liberated from the counterbalancing effects of population growth, paving the way for the emergence of sustained economic growth. (Galor, 2011; Galor and Weil, 2000; Galor and Moav, 2002).

Nevertheless, UGT does not imply that the level of fertility will be similar across the globe. Since fertility rates are affected by economic incentives as well cultural, institutional, and societal characteristics, convergence in fertility rates will take place only if institutional, cultural, and societal characteristics will converge as well (Galor, 2011). Hence, in view of the variations in these characteristics across the globe, UGT suggests fertility rates will differ across world regions in the long run. In particular, deep-rooted historical forces such as migratory distance from Africa and its impact on interpersonal population diversity (Ashraf and Galor, 2013a, b), as well as the time elapsed since the onset of the Neolithic Revolution and its impact on political institutions and cultural traits (Diamond, 1997), would be expected to lead to differential timing of the transition from stagnation to growth across the globe and to persistent difference in fertility rates in the long run.

I follow this theoretical framework to test the hypothesis that ancestral determinants of the contemporary diversity of development levels also explain different stages of the demographic transition around the world. I approach this question through the lens of club convergence analysis, which provides a descriptive synthesis of strong nonlinearities involved in the transition to low fertility. Then, I interpret convergence clubs as the outcome of barriers with different magnitudes to global fertility convergence and search for the ancestral factors that may explain the current variety of transitional paths.

The decline of fertility across the world is characterized by heterogeneity and nonlinearity of time paths. The first significant distinction is between countries converging to the low-fertility club and countries that are still in the pre-transitional regime. Even among the transitioning countries, the timing of the onset of the transition varies substantially. Moreover, in some cases, fertility declines along nonmonotonic time paths with trend inversions due to specific events without changing the direction of the long-term transition. I study club convergence of fertility by applying the econometric methods of Phillips and Sul (2007, 2009), which allow nonstationarity, nonlinearity, and heterogeneity of the time series, in contrast to β- and σ -convergence approaches. I cluster countries according to fertility at the end of the period (2018) and at the beginning (1950) using a reverse convergence regression. Hence, I also detect one club of countries in transition from high initial total fertility rate (TFR) to a low TFR.

In this way, I identify four convergence clubs that face diverse obstacles to join the (fifth) club of the forerunners of low fertility. I investigate the determinants of the barriers to global fertility convergence on a sample of 138 countries using available data on a large set of regressors. Here, the focus is on ancestral factors that may explain the origins and persistence of the striking variety of reproductive behaviors in the world: *interpersonal population diversity*, as determined by migratory distance of the ancestral populations of each country from east Africa (Ashraf and Galor, 2013a), *genetic distance to the United States (US)* (Spolaore and Wacziarg, 2009; 2018), and *years since the transition to agriculture* (Diamond, 1997; Olsson and Hibbs, 2005).

The results show that the probability of lower barriers to fertility decline mainly depends on interpersonal population diversity according to an inverted-U shaped relation. Ashraf and Galor (2013a) found a similar relationship between interpersonal population diversity and income per capita. I also find that increasing genetic distance to the US and time since the transition to agriculture decrease the probability of a country facing low barriers to fertility decline. The last result is in accordance with some research that detects a negative effect of the years elapsed since the onset of the Neolithic transition on important aspects of economic growth (e.g., Ashraf and Galor, 2013a). This effect can be attributed to the persistence of some cultural features of rural society detrimental for growth and behavioral change.

This research makes the following contributions to the literature. First, it produces the first empirical analysis of the role of the ancestral factors: interpersonal population diversity, genetic distance to the US, and years since the Neolithic revolution, in the explanation of persistence of fertility convergence clubs in the world. The paper finds significant confirmations of the UGT, which sees the demographic transition as part of the long-run process of the evolution of the whole economy. Second, this paper's regression framework relies on a dependent variable that summarizes the results of the study of club convergence. Using the approach of Phillips and Sul (2007), I address important nonlinear and stochastic features of the international time series of fertility, producing a reliable convergence club classification. Also, I obtain two clubs in the value of the TFR in 1950 using the same methods with a reversion of the time direction. This novelty in research on convergence allows for the rigorous identification of a club of countries transitioning from high to low fertility.

While there is no literature on the determinants of fertility club convergence, the descriptive part of this paper relates to studies of the time path of international fertility that identify regularities and show remarkable variation across nations with respect to both the onset and pace of fertility decline (e.g., Dyson and Murphy, 1985; Bongaarts and Watkins, 1996; Wilson, 2011). Dorius (2008) investigates β-convergence and σ-convergence of the TFR of a panel of 195 countries from 1955 to 2005 and finds some evidence of fertility convergence in the world but only after the 1980s. Strulik and Vollmer (2015) study the evolution of the world's fertility distribution from 1950 to 2005 by estimating the coefficients of a mixture of two normal distributions for each 5-year interval. Silverman's test suggests that the TFR distribution is characterized by two peaks before 1995 and one peak after 1995. My paper investigates fertility convergence in the world using panel time-series methods, which allow for general patterns of heterogeneity across individuals and over time. I find that the world distribution of the TFR is characterized by four convergence groups in the 2000s.[1]

The next section presents the methodology and results of the analysis of club convergence in the TFR. Section 3 presents the empirical investigation of the influence of ancestral factors on the barriers to global fertility convergence carried out with the estimation of an ordered probit model. Section 4 concludes.

2 Modeling fertility convergence

This section investigates club convergence in the time series of the fertility rate of a large sample of countries in the world after WWII with the application of the methods of Phillips and Sul (2007). The next section studies the factors that explain the barriers that countries may face in the process of convergence to the club of low fertility, which is made up of the forerunners of the demographic transition.

Data on the TFR refers to the annual time series of 190 countries from 1950 to 2018.[2] The source of the data is the World Bank's (2021) World Development Indicators for the years 1960–2018. The years 1950–1959 are covered by the estimates from the United Nations World Population Prospects, 2019 Revision.[3]

2.1 The logt test of convergence

I study club convergence using the *logt* test proposed by Phillips and Sul (2007). Recently, panel time-series econometrics has seen the development of factor models where unobserved common factors and idiosyncratic components can be

[1] Quite recently, demographic research (Gerry et al., 2018) used the same methods as in this paper to study club convergence in life expectancy across 30 OECD countries with a focus on the experience of European post-communist countries after the 1950s.

[2] Table 13 in the appendix provides a list of the countries.

[3] Details on the variables used in this article can be found in the appendix.

distinguished. The case of a factor model for the variable x_{it} for individual i at time t can be represented as:

$$x_{it} = \gamma_{it} + \epsilon_{it},$$

where γ_{it} includes systematic factors, while transitory components enter ϵ_{it}. Phillips and Sul (2007) modify this model assuming the following single-factor representation:

$$x_{it} = \left(\frac{\gamma_{it} + \epsilon_{it}}{\pi_t}\right)\pi_t = \theta_{it}\pi_t, \tag{1}$$

where an unobserved common factor π_t and time-varying idiosyncratic components θ_{it} can be distinguished. In this model, π_t is characterized by a deterministic and/or stochastic trend.[4] The distance between the common factor and the systematic part of x_{it} is specific to the individual i and changes over time.

Relative convergence among the series x_{it} is defined as the long-run equilibrium of their ratios:

$$\lim_{t\to\infty}\frac{x_{it}}{x_{jt}} = \lim_{t\to\infty}\frac{\theta_{it}}{\theta_{jt}} = 1 \textit{ for all } i \textit{ and } j. \tag{2}$$

Hence, relative convergence is equivalent to: $\lim_{t\to\infty}\theta_{it} = \theta$. This definition of convergence allows the analysis of time series that do not cointegrate although they follow the same stochastic trend in the long run. Relative convergence also means that pairs of variables follow the same growth rate in the long run but differ in absolute value, as growth theory establishes when admitting differences in structural parameters.

Phillips and Sul (2007) assume the following model for the coefficients θ_{it}:

$$\theta_{it} = \theta_i + \frac{\rho_i}{L(t)t^{\alpha}}\varepsilon_{it,}$$

where $\rho_i > 0$, $L(t)$ is a slowly varying function as $\log(t)$, and ε_{it} which is $iid(0,1)$, weakly dependent and stationary over time.[5] The null hypothesis of convergence is defined by the conditions: $\theta_i = \theta$ and $\alpha \geq 0$. The alternative is defined by: $\theta_i \neq \theta$ and $\alpha < 0$. It can be noted that the alternative hypothesis is quite general because it admits the possibility of club convergence or local convergence to multiple long-run equilibria. The case $\alpha = 0$ can be interpreted as very slow convergence. The *logt* test of convergence is defined in terms of the relative transition coefficients, $h_{it} = \frac{x_{it}}{\hat{x}_t}$, where $\hat{x}_t$ denotes the cross-sectional average. Convergence now implies $h_{it} \to 1$, and the cross-sectional variance V_t,

[4] Herzer et al. (2012) provide econometric evidence of a stochastic trend in international fertility time series.

[5] Phillips and Sul (2007) show how their framework is even more general because it can be extended to allow the parameter α and the function $L(t)$ to be specific to individual i.

$$V_t = \frac{1}{N}\sum_{i=1}^{N}\left(h_{it}-1\right)^2, \quad (3)$$

goes to zero as t goes to infinity. The test is based on V_t. Phillips and Sul (2007) show the test can be performed with the estimation of the regression equation:

$$\log\left(\frac{V_1}{V_t}\right) - 2\log\left[\log(t)\right] = a + b\log(t) + u_{t,} \quad (4)$$

for $t = [rT], [rT] + 1, \ldots, T$, with $[rT]$ the integer part of rT and r the fraction of the time series observations not considered in the regression. Indeed, the estimate of the coefficient b converges in probability to $2\hat{\alpha}$, where $\hat{\alpha}$ is the estimate of α under the null hypothesis. Accordingly, the *logt* test of convergence is simply the test of the null $b \geq 0$. In this case, $\log\left(V_1/V_t\right)$ diverges to ∞, meaning that V_t tends to zero as t goes to infinity. When the panel time series diverge, $b < 0$, and V_t converge to a positive value. The t-statistic relative to $\hat{b}$ $\left(t_b\right)$ is asymptotically distributed as a standard normal.

Phillips and Sul (2007, 2009) also argue how this approach can be used to test for convergence in the absolute value of the series when the component π_t follows a random walk with drift or a trend stationary process. In this case, the null hypothesis is $\alpha \geq 1$ and the *logt* test can be easily applied with the null $b \geq 2$.

The *logt* test of relative convergence presents important advantages over other largely used convergence tests. Indeed, acceptance of the null hypothesis $\beta < 0$ in a cross-country growth regression provides a necessary but not sufficient condition for $\beta-$ *convergence* (e.g., Kong et al. 2019). The approach of $\sigma-$ *convergence* shares with relative convergence the focus on cross-sectional variability, but the former refers to the variance of the variable of interest. If the cross section variance is a decreasing function of a time trend, then the hypothesis of convergence can be accepted. This methodology has been recently generalized by Kong et al. (2019) with the proposal of *weak* $\sigma-$ *Convergence.* This convergence concept applies to panel time series that are characterized by common factors that do not include a deterministic and/or stochastic divergent trend. After the elimination of common factors from the series, a regression of the cross section variance on a time trend suggests the acceptance of *weak* $\sigma-$ *Convergence* if the coefficient of the trend regressor is significantly negative.

