Dead men tell no tales: how the Homo sapiens became Homo economicus

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Abstract

The paper explains long-term changes in birth, death rates and attitude to personal consumption by changing patterns of cultural transmission. When communities are culturally isolated, they are focused on population growth, resulting in large fertility and welfare transfers to children, limited adult consumption and lack of old-age support. With increasing cultural contact across communities, successful cultural traits induce their hosts to attempt becoming *celebrities* by limiting fertility and increasing longevity via higher consumption and old-age arrangements. Empirical analysis confirms that celebrities have fewer children and live longer; their presence precedes reduced aggregate birth and death rates.

Keywords: cultural transmission, celebrity, demographic transition

JEL codes: J11, J13, J14, Z19

1. Introduction

Theoretical biology disagrees with theoretical economics about the lifetime objectives of a human being. Theoretical biology is based on the Darwinian idea, that the only possible objective of a living organism can be maximization of the growth rate of population to which the organism belongs. This postulate is justified by the standard natural selection

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argument: in the long run, the maximum possible rate of growth of any population is zero; hence any population focused on any objective other than its growth will grow at a lower, i.e. negative, rate, and will eventually become extinct. Throughout this paper, we will refer to the population-growth-maximizing human as the *Homo sapiens*.

Most economists, in contrast, traditionally assume that the objective of humans is to maximize their own material wealth. This assumption is not based on any logical proof, but rather on a tradition introduced by the founding fathers of economics. E.g. in J.S. Mill's words, "[political economy] is concerned with [a man] solely as a being who desires to possess wealth, and who is capable of judging the comparative efficacy of means for obtaining that end." We will use the popular term *Homo economicus* to characterize the human who maximizes personal material well-being.

A number of economists have pointed out that the Homo sapiens and Homo economicus concepts are different (e.g. Robson (2001), Bergstrom (2007)) and attempted to build alternative Homo sapiens-based theories of human economic behavior. For example Robson and Kaplan (2003) study intergenerational transfers and consumption of wealth, as functions of age, that are consistent with the objective of the Homo sapiens. Their model predicts that there should be large donations of wealth from adults to children; that personal consumption of adults should be modest, just enough to maintain life; that no wealth should be donated to old individuals, as they do not contribute to population growth. The results of their research are suitable for the "Malthusian" economies, i.e. for hunter-gatherer and possibly agrarian societies. Kaplan (1994) demonstrates empirically that hunter-gatherer societies indeed do not support the elderly.

At the same time, the model of the Homo sapiens cannot explain changes in human lifestyles that occurred in the recent two centuries, i.e. throughout the demographic transition. Modern societies no longer appear to maximize the population rate of growth, as such rate is falling in all countries of the world, and is lowest in countries that are widely regarded

as "successful". Most people in such "successful" countries also appear to be interested in luxurious lifestyles; such countries practice various forms of old-age support designed to increase life expectancy. The competing Homo economicus model appears to be a better fit to the lives of modern humans. Within this model, fertility declines because large number of children increasingly stands in a way of personal consumption, that of parents or of children themselves (Becker and Lewis (1973), recently reviewed in Doepke (2015) and in Lee (2015)), old-age support helps individuals to enjoy consumption for a longer time period, and the desire for a luxurious lifestyle doesn't even have to be explained. For this reason, the Homo economicus concept remains the mainstream of economics despite the above mentioned lack of theoretical foundation. In particular, theories of demographic transition, e.g. Becker et al. (1990) and Galor and Moav (2002), are typically based on the Homo economicus concept. Even the latter of these two, which introduces some elements of natural selection into the model, assumes that the importance of personal consumption in human preferences is exogenous and is exempt from any natural selection.

The objective of this paper is to propose a theory of how humans could evolve away from the Homo sapiens toward the Homo economicus. Because the standard natural selection of *genes* clearly cannot explain the drift away from the Homo sapiens, there must be another type of natural selection at play. This paper emphasizes the natural selection of *cultural traits* as the main driving force of changing lifestyles. The narrative of the theory goes as follows.

1.1. The theory

Compared to other species, humans have an unprecedented ability to copy each others behavior (Boyd and Richerson, 1985; Tomasello, 1999). Initially, when the genotype of modern humans evolved, such imitation ability allowed individuals to learn not only from their own mistakes but also from those of others, thus allowing to be more efficient at survival

and procurement of resources, and to adapt faster to changing environment. Such imitation process has led to the emergence of persistent (though evolving) behavioral patterns that are labeled as *cultures* and that are passed from one generation to the next. The latter process is labeled *cultural transmission*.