However, when common divergent trends are clearly present in panel time series, Phillips and Sul's test of *relative convergence* is the only choice available. This methodology produces a test of convergence and a clustering algorithm appropriate for panels of time series that follow heterogenous trends that may diverge during the transition but in the long run converge like time series that cointegrate at the end of the period. This feature of relative convergence closely corresponds to the statistical context of convergence tests in the field of the demographic transition where the typical trajectory sees a phase of increasing fertility followed by its decline. Differences in the timing of the onset of the transition also characterize cross-country heterogeneity. This is the focus of the methodology that, using the relative transition coefficients, removes the common factor and avoids its modeling. The *logt* test derives from quite a general approach that specifies a semiparametric model of the idiosyncratic time varying component θ_{it}.

Phillips and Sul (2007) also propose a procedure to identify club convergence in the long run. The algorithm is made of four steps. In the first, all cross-sectional units in the panel are ordered according to the value of the last available observation(s), x_{iT}. In the second step, a core group of units can be detected. This step requires the selection of the first k countries with a *logt* test that does not reject the null (i.e., at the 5% level, $t_k > -1.65$).[6] In the third step of the algorithm, each country is added to the core group to run the *logt* test that provides a statistic denoted $\hat{t}$. Those countries with $\hat{t} > c$, where c is a critical value, enter the convergence club. The critical value I choose, c = 0, is quite conservative, as Phillips and Sul (2007) recommend. In the fourth step, a *logt* test is conducted on the remaining countries for which $\hat{t} < c$ to verify if the null of convergence can be accepted (i.e.,$t_b > -1.65$). If not, the first three steps can be repeated in the remaining countries to determine whether this set can be classified in two or more convergence clubs, or simply they all diverge. This procedure can be iterated until every country in the panel is classified. Phillips and Sul (2009) note that when the time dimension of the panel is small, the application of their methodology could lead to more clubs than the correct number and suggest the running of the *logt* test to verify the possible merge of pairs of adjacent clubs. In the following subsection, I apply this clustering procedure to the fertility rate in a panel of 190 countries.

2.2 Club convergence in world fertility rates

I applied the *logt* test after removing the first one-third of the time series observations of each country. I also used *t*-statistic calculated with a heteroskedasticity- and autocorrelation-consistent estimator of the standard error. Table 1 presents the results of the *logt* test for the whole sample of 190 countries in the years from 1950 to 2018. The null of convergence in fertility rates in the world is strongly rejected at usual test levels. The same result emerges from the *logt* regression on the panel data starting in two more recent years: 1980 and 1990 that focus on countries where the demographic transition has already begun. Given the remarkable generality of the *logt* test from the methodological point of view exposed above, these results strongly suggest the demographic transition will be an open-ended question in the future of many developing countries.

It is possible that the alternative to global convergence is club convergence. I have pursued the investigation of such an alternative configuration of fertility trends by applying Phillips and Sul's (2007) clustering algorithm to the TFR data for the period from 1950 to 2018.[7] Table 2 presents the results of the application of the clustering algorithm and testing of the null of club merging. Initially, I found five

[6] The core group size k is given by the criterion:
$k^* = arg\ \max_k \{t_k\}$ subject to $min\{t_k\} > -1.65$.

[7] I ordered all countries in the panel according to the TFR of the last observation from the highest to the lowest.

clubs, reduced to four after the merge of the third and fourth clubs, as suggested by the *logt* test.[8] Phillips and Sul (2009) note that club convergence involves economies in transition, and this phenomenon may affect the boundaries of the clubs, suggesting the investigation of possible movements of countries from one club to another adjacent club. Here, I note some overlap between the third club and the fourth in terms of TFR in 2018: a few countries in Club 4 with TFR greater than the minimum in Club 3, and some countries in Club 3 with TFR lower than the maximum in Club 4. I obtain two clearly distinct clubs applying the *logt* test first to the hypothesis that Club 3 and three countries in Club 4 (Eritrea, Madagascar and Solomon Islands) can be merged, accepting the null ($\widehat{b} = 0.006$, and $t_b = 0.1$) and subsequently testing the hypothesis that Israel and Yemen, formerly in Club 3, can be merged with Club 4, again accepting it ($\widehat{b} = 0.03$, and $t_b = 0.33$).

Table 3 presents the descriptive statistics of the final four clubs. The analysis produced a reliable classification in four clearly distinct clubs. I denote clubs from 1 to 4 respectively *Club Highest*, *Club High*, *Club Intermediate*, and *Club Low*, hinting at average fertility in each club. *Club Highest* includes Congo, Niger, and Somalia, three countries where fertility remains very high. The same can be said of Chad and Mali, which compose *Club High*. The *logt* test for the merge of the two clubs rejects the null with $\widehat{b} = -0.407$ and $t_b = -5.139$. Furthermore, *Club High* cannot be merged with *Club Intermediate*. *Club Intermediate* is composed of 34 countries where after 1950 adults started a demographic transition that is far from concluding, showing an average TFR greater than four births per woman (4.594) in 2018. The last convergence club derives from running the convergence test on the time series of all the remaining countries. In this case, the *logt* test does not reject the null of convergence ($t_b = -0.009$), although its value ($\widehat{b} = -0.091$) indicates slow convergence. *Club Low* consists of 151 countries with low TFR at the end of the 1950–2018 period (2.183); *Club Low* includes those countries where the onset of the fertility transition occurred before 1950 and several countries where the same process started after 1950.[9]

This distinction better characterizes the demographic transition in developing countries and the reproductive behavior (past and perspective) of low fertility countries. According to Reher (2004), a group of 23 countries can be classified as *Forerunners* because the decline of fertility began before 1935. This group includes countries from Europe (16), North America (5), and South America (2).[10] However,

[8] See Table 13 in the appendix for the final list of countries in each convergence club.

[9] Following an anonymous referee's suggestion, I also consider the number of children under age-5 per woman aged 15–49 (child-woman ratio) as an alternative proxy for family size. Indeed, this side of family choices does not coincide with fecundity and is often pivotal in the demographic transition theory. Replicating the analysis of club convergence on the child-woman ratio of 190 countries in the years 1950–2018, I find a similar, but not the same, picture as that based on TFR. In fact, the clustering procedure yields 6 clubs with the last composed of 139 countries that largely correspond to the last of the TFR clubs. Also, the rest of the clubs are quite similar to the other 3 TFR clubs. To take into account the tempo effect in family decisions over the number of children, the referee suggested the use of parity progression ratios. However, I could not find international panel data on parity progression ratios comparable to that on TFR of this paper.

[10] Table 13 in the appendix distinguishes *Forerunner* countries with an asterisk on their names.

Table 1 *Logt* test of global convergence in fertility in different periods

	1950–2018	1980–2018	1990–2018
TFR	−0.954***	−0.512 ***	−0.399***
SE	(0.026)	(0.059)	(0.047)

Test of the null hypothesis of convergence in TFR across 190 countries in three periods. Coefficients $\hat{b}$ from the estimation of the *logt* regression Eq. (4). SE denotes heteroskedasticity- and autocorrelation-consistent standard errors. *** $p<0.01$

Table 2 Club convergence of fertility and test of club merging

Initial clubs			Test of club merging				Final clubs	
	Obs	$\hat{b}$(SE)	Club 1 + Club 2	Club 2 + Club 3	Club 3 + Club 4	Club 4 + Club 5	Final	Obs
Club 1	3	0.054	−0.407***				0.054	3
		(0.099)	(0.079)				(0.099)	
Club 2	2	0.711		−0.280***			0.711	2
		(1.374)		(0.026)			(1.374)	
Club 3	9	0.257			−0.076		−0.076	33
		(0.040)			(0.102)		(0.102)	
Club 4	24	0.271				−0.616***		
		(0.069)				(0.028)		
Club 5	152	−0.009					−0.009	152
		(0.102)					(0.102)	
Total	190							190

The initial clubs derive from the application of the clustering procedure to the time series of TFR of 190 countries from 1950 to 2018. Club merging is based on the *logt* convergence test. The final clubs take account of the results of the test of club merging. Coefficients $\hat{b}$ from the estimation of the *logt* regression Eq. (4). Heteroskedasticity- and autocorrelation-consistent standard errors in parentheses. *** $p<0.01$

Reher's classification refers to 145 countries and does not consider other countries in my dataset. Referring to this panel data, the main question is how to distinguish countries according to their TFR in 1950. In other words, can I cluster countries according to the starting value of TFR? To answer this question, I apply a clustering algorithm to the time series of TFR reverting the time arrow: from the last year to the first year of the time period. Accordingly, referring to x_{it}, I define a new variable: $k_{it} = x_{i,T+1-t}, t = 1 \ldots T$, and apply the methods of subsection 2.1 to k_{it} to investigate club convergence of TFR in 1950.

The results of the clustering algorithm are shown in Table 4. They support a reliable partition of 190 countries into two groups according to the initial fertility rate when the time period is close to 1950 (1950–1975). The first group includes 146 countries with high average TFR in 1950: 6.148; *Forerunners* and other 21 countries compose the second group characterized by low average TFR in 1950: 2.862. The outcome of the Phillips and Sul (2007) clustering methodology seems quite good

Table 3 Descriptive statistics of the total fertility rate in convergence clubs, 2018

	Observations	Mean	SD	Minimum	Maximum
Club Highest	3	6.301	.535	5.919	6.913
Club High	2	5.812	.092	5.747	5.877
Club Intermediate	34	4.594	.403	4.023	5.519
Club Low	151	2.136	.703	.977	3.969
Club Low sub-groups					
Club High-to-Low	107	2.290	.719	.977	3.877
Club Low-to-Low	44	1.761	.496	1.301	3.969
Total	190	2.680	1.278	.977	6.913

The first four clubs derive from the application of the clustering algorithm to TFR over the period 1950–2018, while the last two come from the splitting of Club Low according to the initial TFR in 1950, high or low. SD denotes the standard deviation

because the average 1950 TFR in low initial fertility countries is so close to that of the *Forerunners*: 2.802. Combining the two club classifications shows that on average a woman had many children just after WWII in a large part of the world, but in the following decades, fecundity declined in many countries. This is also the case of clubs Highest, High, and Intermediate, where TFR recently began to follow a declining path.

Figure 1 depicts the average TFR of each convergence club over the years 1950–2018 and shows some interesting patterns. The most impressive phenomenon is the strong process of fertility reduction experienced by many countries in *Club Low* after WWII. Within *Club Low*, I distinguish a group of 107 countries that I also classified as high initial fertility, and in 2018, they converge into the club of low initial TFR. I denote this convergence club *Club High-to-Low*. Some sub-Saharan countries (e.g., Eritrea, Ghana, Kenya, South Africa, Zimbabwe) enter *Club High-to-Low*, which also includes many other countries of Latin America, Asia, Africa, and Oceania. Figure 1 shows that the average onset of the fertility decline in this group occurs during the sixties, before other developing countries, and then proceeds along a steep path. The remainder of *Club Low*, which I denote *Club Low-to-Low*, includes those 44 countries where fertility is low in 1950 and in 2018, and after the 1980s, it further declines below the significant value of two.

A general result of the former convergence analysis is the acceptance of the null hypothesis with a value of the coefficient $\widehat{b}$ so close to zero for each of the four clubs. This means relative convergence occurred at a very slow rate, which is coherent with the propositions of the unified growth theory. However, the earliest start of the demographic transition in countries of the *Club Low-to-Low* would suggest the possible acceptance of the null of absolute convergence in this club. Table 5 shows the results of running the *logt* test on the TFR time series of countries in *Club Low-to-Low* and among the *Forerunners*. I find evidence of relative but not absolute convergence in the two convergence clubs. Indeed, both coefficients $\widehat{b}$ are significantly positive but largely lower than 2, the critical value that identifies absolute convergence.

Table 4 Convergence clubs of countries classified according to fertility in 1950

logt test	$\hat{b}$	SE	Observations	Mean TFR, 1950
High TFR, 1950	−0.048	0.029	146	6.148
Low TFR, 1950	0.120	0.115	44	2.862

Results of the clustering procedure on the TFR time series with a reversion of the time direction. Time is defined as $T + 1 - t$, $T = 1975, t = 1950, \ldots, 1975$. SE denotes heteroskedasticity- and autocorrelation-consistent standard errors

The robustness of the results that I obtain could be weakened by the presence in the sample of countries with a particular institutional setting affecting the reproductive behavior of the population. Here, I concentrate on the effects of the inclusion of socialist countries and also consider the importance on club formation of China and India that adopted significant policies of birth control. In the main analysis, all these countries enter *Club Low*. Table 6, Panel A shows the results of the clustering procedure when the sample excludes 34 socialist countries.[11] In panel B, the dataset does not include China and India. In both cases, the club classification does not change, and the *logt* test on *Club Low* gives the same outcome. Hence, the results of the club convergence analysis do not depend on these two particular sets of countries.

The statistical investigation of convergence of average fertility after WWII highlights important but slow transitional processes and significant delays. It seems to provide answers to several questions over the features of a possible phenomenon of global fertility convergence raised in Wilson (2011) on the basis of a descriptive study of TFR time series in three country aggregates whose plot closely resemble those of Fig. 1. International club convergence raises interesting questions on the interpretation of the phenomenon and the quantitative evaluation of the role of the principal explanatory factors. This is the main goal of my research in the next section.

3 Long-term obstacles to global fertility convergence

A possible interpretation of the results of the previous section follows along the lines of UGT. In this theoretical framework, the pace of the economic and demographic transition from a Malthusian regime to a modern growth regime differs across countries because of the diversity of fundamental factors that can be identified in the categories of geography, culture, institutions, and other relevant features of societies.[12] The same can be said of the final long-run equilibrium if one is prone to imagine that structural diversity across the world (or just its effect on the economy) could disappear only in the very long term. Accordingly, club convergence depends on the action of those factors that produce barriers to economic and demographic dynamics

[11] I refer to those countries with a socialist or communist legal origin according to La Porta et al. (1999) classification.

[12] Galor (2011) deals extensively with differences in economic development across the world.

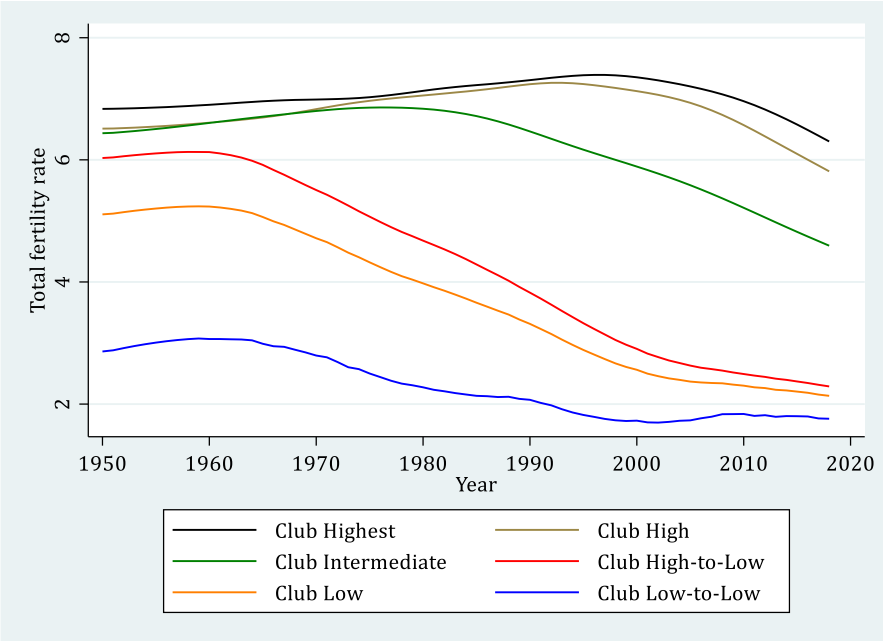

Fig. 1 Average fertility in convergence clubs (1950–2018). The figure plots the mean TFR in the four clubs that emerge from the clustering procedure and in the two clubs, High-to Low and Low-to Low, that derive from splitting the Club Low according to countries' initial value of TFR, high or low

Table 5 Convergence in two clusters of low fertility countries, 1950–2018

	logt test	Observations	Mean TFR, 2018
	$\hat{b}$		
Club Low-to-Low	0.354	44	1.761
	(0.135)		
Forerunners	1.003	23	1.653
	(0.065)		

The test shows that relative convergence in each cluster can be accepted but absolute convergence cannot. Heteroskedasticity- and autocorrelation-consistent standard errors in parentheses

at the country level. In this section, I investigate the role of three fundamental obstacles: interpersonal diversity in a country's population, genetic distance to the US, and years since the Neolithic transition to agriculture. These factors may explain the formation of convergence clubs in the process of fertility decline in the world in the years after WWII.

Table 6 Club convergence of fertility, robustness to sample composition

	Observations	$\hat{b}$	SE
Panel A: Excluding socialist countries			
Club1	3	0.054	0.099
Club2	2	0.711	1.374
Club3	33	−0.076	0.102
Club4	118	−0.044	0.126
Panel B: Excluding China and India			
Club1	3	0.054	0.099
Club2	2	0.711	1.374
Club3	33	−0.076	0.102
Club4	150	−0.004	0.101

The dataset in Panel A does not include 34 countries with socialist legal origin. The club classification of the rest of the countries does not change. *logt* convergence test in each club. SE denotes heteroskedasticity- and autocorrelation-consistent standard errors

3.1 Econometric model and data

The classification of countries in four clubs of Sect. 2 can be interpreted as the result of the differentiated effects of obstacles to economic development and demographic transition. The clustering approach that looks forward and backward in time provides a classification coherent with the arguments of UGT. Countries in the first three clubs (*Highest*, *High*, and *Intermediate*) share the greatest difficulties entering a path of significant decline of fecundity. The *Club High-to-Low* collects those countries that experienced a successful demographic transition after 1950, starting from high TFRs. In *Club Low-to-Low,* I find countries where fertility was already low in 1950 because the demographic transition started several years before. Hence, the classification can be thought of as the result of barriers whose magnitude declines from the first club to the last. A tight relation between club membership and barriers' magnitude is key to the definition of the ordinal categorical variable *CLUB*, where the barriers are high, medium, and low if country i is a member of respectively: the first three clubs *Highest*, *High,* and *Intermediate*; the *Club High-to-Low*; and the *Club Low-to-Low*.[13]

I specify the following OPM to estimate the effect of a set of regressors on the probability of country i in one of the three categories of *CLUB* (*Club High barriers*, *Club Medium barriers*, *Club Low barriers*). The continuous latent variable y_i^* denotes an index of the barriers faced by country i, which are explained by the linear model:

[13] I define *CLUB* aggregating the first three clubs in the first category because only five countries enter *Club Highest* and *Club High*. As a robustness check, I produce estimates of *CLUB* with the exclusion of the first two clubs.

$$y_i^* = \beta' x_i + u_i, i = 1, \ldots, N, \quad (5)$$

where x_i is a vector of regressors and u_i is a random term. x_i includes: the three ancestral variables that are the focus of my analysis; a set of dummies for world regions as defined by the World Bank; [14]geographic and climate controls; and other control variables. The regression model of the ordinal variable *CLUB* follows from the assumption that.

$$\Pr(CLUB_i = j|x_i) = \Pr\left(\tau_{j-1} < y_i^* < \tau_j\right), j = 1, 2, 3 \quad (6)$$

where j denotes the three categories of *CLUB* and τ_j denotes the threshold parameters.[15]

Recent research on the barriers to economic development has focused on factors deeply rooted in the history of the world population (Spolaore and Wacziarg, 2013). Here, I follow the same approach to investigate differences in global fertility decline after WWII. In this research line, some works concentrate on causes of heterogeneity of human societies with origins that date back thousands of years ago and to the early phases of the process of diffusion of humans across the world. The Neolithic transition from a hunter-gatherer society to one based on agriculture and breeding of domestic animals is the crucial historical phenomenon that explains the large differences in economic development in the modern world according to the influential book of Diamond (1997). Indeed, agriculture significantly improved the productivity of labor in food production and allowed for the emergence and growth of activities devoted to culture and knowledge production that slowly brought about increasing technological progress and institutional development. In this framework, the main factors of the transition to agriculture are biogeographic. They refer to the presence of edible wild plants and animal species suited to domestication, to favorable climatic conditions such as those of the Euroasian continent that also took advantage of a large size, and an East–West orientation that favored the diffusion of agriculture (Olsson and Hibbs, 2005). The debate on the empirical relevance of this thesis is still open. Significant favorable evidence in the explanation of cross-country growth during the Malthisian regime has been found (e.g., Ashraf and Galor, 2011; 2013a, b; Spolaore and Wacziarg, 2013). But the results of empirical investigations of contemporary differences in income per capita are contrasting (e.g., Ashraf and Galor, 2013a; Spolaore and Wacziarg, 2013).

Other important research looks even further in the past to the dawn of the human presence on Earth to investigate the power of interpersonal diversity, inside and across populations, in the explanation of unequal economic development in the world. Spolaore and Wacziarg (2009) argue that the process of diffusion of general innovations across societies is significantly influenced by their degree of relatedness. The latter relates to genetic distance between populations. Population traits are

[14] East Asia and Pacific; Europe and Central Asia; Latin America and Caribbean; Middle East and North Africa; North America; South Asia; Sub-Saharan Africa.

[15] I set $\tau_0 = -\infty$ and $\tau_3 = +\infty$.

transmitted over time through biological and cultural interactions between generations of individuals. This information is contained in the human genome. Individuals who share the same ancestors have similar traits that facilitate all forms of relations. Spolaore and Wacziarg (2009) construct an index of genetic distance between each country and the US (technological frontier) and define differences of this index between country pairs as the *relative genetic distance*. They find this variable significantly explains current international differences in income per capita.

According to Ashraf and Galor (2013a), increasing interpersonal population diversity has positive and adverse effects on the economy in the long term. The benefits of diversity come through increasing productivity and technical change deriving from higher specialization and skill complementarity effects in any economic activity and especially in those that are knowledge intensive. On the other hand, different traits in a community facilitate the diffusion of hostile behavior and contrast the affirmation of the attitude toward coordination, trust and cooperation, with the consequent establishment of poor institutions and bad collective organizations. To explain the time evolution of interpersonal population diversity around the world, Ashraf and Galor (2013a) refer to the origins of Homo sapiens in East Africa and the successive spread of the human presence in the rest of the world that gradually occurred in a long series of steps over thousands of years. One main consequence of stepwise population migration was the loss of part of the genome of the new community with respect to the original. Hence, contemporary interpersonal population diversity is well explained by the distance of a population from East Africa. Ashraf and Galor (2013a) use this framework to search for the causes of population density inequality in the Malthusian era—1500 CE (Common Era)—and income inequality in the Modern regime—2000 CE. They find strong evidence of an inverted-U-shaped relationship between interpersonal population diversity and wealth indicators, as the theory predicts.