Because early humans lived in relatively small groups not exceeding few hundred people, with limited contact with other groups, cultural transmission was mostly *vertical*, from parent to child, i.e. happened between individuals who were relatives and knew each other. But as human population density grew, literacy increased, communication technology improved, humans became increasingly able to observe and imitate alternative lifestyles outside of their community, i.e. *oblique* cultural transmission became more prominent. Because oblique cultural transmission happens between individuals who do not share the same genes, it generally does *not* contribute to population growth rate of the imitating community. In other words, changing patterns of communication between humans have led to maladaptive, from the point of view of the Homo sapiens, patterns of cultural transmission, and eventually led to the emergence of the modern Homo economicus.

The above ideology of the demographic transition is not entirely new and has circulated for some time in social sciences other than economics, especially to explain the declining fertility rates. Newson et al. (2007) explains lower fertility by less cultural influence from within community and more such influence from outside. Ihara and Feldman (2004) and Zakharenko (2016b) propose models in which lower fertility enables individuals to achieve higher social status, meaning that their way of life will be more imitated.

Much less effort was made to explain the rise of preference for luxurious lifestyle and of old-age support. The rise of luxurious lifestyle can be explained by the hypothesis that such lifestyle makes individuals more socially visible and more likely to become imitated, although one would then have to explain *why* luxurious lifestyles are more imitated. Zakharenko

(2016a) explains rising consumption by falling population growth rates;[3] this driving factor, however, cannot plausibly explain the full magnitude of consumption increase. In calibration of Zakharenko (2016a), in particular, consumption grows at a slower rate than income. Evolutionary explanations of the emergence of old-age support, to the best of my knowledge, are non-existent in the literature.

This paper adds to this line of cultural transmission literature by pointing out a very simple yet powerful "dead men tell no tales" argument. Even if the chance of being imitated does not depend on special effort to achieve higher social status, or on levels of consumption, individuals can still increase the number of cultural followers by simply living longer, as long as alive individuals are more imitated than the dead. This idea gives a whole new meaning to the value of human life: besides traditional production of new humans, life is valuable because it can recruit new cultural followers from outside own community via oblique cultural transmission. If the latter method to produce cultural offspring is less sensitive to age than physical reproduction, the value of longevity increases as oblique cultural transmission becomes more widespread. Higher value of long life, in turn, can explain increasing consumption (which helps to reduce mortality) and welfare transfers to the elderly.

As the frequency of communication between non-relatives increases, some individuals may adapt to the new environment faster than others. Those who adapt sooner, according to the theory, should have lower fertility and live longer than the general population. As their lifestyle is better suited to the changed environment, they attract many cultural followers which makes them *celebrities*.

The model developed in this paper is different from models of cultural transmission orig-

[3]In theoretical biology models, population growth rate plays the same role as the discount rate in economics. If population grows fast, an individual maximizing the share of her offspring in that population has to produce offspring as soon as possible, and is thus impatient. As population growth slows down, production of offspring can be more spread over time, and the individual is incentivized to have more personal consumption which reduces mortality risks and thereby increases expected number of offspring in future periods.

inated by Bisin and Verdier (2001). In that line of literature, the domain of possible cultural types is usually limited to few (usually two) elements, usually with equal and predetermined role of personal consumption, as well as a concern about culture chosen by own children, embedded into the preferences. Baudin (2010) is an example of demographic transition theory built on this platform. By construction, equilibria of these models are not invasion-proof: a new cultural type that prescribes to care less about personal consumption and more about the culture of children will overcrowd the initial cultural types. The current paper, in contrast, makes no ex-ante assumptions about the importance of personal consumption, and studies only cultural traits that prescribe the only possible invasion-proof objective of maximizing the rate of growth of population belonging to that culture.

Section 2 of this paper formalizes the above intuition in a model, while section 3 verifies empirically the key predictions of the theory. Prior to these sections, we discuss the empirical evidence that already exists.

1.2. Existing empirical evidence

Most existing studies of cultural transmission relevant for demographic transition focus on fertility. Colleran et al. (2014) find that fertility of an individual is more affected by average education in her community than by her own education. This finding indicates that fertility is more affected by patterns of cultural transmission, associated with average community education, than by productive skills acquired individually at school. This finding opposes the traditional economic theory (e.g. Becker et al. (1990)) that fertility declines as a response to increased productive capabilities.

La Ferrara et al. (2012) find that fertility in Brazilian communities declines when these communities are connected to a TV channel that broadcasts movies portraying successful low-fertility families. Because such movies cannot affect productive skills of the viewers, this finding is a direct evidence that cultural transmission plays a role in fertility decline.

Van Bavel (2004) finds that 19-th century Flemish couples in the Belgian city of Leuven reduced their fertility if their neighbors were French-speaking families, known to have lower average fertility during that period. This finding also points to the contagious, culturally transmitted nature of fertility decline.

A stark example of the link between cultural transmission and fertility is modern Amish villages in the United States. Amish are religious communities which, despite living in modern times in a modern country, have some of the highest fertility rates in human history. Greksa (2002) estimates their fertility at 7.7 children per woman while Bailey and Collins (2011) comes up with 6 children per woman. Such fertility cannot be explained by poor education, as traditional economics would suggest: Amish communities have their own schools providing 8 years of education to almost all children.[4] According to Barro-Lee dataset (Barro and Lee, 2013), this amount of human capital in the general U.S. population was observed around 1930, when the national fertility rate did not exceed 3 children per woman.

At the same time, high Amish fertility can be explained within the cultural influence theoretical framework of section 1.1. According to that theory, high fertility is consistent with cultural isolation of a community and lack of external role models. This is indeed the case for the Amish people who are notorious for their cultural isolation and denial of modern communication devices. It is quite telling that the above mentioned study by Bailey and Collins (2011), who work with the U.S. Census which does not explicitly identify Amish people, identify them as individuals (i) speaking Pennsylvania Dutch and (ii) not having a phone. Both of these characteristics, speaking a rare language and rejection of modern communication methods, point to cultural isolation. Kraybill (1998) studies the movies of the Amish behind their abstention from the mass media, and concludes that the Amish view the values/cultural traits of the outside world as a direct threat to their own culture, which

[4]https://www.amishvillage.com/blog/amish-education/

is perfectly consistent with the cultural influence theory of demographic transition.

2. The model

2.1. The Homo sapiens

I first introduce the model of an optimal lifecycle of the Homo sapiens who live in small communities and who are isolated from any external cultural influence. In such environment, natural selection favors cultural traits which maximize the rate of community growth. The model of lifecycle decisions of this section is a simplified version of Robson and Kaplan (2003).

Consider a model set up in continuous time with infinite horizon. There are many isolated communities of humans, each community having its own unique cultural identity. The economy consists of a single consumption good, which, following Robson and Kaplan (2003), we interpret as energy needed to live and reproduce. Humans live finite lives, detailed below.

From age 0 to a_1 humans are children and can only consume; their production of energy is $y(a) = 0, a \in [0, a_1)$. At age a_1, the cultural identity is formed by copying a role model, aged above a_1, selected randomly from the same community. Since all potential role models share the same culture, the cultural transmission process is trivial as all young individuals simply join that culture.

From age a_1 to a_2 humans are adults and can produce two outputs: (i) the consumption good, with exogenous age-dependent productivity $y(a) > 0, a \in (a_1, a_2)$, and (ii) newborn children, detailed below. Adults also pose as role models for those who form their cultural identity.

Ages from a_2 to a_3 are referred to as the *old age*; such humans can produce neither the consumption good ($y(a) = 0, a \in [a_2, a_3]$) nor children. But they can still pose as cultural role models for the young. No life is possible beyond age a_3.

At all ages, humans face a risk of mortality that can be reduced by higher consumption. Mathematically, death is a Poisson process with the rate of $\mu(c)$, where c is consumption while $\mu(\cdot)$ satisfies $\mu(0) = \infty$ (zero consumption results in instant death), $\mu(c)$ is continuous and finite for every $c > 0$, $\mu'(\cdot) < 0$ and $\mu''(\cdot) > 0$. As we assume that no life is possible beyond age a_3, mortality is infinite starting from that age. Given consumption profile $c(a), a \in [0, a_3]$, the probability of survival from birth to age $a \in [0, a_3]$ is then $p(a, c(\cdot)) = \exp(-\int_{t=0}^{a} \mu(c(t))\mathrm{d}t)$, so that

$$p(0, c(\cdot)) = 1,\ \dot{p}(a, c(\cdot)) = -p(a, c(\cdot))\mu(c(a)). \tag{1}$$

We also have that $p(a, c(\cdot)) = 0$ for $a > a_3$.

A birth of a new human requires C_0 units of energy/consumption good. Natural selection leaves only those communities where all members have a common goal of highest population growth rate, and are pooling their resources to achieve that goal. Hence, we can perform our optimization calculations at the community level.