The index of interpersonal population diversity that Ashraf and Galor (2013a) construct is based on the index of expected heterozygosity that has been proposed in population genetics. It can be thought of as the probability that two individuals randomly sampled from a population differ genetically. The basic data come from the HGDP-CEPH Human Genome Diversity Cell Line Panel and refer to 53 ethnic groups that identify 21 countries. To enlarge the data set, Ashraf and Galor (2013a) rely on the econometric regression that well explains the index of expected heterozygosity with the distance between each ethnic group and East Africa (Addis Ababa). Indeed, they calculate this distance—appropriately accounting for natural obstacles—for a large number of countries and use it to predict the variable *interpersonal population diversity*. In the study of contemporary economic development, predicted interpersonal population diversity is modified to take into account the relevant changes in the ethnic composition of many countries that occurred as a consequence of migration flows that occurred after 1500 CE.[16] The following regression analysis includes this variable, *Interpersonal population diversity*, and its square.

[16] See Ashraf and Galor (2013a) for details on the calculation of the "ancestry-adjusted predicted interpersonal population diversity" variable.

Data are from Ashraf and Galor (2013a). If the demographic transition is a significant part of the economic evolution in the long term, I should find a similar non-monotonic effect of genetic diversity.

To econometrically investigate the hypothesis that barriers to the demographic transition have ancestral origins, I also consider the contribution of genetic distance between every country and the US, the current technological frontier. Here, I follow Spolaore and Wacziarg (2018) who calculate an index of weighted genetic distance at the country level using Pemberton et al. (2013) data on the genetic distance between pairs of populations. Weights are the shares of an ethnic group in the population of a country and allow the construction of the variable at the country level.[17] Once again, this variable can be interpreted as the probability that the outcome of the random sampling of two individuals, one from a population and the other from another population, is two genetically different persons. Cross-country data of weighted *Genetic distance to the US* come from Spolaore and Wacziarg (2018).

The third ancestral variable on which I focus my empirical analysis is the estimate of the *Years since the transition to agriculture* (Putterman, 2008). The original data refer to the populations that lived during the Neolithic transition thousands of years ago. However, today the ethnic composition of the population in many countries in the world has changed. Hence, the assignment of a specific year of the transition to the whole country could be incorrect. As for *Interpersonal population diversity*, Ashraf and Galor (2013a) construct an "ancestry-adjusted" measure of the Neolithic transition timing that I use in my estimates.

In a long-term perspective, the effect of ancestral variables cannot be evaluated ignoring the largely diversified natural environment present in the world (e.g., Spolaore and Wacziarg, 2013). Here, the ordinal probit regressions always include some variables that approximate for geographic factors that facilitate the diffusion of economic activities—especially agriculture—as the *log of absolute latitude*, the *log of the percentage of arable land*, the *mean distance to the nearest waterway*, and the log of the index of land suitability to agriculture. The averages of the monthly temperature (*Temperature*) and monthly rainfall (*Rainfall*) in the years from 1901 to 2016 represent the wide variety of climates in the world that also have relevant consequences on opportunities for economic development.

Other variables often present in studies of the fundamental causes of economic inequality must be considered as alternatives to the ancestral factors on which this paper concentrates. A thread of this research highlights the detrimental effects of ethnic fractionalization on development (e.g., Alesina et al. 2003). This cultural phenomenon has deep and long lasting effects on a variety of characteristics of social behavior, including family organization and fertility choices. The same can be said of religion adherence, another strongly persistent cultural factor of development.[18] Here, I extend the baseline regressions with the indexes of *Ethnic Fractionalization* and *Religious Fractionalization* constructed by Alesina et al. (2003). Regressions

[17] Spolaore and Wacziarg (2018) use data on ethnic groups from Alesina et al. (2003).

[18] On culture, religion, and economics see Barro and McCleary (2003); Bisin and Verdier (2011); Benabou et al. (2015).

for *CLUB* also account for religious adherence with three variables: the *Muslim*, *Protestant*, and *Roman Catholic* shares of the population reported in La Porta et al. (1999). Also, the economic research on the factors of uneven economic development has deeply investigated the role of institutions and the legal environment (e.g., La Porta et al., 1999; Acemoglu et al., 2005). Here, the set of explanatory variables is extended with *Polity2*, a general measure of the quality of a political regime produced by the Polity5 Project (Marshall and Gurr, 2021), and with *Rule of Law*, a quantitative evaluation of the public opinion over the legal system produced by the World Bank as one of the World Government Indicators. Conceptually close to the last group of controls is the percentage of the population whose ancestors in 1500 were European (Putterman and Weil, 2010). Indeed, migrating Europeans diffused their culture and model of institutions in the rest of the world. Among regressors, similar arguments can be used to justify the inclusion of the origins of the most diffused legal systems with two dummy variables for the *English Common Law* and the *French Commercial Code* (La Porta et al. 1999).

Finally, regression models take account of the large international differences in population health with the *Malaria Ecology Index* proposed by Kiszewski et al. (2004) to capture some exogenous features of the environment—climate, mosquito vector types, different human biting rates—that approximate for structural factors of Malaria incidence. This issue has been the object of important research in the field of development and demographic economics (e.g., Lorentzen et al. 2008).[19]

3.2 Results

In this section, I present the results of the estimation of the ordered probit model (5, 6) for the dependent variable *CLUB*. A baseline specification is followed by a larger model with further control variables. Then, I discuss the results of robustness checks that refer to the sample composition and other explanatory variables.[20]

3.2.1 Main regression results

I investigate the role of three ancestral variables, *Interpersonal population diversity*, *Genetic distance to US*, and *Years since the transition to agriculture* starting with a baseline specification that includes each variable in turn plus a fixed set of controls given by world regions' dummies and some geographic and climate regressors. The estimation results of these models are shown in the first three columns of Table 7, while the fourth refers to the joint presence of the ancestral variables. The results are quite encouraging. The variables of main interest enter the regressions with statistically significant coefficient estimates. The estimates of Pseudo-R^2 suggest the overall model fitting is quite satisfying. The statistical significance of the estimates of the threshold parameters supports the definition of *CLUB* with three distinct categories.

[19] Further details on variable definitions, data sources and descriptive statistics can be found in the appendix.

[20] Table 14 in the appendix provides descriptive statistics of the variables used in the regression analysis.

These come from the statistical partition of the sample in convergence clubs performed in Sect. 2 whose reliability is confirmed by OPM estimates.

Next, I introduce sequentially cultural, institutional, and legal system variables in baseline OPM regressions with results that are shown in Table 8. *Ethnic fractionalization* does not add a significant contribution to the explanation of *CLUB* produced by the baseline specification. Column 1 shows a statistically significant and positive coefficient of *Religious fractionalization* that loses significance when the shares in the population of the three main religions are included (columns 2–6). The positive sign of *Religious fractionalization* is consistent with an interpretation of this variable as a signal of the peaceful coexistence of different religions in a society (Alesina et. al. 2003). Indeed, the estimates reveal that this effect is trumped by the positive and significant effect of the share of Protestant believers.

The inclusion of variables approximating for the quality of the institutional and legal environment does not provide a significant contribution to the explanation of *CLUB*, as is the case of the *Malaria Ecology Index*. The whole results of Table 8 clearly show stable and statistically significant estimates of the coefficients of the three ancestral variables on which the paper concentrates.

The qualitative interpretation of the results are quite interesting. At first sight, diversity variables confirm the important role in the explanation of international economic development found in the recent literature, while the timing of the Neolithic transition to agriculture displays a statistically significant negative effect on the probability of lower barriers to fertility decline.

As in the case of Ashraf and Galor (2013a), I specify the regression model with *Interpersonal population diversity* and its square. Coefficient estimates are strongly significant at the 1% level and with respectively positive and negative signs that highlight an inverted U-shaped relationship of the variable with the probability of decreasing barriers to the demographic transition. A clear picture is provided by Fig. 2, which shows three graphs, one for each category of *CLUB*, of the relationship between the predicted probability of a country in a category and *Interpersonal population diversity*, with the rest of the explanatory variables fixed at the mean value. The likelihood of a country in the *Club High barriers* follows a U-shaped relationship with *Interpersonal population diversity*, while the opposite hump shape characterizes the *Club Low barriers*. The same regressor does not display any effect on the intermediate category of *Club Medium barriers*. Figure 3 presents three graphs that refer to the marginal effect of a change in *Interpersonal population diversity* measured by the variation of $Pr(CLUB = 1, 2, 3|\boldsymbol{x})$ in response to the proportional increase in *Interpersonal population diversity*.[21] Both Figs. 2 and 3 give coherent information. Confidence intervals at the 95% level highlight the significance of predicted probability and marginal effects in the cases of the nonmonotonic curves and confirm the null influence of the variable on the probability of staying in the middle.

[21] The marginal change of the predicted probability of a country in a club has been calculated at 15 values of *Interpersonal population diversity* and fixing the rest of the regressors at their mean value. Figure 3 includes confidence intervals at 95% level.

Table 7 Long-term barriers to fertility convergence, baseline estimates

	(1)	(2)	(3)	(4)
Interpersonal population diversity	643.551***			609.648***
	(181.444)			(188.761)
$(\text{Interpersonal population diversity})^2$	−451.854***			−431.170***
	(128.671)			(133.759)
Genetic distance to the US		−36.977**		−52.178**
		(17.072)		(21.526)
Years since transition to agriculture			−0.021**	−0.033***
			(0.009)	(0.011)
Log absolute latitude	−0.536*	−0.251	−0.352	−0.740**
	(0.314)	(0.303)	(0.298)	(0.297)
Log arable land, %	−0.319*	−0.310*	−0.252	−0.409**
	(0.183)	(0.184)	(0.170)	(0.195)
Log land suitability for agriculture	0.204	0.200	0.154	0.366*
	(0.178)	(0.170)	(0.163)	(0.190)
Mean distance to nearest waterway	−1.505***	−1.316***	−1.418***	−1.552***
	(0.356)	(0.340)	(0.335)	(0.356)
Temperature	−0.104***	−0.105***	−0.082***	−0.103***
	(0.030)	(0.030)	(0.029)	(0.031)
Rainfall	−0.007*	−0.002	−0.007**	−0.010***
	(0.004)	(0.003)	(0.003)	(0.004)
Threshold 1	220.773***	−7.598***	−7.909***	201.894***
	(63.438)	(1.847)	(1.647)	(66.108)
Threshold 2	224.551***	−4.045**	−4.447**	206.011***
	(63.609)	(1.971)	(1.780)	(66.369)
Observations	138	138	138	138
Pseudo R^2	0.586	0.573	0.573	0.616

The dependent variable *CLUB* identifies three categories of countries with high, medium and low barriers to fertility convergence. The baseline model is specified with three ancestry variables and a set of geographic and climatic regressors. All regressions include dummy variables for world regions in the World Bank classification. Ordered probit maximum likelihood estimates. Robust standard errors in parentheses. $* \ p < 0.1$; $** \ p < 0.05$; $*** \ p < 0.01$. Threshold coefficients distinguish the three categories of *CLUB* in the OPM

The interpretation of marginal effects in an ordered probit model with three categories derives from its analytics. It says that the sign of a marginal effect of a variation of a regressor x on the conditional probability of a country in a category is the same sign of β_x for the last category and $(-\beta_x)$ for the first. The same effect on the composition of the intermediate category depends on two components that go in opposite directions. For example, if $\beta_x > 0$, a marginal increase in x would mean some countries in the *Club High barriers* pass into the *Club Medium barriers* and other countries in the intermediate club transfer to the *Club Low barriers*. The sign of the net effect is a priori indeterminate.

Table 8 Long-term barriers to fertility convergence, additional controls

	(1)	(2)	(3)	(4)	(5)	(6)
Interpersonal population diversity	639.392***	630.200***	611.414***	601.054***	636.081***	626.473***
	(209.493)	(211.420)	(217.418)	(216.240)	(221.326)	(220.622)
(Interpersonalpopulationdiversity)^2	−456.199***	−452.606***	−441.440***	−433.481***	−459.397***	−452.587***
	(148.270)	(150.347)	(154.661)	(154.040)	(158.261)	(157.793)
Genetic distance to the US	−55.837***	−64.380***	−75.986***	−66.801**	−76.180***	−82.794***
	(19.500)	(21.696)	(22.785)	(27.456)	(27.919)	(29.898)
Years since transition to agriculture	−0.033***	−0.019**	−0.019*	−0.019*	−0.018*	−0.021**
	(0.011)	(0.010)	(0.010)	(0.010)	(0.009)	(0.009)
Log absolute latitude	−0.815***	−0.747**	−0.736**	−0.754***	−0.785***	−0.798***
	(0.296)	(0.294)	(0.290)	(0.289)	(0.278)	(0.285)
Log arable land	−0.358*	−0.175	−0.187	−0.210	−0.308	−0.316
	(0.199)	(0.206)	(0.214)	(0.214)	(0.203)	(0.197)
Log land suitability for agriculture	0.178	0.001	0.030	0.054	0.130	0.130
	(0.200)	(0.213)	(0.236)	(0.238)	(0.235)	(0.233)
Mean distance to nearest waterway	−1.478***	−1.117***	−1.113***	−1.066***	−1.173***	−1.226***
	(0.371)	(0.375)	(0.415)	(0.414)	(0.406)	(0.426)
Temperature	−0.078**	−0.050	−0.052	−0.049	−0.062*	−0.070*
	(0.034)	(0.035)	(0.036)	(0.036)	(0.036)	(0.041)
Rainfall	−0.012***	−0.012***	−0.012***	−0.012***	−0.013***	−0.013***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Ethnic fractionalization	−1.785*	−1.285	−1.196	−1.290	−1.108	−1.165
	(1.031)	(1.069)	(1.086)	(1.049)	(0.997)	(1.019)
Religious fractionalization	3.034***	1.106	1.014	1.109	1.114	1.093
	(0.893)	(0.788)	(0.853)	(0.878)	(0.989)	(1.007)
Protestant population		0.038***	0.041***	0.040***	0.030**	0.031**
		(0.012)	(0.012)	(0.012)	(0.012)	(0.012)

Table 8 (continued)

	(1)	(2)	(3)	(4)	(5)	(6)
Catholic population		−0.003	−0.004	−0.005	0.000	0.000
		(0.007)	(0.007)	(0.007)	(0.008)	(0.009)
Muslim population		−0.014**	−0.016***	−0.014*	−0.014*	−0.015**
		(0.006)	(0.006)	(0.007)	(0.007)	(0.007)
Polity2 Index			−0.041	−0.040	−0.058	−0.062
			(0.045)	(0.045)	(0.043)	(0.044)
Rule of law			0.103	0.092	−0.032	−0.038
			(0.249)	(0.248)	(0.241)	(0.240)
Population of European origins				0.453	0.509	0.413
				(0.931)	(0.924)	(0.971)
English common law					0.840	0.887
					(0.615)	(0.622)
French civil law					−0.083	−0.064
					(0.576)	(0.586)
Malaria Ecology Index						0.025
						(0.035)
Threshold 1	211.035***	207.662***	199.496***	196.485***	207.477***	203.434***
	(73.485)	(74.107)	(76.131)	(75.520)	(77.006)	(76.642)
Threshold 2	215.493***	211.855***	203.765***	200.750***	211.827***	207.839***
	(73.891)	(74.353)	(76.390)	(75.776)	(77.301)	(76.971)
Observations	138	138	138	138	138	138
Pseudo *R*2	0.650	0.682	0.685	0.686	0.696	0.697

The dependent variable *CLUB* identifies three categories of countries with high, medium and low barriers to fertility convergence. The baseline model is augmented with additional variables capturing cultural, institutional and health factors. Ordered probit maximum likelihood estimates. Robust standard errors in parentheses. All regressions include dummy variables for world regions in the World Bank classification. $* p < 0.1$; $** p < 0.05$; $*** p < 0.01$. Threshold coefficients distinguish the three categories of *CLUB* in the OPM

Looking at Fig. 2, I note that the first and last graphs are consistent with an interpretation of the effect of increasing *Interpersonal population diversity* that initially reduces the barriers to the demographic transition, and, after an optimal threshold, it causes the opposite detrimental effect. This picture is also consistent with the not statistically significant marginal effect of *Interpersonal population diversity* on $Pr(CLUB = 2|x)$ because the *Club Medium barriers* includes, by the definition of *CLUB*, countries transitioning from the state of high fertility to that of low. Figure 3 shows that at every level of *Interpersonal population diversity*, its effect on the composition of this club is null. Table 9 displays the average of the marginal effect of a proportional change in a variable on the conditional probability of each club:

$$\frac{\partial Pr\left(CLUB = 1, 2, 3|\bar{x}, x\right)}{\partial[ln(x)]}$$

where $\bar{x}$ denotes the rest of the variables at their mean value. The estimates of the effect of *Interpersonal population diversity* are statistically significant for the first and third categories, while the same effect is not significant in the case of the second. The whole set of results suggest that, given the estimate of a nonmonotonic relationship, the prevailing effect of *Interpersonal population diversity* can be found on the right arm of the curves in Figs. 2 and 3. On average, increasing diversity lowered the probability of a demographic transition. The size of the marginal effects is quite large. On average, a ten percentage point increase in *Interpersonal population diversity* raises the probability of a country in the *Club High barriers* by 0.23, while the same increase would decrease the probability of a country in the *Club Low barriers* by 0.19.

The results of the OPM estimation highlight also the strong influence of *Genetic distance to US* on the likelihood of declining barriers to international fertility convergence. The negative sign of the coefficient of this variable means that countries farther from the frontier of technology have less chances of being involved in a process of declining fertility. The estimates of the average marginal effects presented in Table 9 say that a 10 percentage points increase in the *Genetic distance to US* brings about a rise in the conditional probability of a country in the *Club High barriers* by 0.025 and a reduction of the probability of *Club Low barriers* by 0.018. A similar negative effect (-0.08) is obtained for the *Club Medium barriers*. Since the average *Genetic distance to US* declines from the first club to the third, the negative effect implies lower barriers to fertility decline among countries in the second and third categories of *CLUB* where fertility decreased in the period considered.

The estimates of the enlarged model in Table 8 confirm the negative sign of the coefficient of *Years since the transition to agriculture* (ancestry adjusted). Accordingly, countries where this radical process of economic transformation started earlier faced greater obstacles in the contemporary era in starting and completing a demographic transition. This effect seems at odds with the hypothesis advanced by Diamond (1997) that I summarize in Sect. 3.1. Actually, this thesis has been substantially confirmed in studies of growth in the Malthusian era (e.g., Olsson and Hibbs, 2005; Ashraf and Galor, 2011) but failed to provide robust evidence of its validity

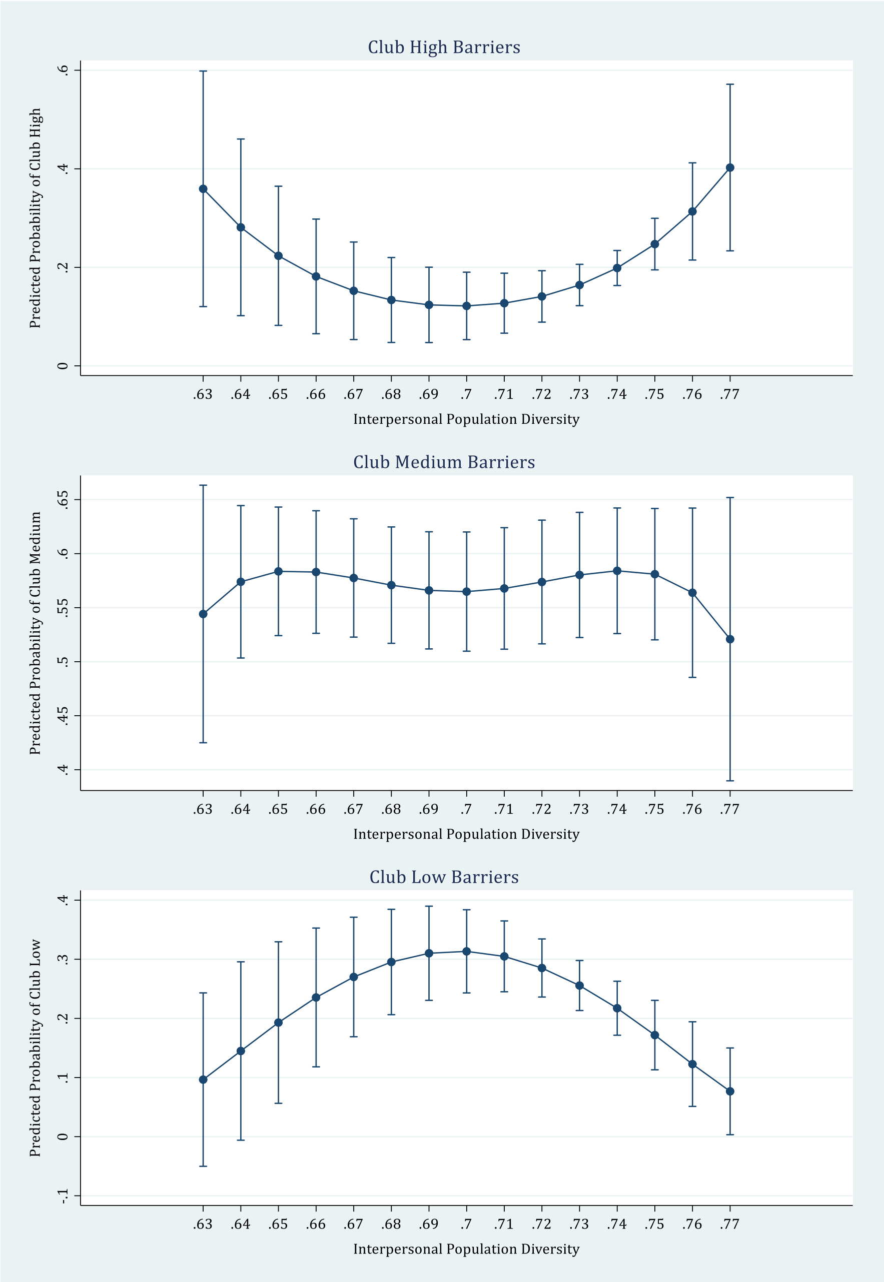

Fig. 2 Predicted probability of Clubs with High, Medium and Low barriers to fertility convergence and *Interpersonal population diversity*. The probability of belonging to a club has been calculated using the coefficients of model (3) in Table 8 at 15 values of *Interpersonal population diversity* and the rest of the regressors fixed at their mean value. Confidence intervals at 95% level

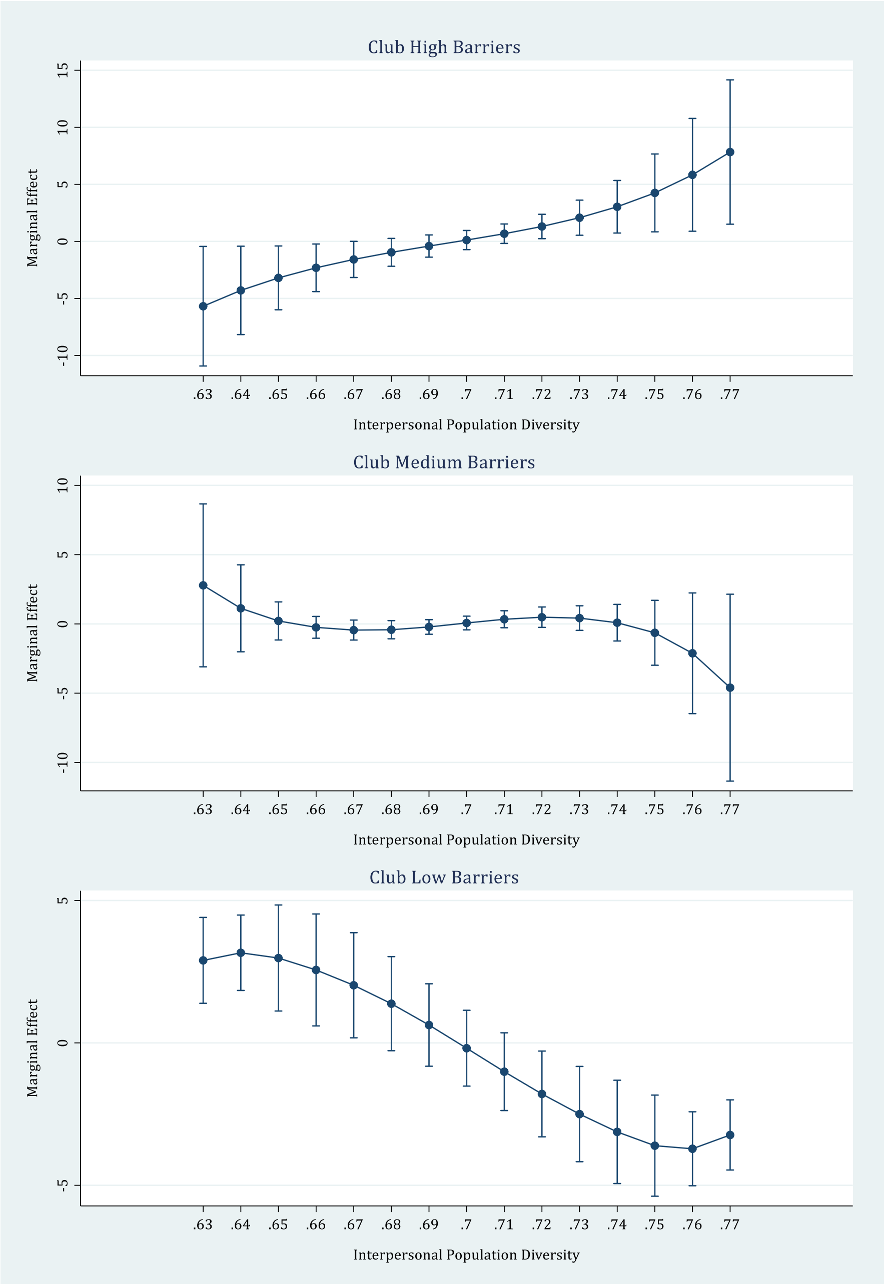

Fig. 3 Marginal effect of a proportional variation in *Interpersonal population diversity* on the predicted conditional probability of Clubs with High, Medium and Low barriers to fertility convergence. The marginal change in the probability of belonging to a club in response to a proportional increase in *Interpersonal population diversity* has been calculated using the coefficients of model (3) in Table 8 at 15 values of *Interpersonal population diversity* and the rest of the regressors fixed at their mean value. Confidence intervals at 95% level

Table 9 Average marginal effect of a proportional change in main variables on the conditional probability of each club

	Club High barriers		Club Medium barriers		Club Low barriers	
	$\widehat{\beta}$	$\widehat{\sigma}$	$\widehat{\beta}$	$\widehat{\sigma}$	$\widehat{\beta}$	$\widehat{\sigma}$
Interpersonal population diversity	2.269***	0.731	−0.323	0.409	−1.946**	0.789
Genetic distance to the US	0.255***	0.085	−0.079	0.042*	−0.176***	0.060
Years since transition to agriculture	0.085**	0.039	0.089	0.045**	−0.174**	0.074
Mean distance to nearest waterway	0.053**	0.022	−0.016	0.025	−0.037***	0.014
Rainfall	0.105***	0.028	0.029	0.023	−0.134***	0.037
Protestant	−0.026**	0.013	0.012	0.008	0.014**	0.006
Muslim	0.022	0.016	−0.011	0.012	−0.011*	0.006
Log absolute latitude	0.068**	0.030	0.023	0.014	−0.091**	0.036

The average of the marginal effect of a proportional change in a variable on the conditional probability a country belongs to one of the categories of *CLUB* has been calculated from the OPM estimates of model (3) in Table 8, fixing the rest of the variables at their mean value. $*\ p < 0.1$; $**\ p < 0.05$; $***\ p < 0.01$

when used to explain income differences in the contemporary world. In particular, Ashraf and Galor (2013a) find this variable largely ineffective in the estimates of regression models of cross-country income per capita in 2000 CE that include *Interpersonal population diversity* among regressors. Furthermore, their regression analysis shows the Neolithic transition timing is not significantly related to the degree of interpersonal trust, and it negatively correlates with the production of scientific articles per capita. Hence, my results confirm several doubts on the relevance of this approach for the interpretation of the deep causes of economic growth after the Industrial Revolution.

A possible line of interpretation of this evidence could point to those features of the agricultural economy that did not contribute to the expansion of knowledge that led to the Renaissance and the Industrial Revolution, but persist even in modern times. Usually such strong persistence concerns cultural factors, for example religion, which shows in my estimates significant effects on barriers to global fertility convergence. An indirect confirmation of this hypothesis arises from estimates that compare the effect on $Pr(CLUB = 1, 2, 3|\boldsymbol{x})$ of *Years since the transition to agriculture*, adjusted for the ancestral composition of the population and not adjusted. Table 10 presents the results of the estimation of the baseline and enlarged (column 6 in Table 8) model specifications when the not-ancestry-adjusted variable replaces the adjusted version, together with the results of the "horse race" between the two regressors in the last column. I find that the unmodified quantification of the time elapsed since the Neolithic transition has a strong explanatory power with negative statistically significant coefficients and trumps the adjusted version that becomes not significantly different from zero in the "horse race" of column 3. Hence, the detrimental effect of a larger experience with agriculture seems connected to features of rural societies that today withhold their strength even after centuries of international migrations.

Table 10 Long-term barriers to fertility convergence, years since the transition to agriculture without adjustment for ancestry

	(1)	(2)	(3)
Interpersonal population diversity	525.330***	573.469**	594.784**
	(191.722)	(224.402)	(240.942)
$(\text{Interpersonal population diversity})^2$	−372.609***	−416.982***	−438.098**
	(136.118)	(160.651)	(172.831)
Genetic distance to the US	−38.656**	−84.458***	−59.464**
	(18.158)	(29.741)	(27.197)
Years since transition to agriculture, not-ancestry adj	−0.038***	−0.027***	−0.066**
	(0.010)	(0.009)	(0.030)
Years since transition to agriculture			0.048
			(0.032)
Log absolute latitude	−0.841***	−0.862***	−0.908***
	(0.285)	(0.277)	(0.284)
Log arable land, %	−0.404**	−0.326*	−0.309
	(0.200)	(0.193)	(0.194)
Log land suitability for agriculture	0.338*	0.142	0.151
	(0.192)	(0.230)	(0.225)
Mean distance to nearest waterway	−1.613***	−1.305***	−1.217***
	(0.361)	(0.421)	(0.444)
Temperature	−0.096***	−0.071*	−0.062
	(0.032)	(0.041)	(0.044)
Rainfall	−0.012***	−0.015***	−0.015***
	(0.004)	(0.004)	(0.004)
Log ethnic fractionalization		−1.260	−1.623
		(1.021)	(1.023)
Log religious fractionalization		1.271	1.195
		(1.001)	(0.989)
Protestant population		0.027**	0.024**
		(0.012)	(0.012)
Catholic population		0.001	0.001
		(0.009)	(0.009)
Muslim population		−0.015*	−0.016*
		(0.008)	(0.008)
Polity2 Index		−0.060	−0.048
		(0.044)	(0.045)
Rule of law		−0.079	−0.113
		(0.232)	(0.231)
Population of European origins		0.267	0.254
		(1.007)	(1.069)
British common law		1.069*	0.767*
		(0.598)	(0.466)
French commercial code		0.119	−0.045

Table 10 (continued)

	(1)	(2)	(3)
		(0.536)	(0.514)
Malaria Ecology Index		0.032	0.026
		(0.035)	(0.035)
Observations	138	138	138
Pseudo R^2	0.639	0.703	0.704

The table presents the results of a "horse race" between the variables *Years since transition to agriculture* adjusted and not adjusted for the composition of the current population according to the country of origin in the year 1500CE. The dependent variable *CLUB* identifies three categories of countries with high, medium, and low barriers to fertility convergence. Ordered probit maximum likelihood estimates. Robust standard errors in parentheses. All regressions include dummy variables for world regions in the World Bank classification. $*\ p < 0.1$; $**\ p < 0.05$; $***\ p < 0.01$. Threshold coefficients estimates omitted

3.2.2 Robustness to sample composition and further control variables

In this section, I present the results of the analysis of robustness of the main results to three changes in some dimensions of the econometric study. The first is the estimation of the largest model specification (column 6 in Table 8) on samples that exclude particular groups of countries. Column 1 in Table 11 shows the regression results that derive from the exclusion of countries in *Club Highest* and *Club High*. Hence, the first category of *CLUB* includes the *Club Intermediate* only. Coefficient estimates of the three ancestral variables are not largely affected by this restriction that provides a sample more in line with club convergence analysis. Column 2 refers to estimates on a sample that does not include China and India, two countries that during the period adopted important forms of birth control. The exclusion of OPEC countries (column 3) is justified by the influence of oil extraction on the economic performance that distinguishes these countries. Finally, column 4 shows the estimates of the baseline model specification on a sample that does not include Socialist/Communist countries, where for a large period the market mechanism did not work.[22] In all the regressions of Table 11 changes in sample composition do not significantly modify the coefficients of the three ancestral variables of interest in this study. This result is confirmed by the statistically non-significant coefficient of the dummy variable for countries with socialist legal origins shown in column 4 of Table 12.

The second robustness check derives from the inclusion of additional geographic controls to specification 6 of Table 8. In sequence, I add (Table 12, columns 1–3) the percentage of the population living in tropical zones, the share of the population living in temperate zones, the log continent size, soil fertility, mean elevation, the log country land area, and geodesic distance to the US. The last variable might confound the estimation of *Genetic distance to US*. Even this robustness exercise does not affect the validity of the main regression analysis.

[22] In this case, the sample reduces to 108 countries, and this generates some problems with the maximum likelihood estimation of the largest model specification that do not arise in the estimate of the baseline model.

Table 11 Long-term barriers to fertility convergence, robustness to sample composition

	(1)	(2)	(3)	(4)
	No clubs Highest, High	No China, India	No OPEC	No socialist
Interpersonal population diversity	637.553***	639.046***	629.244**	592.680**
	(225.738)	(223.055)	(298.183)	(238.866)
$(Interpersonal population diversity)^2$	−457.770***	−459.549***	−453.570**	−420.396**
	(160.599)	(158.910)	(213.440)	(169.914)
Genetic distance to the US	−64.770**	−63.248**	−72.000**	−67.545**
	(30.780)	(30.025)	(36.146)	(27.684)
Years since the transition to agriculture	−0.020**	−0.018*	−0.027*	−0.035**
	(0.009)	(0.010)	(0.014)	(0.014)
Log absolute latitude	−0.864***	−0.785***	−0.203	−1.150***
	(0.334)	(0.281)	(0.334)	(0.369)
Log arable land, %	−0.373**	−0.366*	−0.339	−0.717***
	(0.189)	(0.191)	(0.250)	(0.259)
Log land suitability for agriculture	0.150	0.156	0.000	0.776***
	(0.233)	(0.230)	(0.345)	(0.256)
Mean distance to nearest waterway	−1.202***	−1.220***	−0.791	−3.060***
	(0.437)	(0.428)	(0.492)	(0.800)
Temperature	−0.049	−0.051	0.005	−0.130***
	(0.039)	(0.039)	(0.053)	(0.042)
Rainfall	−0.014***	−0.013***	−0.016***	−0.018***
	(0.004)	(0.004)	(0.006)	(0.004)
Log ethnic fractionalization	−1.682	−1.591	−2.422*	
	(1.044)	(1.045)	(1.436)	
Log religious fractionalization	1.042	1.170	2.153	
	(0.996)	(0.974)	(1.408)	
Polity2 Index	−0.049	−0.058	−0.015	
	(0.045)	(0.045)	(0.066)	
Rule of law	−0.089	−0.042	−0.250	
	(0.249)	(0.233)	(0.330)	
Catholic population	−0.001	−0.000	0.004	
	(0.008)	(0.008)	(0.009)	
Muslim population	−0.014*	−0.014*	−0.020**	
	(0.008)	(0.008)	(0.010)	
Protestant population	0.026**	0.023**	0.029**	
	(0.012)	(0.011)	(0.014)	
Population of European origins	0.544	0.490	0.919	
	(0.998)	(1.007)	(0.990)	
British common law	0.617	0.694	0.725	
	(0.575)	(0.560)	(0.668)	

Table 11 (continued)

	(1)	(2)	(3)	(4)
French commercial code	−0.164	−0.132	−0.620	
	(0.560)	(0.548)	(0.721)	
Malaria Ecology Index	0.021	0.014	0.015	
	(0.035)	(0.034)	(0.051)	
Observations	133	136	125	108
Pseudo R^2	0.678	0.690	0.766	0.691

The table shows that the results of the estimation of the OPM model do not rely on the inclusion of countries with particular characteristics. Countries in Clubs Highest and High can be distinguished for the highest TFR in the period. China and India after WWII adopted serious birth control policies. OPEC economies rely on oil extraction. The institutional structure of socialist countries differs from that of market economies. Column (4) reports the results of the estimation of the baseline model because the larger specification generates problems with the maximum likelihood estimation. The dependent variable *CLUB* identifies three categories of countries with high, medium, and low barriers to fertility convergence. Ordered probit maximum likelihood estimates. Robust standard errors in parentheses. All regressions include dummy variables for world regions in the World Bank classification. $* p < 0.1$; $** p < 0.05$; $*** p < 0.01$. Threshold coefficients estimates omitted

Finally, I consider replacing *Interpersonal population diversity* with the *Migratory distance from East Africa*. Note that Ashraf and Galor (2013a) construct *Interpersonal population diversity* as the prediction from a first-stage regression of expected heterozygosity on the migratory distance from Ethiopia (Addis Ababa) that is justified by the "Out of Africa" theory of the origins of humans. The use of predicted *Interpersonal population diversity* in a second-stage regression is subject to the well known problem of biased estimates of coefficients' standard errors that is usually fixed with the application of bootstrap to both stages. Here, I choose a reduced-form regression framework that means I can replace *Interpersonal population diversity* with the *Migratory distance from East Africa*. Regression results are presented in Table 12. Estimates of baseline and extended regression models display the same hump-shaped relationship of *Migratory distance from East Africa* that I have found using *Interpersonal population diversity*.

4 Conclusions

This paper studies the dynamics of fertility that have occurred in the world after World War II from a new empirical perspective that focuses on Total Fertility Rate club convergence. I interpret this phenomenon as the outcome of barriers to global convergence and search for the ancestral causes of these barriers. To account for the strong nonlinearities involved in this phenomenon, I choose a framework where I first investigate club convergence in TFR to highlight some regularities and identify largely different patterns across countries. The methodology of Phillips and Sul (2007) is the sole available for analyses with these characteristics. I apply their clustering procedure to search for both club convergence at the end of the period (2018) and, reverting the time direction, at the beginning (1950). In this way, I distinguish

Table 12 Long-term barriers to fertility convergence, robustness to changes in model specification

	(1)	(2)	(3)	(4)	(5)	(6)
Interpersonal population diversity	524.554**	677.666***	656.836***	620.233***		
	(253.695)	(255.444)	(228.575)	(221.377)		
(Interpersonalpopulationdiversity)^2	−374.392**	−489.373***	−472.345***	−447.983***		
	(180.131)	(183.132)	(163.124)	(158.372)		
Distance from East Africa					0.438***	0.566***
					(0.152)	(0.195)
(DistancefromEastAfrica)^2					−0.025***	−0.027***
					(0.008)	(0.009)
Genetic distance to the USA	−85.036***	−85.639***	−66.852**	−81.223***	−52.178**	−66.079**
	(26.721)	(30.552)	(29.500)	(30.017)	(21.526)	(29.852)
Years since transition to agriculture	−0.017*	−0.016	−0.020**	−0.021**	−0.033***	−0.019**
	(0.009)	(0.010)	(0.009)	(0.009)	(0.011)	(0.009)
Log absolute latitude	−0.741**	−0.896***	−0.792***	−0.799***	−0.740**	−0.803***
	(0.357)	(0.317)	(0.295)	(0.285)	(0.297)	(0.292)
Log arable land	−0.373*	−0.347*	−0.321	−0.311	−0.409**	−0.369*
	(0.199)	(0.191)	(0.199)	(0.198)	(0.195)	(0.189)
Log land suitability for agriculture	0.148	−0.129	0.138	0.128	0.366*	0.170
	(0.223)	(0.307)	(0.236)	(0.233)	(0.190)	(0.233)
Mean distance to nearest waterway	−0.894*	−1.350***	−1.246***	−1.221***	−1.552***	−1.209***
	(0.466)	(0.436)	(0.433)	(0.423)	(0.356)	(0.433)
Temperature	−0.022	−0.082*	−0.059	−0.070*	−0.103***	−0.050
	(0.044)	(0.045)	(0.042)	(0.041)	(0.031)	(0.039)
Rainfall	−0.014***	−0.012***	−0.013***	−0.013***	−0.010***	−0.013***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Log ethnic fractionalization	−0.817	−0.751	−1.330	−1.219		−1.571

Table 12 (continued)

	(1)	(2)	(3)	(4)	(5)	(6)
	(0.947)	(1.096)	(0.995)	(1.017)		(1.044)
Log religious fractionalization	0.921	1.154	0.954	1.126		1.092
	(0.969)	(1.088)	(0.988)	(0.997)		(0.979)
Catholic population	0.004	0.003	0.000	0.000		−0.001
	(0.008)	(0.008)	(0.009)	(0.009)		(0.008)
Muslim population	−0.012	−0.014*	−0.014*	−0.014*		−0.014*
	(0.007)	(0.008)	(0.008)	(0.008)		(0.007)
Protestant population	0.023**	0.034**	0.026**	0.031***		0.024**
	(0.011)	(0.014)	(0.011)	(0.012)		(0.011)
Polity2 Index	−0.025	−0.082*	−0.056	−0.058		−0.056
	(0.040)	(0.042)	(0.045)	(0.044)		(0.045)
Rule of law	−0.146	0.044	−0.039	−0.008		−0.041
	(0.210)	(0.261)	(0.237)	(0.265)		(0.237)
Population of European origins	−0.685	0.115	0.514	0.409		0.466
	(1.464)	(1.066)	(0.988)	(0.975)		(1.004)
British common law	−0.045	1.014	0.664	1.138*		0.674
	(0.604)	(0.628)	(0.597)	(0.673)		(0.589)
French commercial code	−0.739	−0.035	−0.175	0.224		−0.161
	(0.600)	(0.595)	(0.591)	(0.653)		(0.576)
Socialist/communist law				0.362		
				(0.740)		
Malaria Ecology Index	0.008	0.028	0.026	0.025		0.015
	(0.035)	(0.039)	(0.037)	(0.034)		(0.034)
Population in tropics	0.168					

Table 12 (continued)

	(1)	(2)	(3)	(4)	(5)	(6)
	(0.613)					
Population in temperate zones	1.370**					
	(0.675)					
Log continent size	−0.418					
	(0.663)					
Soil fertility		2.761*				
		(1.612)				
Mean elevation		−0.321				
		(0.449)				
Log land area		0.116				
		(0.101)				
Geodesic distance to the USA			5.479			
			(5.733)			
Threshold 1	166.675*	224.263**	216.467***	201.687***	−11.652***	−9.650***
	(85.137)	(88.736)	(80.017)	(76.848)	(2.260)	(2.419)
Threshold 2	171.019**	228.893**	220.862***	206.092***	−7.535***	−5.199**
	(85.438)	(89.173)	(80.303)	(77.174)	(2.186)	(2.482)
Observations	136	138	138	138	138	138
Pseudo R^2	0.681	0.705	0.693	0.697	0.616	0.691

The table presents the results of the OPM estimates of model (6) in Table 8 augmented with further geographic variables that distinguish countries in the sample. The last two columns show the results of the estimates that replace the variable *Interpersonal population diversity* with *Distance from East Africa*. Ashraf and Galor (2013a) use the last variable to predict the first. The dependent variable *CLUB* identifies three categories of countries with high, medium, and low barriers to fertility convergence. Ordered probit maximum likelihood estimates. Robust standard errors in parentheses. All regressions include dummy variables for world regions in the World Bank classification. * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$. Threshold coefficients distinguish the three categories of *CLUB* in the OPM the set of countries transitioning from high to low TFR. In the second stage of my research, I estimate the ancestral factors of the magnitude of the barriers to fertility decline with an ordered probit model. Interpersonal population diversity of populations and genetic distance of a population to the technological leader country emerge as important determinants of the obstacles to global fertility convergence. Moreover, the time elapsed since the Neolithic transition to agriculture seems to hinder convergence to the club of low fertility countries. Aside from genetic factors, religion displays significant explanatory power with a positive effect of Protestant adherance and a negative influence of the Muslim religion.

The results highlight the persistence of different models of human reproduction across the world whose causes are deeply rooted in the biological and cultural evolution of human populations. Although fertility rates are low in many countries today, the process of convergence has not come to an end. This paper provides new empirical evidence on the relevance of this approach to historical economic development even from the point of view of human reproduction and suggests an important direction for further research on the fundamental determinants of the demographic transition.

5 Variable definition and sources

TFR. Annual time series of the Total Fertility Rate. Source: years 1960–2018, World Development Indicators 2021, The World Bank; years 1950–1959, United Nations World Population Prospects, 2019 Revision.

Interpersonal population diversity. This variable (named *predicted genetic diversity*) has been constructed by Ashraf and Galor (2013a). The basic data is expected heterozygosity taken from the HGDP-CEPH Human Genome Diversity Cell Line Panel. It refers to 53 ethnic groups that identify 21 countries. The data has been calculated for 145 countries using the coefficients of a regression of expected heterozygosity in 53 ethnic groups on the migratory distance from Addis Ababa (Ethiopia). The latter measures the great circle distance of a population from the geographic area where the origins of modern humans are located and considers the natural obstacles that humans faced in reaching the rest of the world. In their contemporary analysis, Ashraf and Galor (2013a) adjust the *predicted genetic diversity* variable to take into account the differences in the composition of the population in 2000 CE due to migrations occurring since the year 1500 CE. The *World Migration Matrix, 1500–2000* (Putterman and Weil, 2010) is the source of the data on the share of the contemporary population in a country that descends from other populations in 1500 CE. Details on the construction of predicted genetic diversity can be found in Ashraf and Galor (2013a). Source: Ashraf and Galor (2013a).

Interpersonal population diversity not adjusted for ancestry. The variable *predicted genetic diversity* of Ashraf and Galor (2013a) calculated on country population at 1500 CE. Source: Ashraf and Galor (2013a).

Distance from East Africa. The geodesic distance from the contemporary capital city to Addis Ababa (Ethiopia) calculated taking into account only routes that do not imply the crossing of seas or other large barriers of water. This variable has been calculated by Ashraf and Galor (2013a) adjusting for migrations since 1500 CE as they have done for *Interpersonal population diversity*. Source: Ashraf and Galor (2013a).

Genetic distance to the USA. The weighted F_{ST} genetic distance between a country and the USA calculated from the data on F_{ST} of ethnic populations provided by Pemberton et al. (2013) with weights given by the shares of each ethnic group in a country population drawn from Alesina et al. (2003). Source: Spolaore and Wacziarg (2018).

Years since the transition to agriculture. The difference between 2000 CE and the estimated year of the transition from hunting and gathering to a sedentary agricultural economy at a country level (Putterman, 2008). As *Interpersonal population diversity*, this variable has been adjusted by Ashraf and Galor (2013a) to take into account different ancestry in the contemporary population. Source: Ashraf and Galor (2013a).

Years since the transition to agriculture not adjusted for ancestry. The variable *Years since the transition to agriculture* without the consideration of the heterogeneity of country population with respect to the lineage in 1500 CE. Source: Ashraf and Galor (2013a).

Absolute latitude. Source: The World Factbook in CIA website, https://www.cia.gov/the-world-factbook.

Arable land. The percentage of arable land according to the UN-FAO definition. Source: World Development Indicators, World Bank.

Land suitability for agriculture. An index of the quality of land for agriculture at the country level. The index takes into account climate characteristics (temperature, precipitation, and potential sunshine hours) and soil suitability (total organic content and the nutrient availability). Source: Michalopoulos (2012).

Mean distance to nearest waterway. Mean distance to nearest ice-free coastline or sea-navigable river. Source: Geography Datasets, Harvard University Dataverse, Center for International Development.

Temperature. Monthly temperature, degrees Celsius, average of the years 1901–2016. Source: World Bank Group, Climate Change Knowledge Portal.

Rainfall. Monthly precipitation, MM, average of the years 1901–2016. Source: World Bank Group, Climate Change Knowledge Portal.

Ethnic fractionalization. The probability that a random sample of two individuals of a population contains two subjects that belong to two distinct ethnic groups. Source: Alesina et al. (2003).

Religious fractionalization. The probability that a random sample of two individuals of a population contains two subjects that adhere to two distinct religions. Source: Alesina et al. (2003).

Catholic. Percentage of the population that adheres to the Roman Catholic religion. Source: La Porta et al. (1999).

Muslim. Percentage of the population that adheres to the Muslim religion. Source: La Porta et al. (1999).

Protestant. Percentage of the population that adheres to the Protestant religion. Source: La Porta et al. (1999).

Polity2. Index of the quality of political institutions built in the Polity Project (Marshall and Gurr, 2021). The index is calculated as the difference between the index of Democracy (scores from 0 to 10) and the index of Autocracy (scores from 0 to 10). Both indexes evaluate the following features of political regime: *Competitiveness of Executive Recruitment; Openness of Executive Recruitment; Constraint on Chief Executive; Competitiveness of Political Participation.* Average of the years 1950–2018. Source: Polity5 Project, Political Regime Characteristics and Transitions, 1800–2018, Center for Systemic Peace.

Rule of Law. Indicator of The World Bank, Worldwide Governance Indicators. It refers to the quality of enforcement of contracts and property rights, to the efficiency of the police, and the courts, as well as to the diffusion of crime and violence. The indicator measures (range from -2.5 to 2.5) the perception of the quality of governance in a country. Average of the years 1996–2019. Source: Worldwide Governance Indicators, The World Bank.

Population of European origins. The share of the population of a country in 2000 CE that descends from the population of a European country. The variable has been calculated by Ashraf and Galor (2013a) from data of the *World Migration Matrix, 1500–2000* of Putterman and Weil (2010). Source: Ashraf and Galor (2013a).

British common law. Dummy variable of the British common law among commercial legal traditions in the world. Source: La Porta et al. (1999).

French civil law. Dummy variable of the French civil law among commercial legal traditions in the world. Source: La Porta et al. (1999).

Socialist/Communist law. Dummy variable of the legal tradition of the Soviet Union. Source: La Porta et al. (1999).

Malaria Ecology Index. Index calculated by Kiszewski et al. (2004) to capture structural factors of Malaria incidence in the world. The index takes into account climatic factors, different mosquito vector types, and human biting rates of diverse mosquito vectors. Source: Kiszewski et al. (2004), data drawn from https://sites.google.com/site/gordoncmccord/.

Population in tropical zones. Percentage of the population in 1995 that lives in a country of a tropical zone according to the Köppen-Geiger classification. Source: Geography Datasets, Harvard University Dataverse, Center for International Development.

Population in temperate zones. Percentage of the population in 1995 that lives in a country of a temperate zone according to the Köppen-Geiger classification. Source: Geography Datasets, Harvard University Dataverse, Center for International Development.

Continent size. The landmass of continents in Km^2. Source: Encyclopaedia Britannica.

Soil fertility. The soil suitability component of the index of *Land suitability for agriculture*. Source: Michalopoulos (2012).

Mean elevation. Elevation of a country above sea level. Source: William Nordhause's *G-ECON Project* at Yale University.

Land area. A country's total area in Km^2, excluding areas under inland water bodies. Source: World Development Indicators, World Bank.

Distance to USA. Geodesic distance to the USA. Source: Spolaore and Wacziarg (2018).

Appendix

Table 13 List of countries in convergence clubs

Club Highest	Club High	Club Intermediate		Club Low	
			Club High-to-Low		Club Low-to-Low
Congo, Dem. Rep	Chad	Afghanistan	Albania	Lesotho	Argentina*
Niger	Mali	Angola	Algeria	Libya	Australia
Somalia		Benin	Antigua & Barbuda	Macao	Austria*
		Burkina Faso	Armenia	Malaysia	Bahamas, The
		Burundi	Aruba	Maldives	Belarus
		Cameroon	Azerbaijan	Malta	Belgium*
		Central African Rep	Bahrain	Mauritius	Bulgaria*
		Comoros	Bangladesh	Mexico	Channel Islands
		Congo, Rep	Barbados	Micronesia, Fed	Croatia
		Cote d’Ivoire	Belize	Moldova	Cuba*
		Equatorial Guinea	Bhutan	Mongolia	Czech Republic
		Eritrea	Bolivia	Montenegro	Denmark*
		Ethiopia	Bosnia & Herzeg	Morocco	Estonia
		Gambia, The	Botswana	Myanmar	Finland*
		Guinea	Brazil	Namibia	France*
		Guinea-Bissau	Brunei Darussalam	Nepal	Gabon
		Liberia	Cabo Verde	New Caledonia	Georgia
		Madagascar	Cambodia	Nicaragua	Germany*
		Malawi	Canada*	North Macedonia	Greece
		Mauritania	Chile	Oman	Hungary*
		Mozambique	China	Pakistan	Iceland
		Nigeria	Colombia	Panama	Ireland
		Rwanda	Costa Rica	Papua New Guinea	Italy*
		Sao Tome Principe	Cyprus	Paraguay	Jamaica*
		Senegal	Djibouti	Peru	Korea, Dem. Rep
		Sierra Leone	Dominican Rep	Philippines	Kyrgyz Republic
		Solomon Islands	Ecuador	Poland	Latvia
		South Sudan	Egypt, Arab Rep	Puerto Rico	Lithuania
		Sudan	El Salvador	Qatar	Luxembourg
		Tanzania	Eswatini	Samoa	Netherlands*
		Timor-Leste	Fiji	Saudi Arabia	New Zealand
		Togo	French Polynesia	Singapore	Norway*
		Uganda	Ghana	Slovak Republic	Portugal*
		Zambia	Grenada	South Africa	Romania*
			Guam	Sri Lanka	Russian Federation
			Guatemala	St. Lucia	Slovenia
			Guyana	St. Vincent & Gren	Spain*

Table 13 (continued)

Club Highest	Club High	Club Intermediate		Club Low	
			Haiti	Suriname	Sweden*
			Honduras	Syrian Arab Rep	Switzerland*
			Hong Kong	Tajikistan	Turkmenistan
			India	Thailand	Ukraine
			Indonesia	Tonga	United Kingdom*
			Iran, Islamic Rep	Trinidad & Tobago	United States*
			Iraq	Tunisia	Uruguay*
			Israel	Turkey	
			Japan	United Arab Emir	
			Jordan	Uzbekistan	
			Kazakhstan	Vanuatu	
			Kenya	Venezuela, RB	
			Kiribati	Vietnam	
			Korea, Rep	Virgin Islands (U.S.)	
			Kuwait	Yemen, Rep	
			Lao PDR	Zimbabwe	
			Lebanon		

An asterisk denotes a country in the group of the Forerunners in the classification of Reher (2004)

Table 14 Descriptive statistics for variables in the ordered probit model

	Mean	Standard deviation	Minimum	Maximum
CLUB	2.058	0.702	1	3
Interpersonal population diversity	0.726	0.0274	0.628	0.774
Genetic distance to the US	0.0298	0.0143	0.00995	0.0551
Years since transition to agriculture (in 100 s)	53.29	21.10	13.57	104
Log absolute latitude	2.994	0.955	0	4.159
Log arable land	2.244	1.159	-2.120	4.129
Log land suitability for agriculture	-1.400	1.255	-5.809	-0.0408
Mean distance to nearest waterway	0.366	0.469	0.0142	2.386
Temperature	17.66	8.424	-6.886	28.28
Rainfall	86.75	61.54	2.772	254.9
Log ethnic fractionalization	0.362	0.184	0.00200	0.658
Log religious fractionalization	0.341	0.168	0.00275	0.621
Polity2 Index	0.785	5.784	-10	10
Rule of law	-0.193	1.004	-2.310	1.982
Catholic population	29.59	35.56	0	96.90
Muslim population	24.96	36.87	0	99.80
Protestant population	11.11	19.79	0	97.80
Population of European origins	0.323	0.417	0	1
Malaria Ecology Index	3.763	6.778	0	31.55
British common law	0.254	0.437	0	1
French commercial code	0.464	0.501	0	1

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