Denote the rate of population growth by r and assume the measure of newborns at time t_0 is normalized to unity. Then, the measure of individuals of age a at t_0 is $e^{-ra}p(a, c(\cdot))$, where e^{-ra} is the measure of people born at time $t_0 - a$, while $p(a, c(\cdot))$ is their rate of survival to time t_0. Then, the total amount of energy allocated by the community to births is $\int_{a=0}^{a_3} e^{-ra}p(a, c(\cdot))\,(y(a) - c(a))\,\mathrm{d}a$ and the mass of newly born at t_0 is

$$u_0(c(\cdot), r) \equiv \frac{\int_{a=0}^{a_3} e^{-ra}p(a, c(\cdot))\,(y(a) - c(a))\,\mathrm{d}a}{C_0}. \tag{2}$$

By assumption we have that such mass is unity:

$$u_0(c(\cdot), r) = 1. \tag{3}$$

Robson and Kaplan (2003) in Lemma 1 show that $u_0(c(\cdot), r)$ must be maximized over $c(\cdot)$

for a given r; otherwise a higher r is possible. The optimal consumption path then satisfies

$$-\mu'(c(a))V_0(a) = 1, \tag{4}$$

where

$$V_0(a) \equiv \frac{1}{p(a, c(\cdot))} \int_{t=a}^{a_3} e^{-r(t-a)} p(t, c(\cdot)) \left(y(t) - c(t)\right) \mathrm{d}t \tag{5}$$

is the expected value of life remaining beyond age a, in terms of energy surplus produced, discounted by the population growth rate. At the terminal age a_3, the value of life is zero, hence (4) implies zero consumption, as well. By applying reverse induction from age a_3 to age a_2, where $y(a) = 0$, we conclude that both $V_0(a) = 0$ and $c(a) = 0$ in this interval. In other words, it is not optimal to support the elderly as they do not contribute to population growth, and hence there is no life beyond age a_2. For individuals younger than a_2, optimal value of life is positive and so is consumption.

The maximal population growth rate r is then pinned down by (3) given optimal path $c(\cdot)$ and (1).

This model fits all characteristics of a Malthusian steady state. In particular, the rise in available resources $y(\cdot)$ decreases mortality and increases fertility (as measured by u_0 for a given r), and therefore increases the population rate of growth. The model fails to explain high infant mortality observed in all societies of humans; Robson and Kaplan (2003) do a better job at explaining it by introducing endogenously accumulated *somatic capital* (i.e. body mass). The somatic capital of infants is low and so the value of their life is lower than that of grown-up individuals. In this paper, endogenous somatic capital is omitted because infant mortality is not the main focus.

Another important distinction between this paper and Robson and Kaplan (2003) is that the latter assume genetically hardwired consumption paths and mortality levels. This paper assumes behaviors and associated mortality are transmitted culturally rather than

genetically.

2.2. Oblique cultural transmission: community effects

We now generalize the model of section 2.1 to add cultural transmission across communities. The mathematical concept of cultural transmission is adapted from Zakharenko (2016a) and Zakharenko (2016b).

By *followers* we will label individuals of age a_1, i.e. those who are about to find a cultural role model. Suppose that, due to rising population density and improvements in communication technology, there is probability q that a follower picks up a role model from outside her community. We will refer to q as the *cultural openness* of the world's communities to each other.[5] While previous studies assumed that potential outside role models can increase the chance of being followed by allocating effort and/or resources toward that goal, this paper makes a more innocuous assumption that all living individuals above age a_1 are equally likely to become role models. Even this simple setting is sufficient to explain changes in human lifestyles; introducing special effort to become a role model would only reinforce the conclusions of this paper.

Since we account individuals by their culture, not their genotype, followers who picked external cultural types migrate to the community of their role models. Each community therefore retains only fraction $1-q$ of followers born in that community, but it also recruits new followers via oblique cultural transmission from outside.

Suppose for a follower born in community i, the total mass of external role models is N_i. Since we assume that the population share of any community i is infinitesimal, N_i is equal to global population of potential role models, and is therefore equal across communities i. But then, any potential role model will draw external followers at Poisson rate qR where R

[5]This paper treats cultural openness q as an exogenous variable. Zakharenko (2016a) assumes q positively depends on population density, making it endogenous.

is the global ratio of followers to role models.

Suppose the mass of new followers recruited into a specific cultural type at time t_0 is normalized to unity, while the mass of births by parents of that cultural type is b.

Assuming the population of the cultural type in question grows at constant rate r, the mass of births at time $t_0 - a_1$ was be^{-ra_1}, the mass of survivors to age a_1 is $be^{-ra_1}p(a_1, c(\cdot))$, and the mass of followers who retain the cultural type of their parents is $(1-q)be^{-ra_1}p(a_1, c(\cdot))$. This is the amount of recruitment into the cultural type in question at time t_0 via vertical cultural transmission.

Denote by $p_1(a, c(\cdot)), a \geq a_1$ the probability of survival from age a_1, when cultural identity is formed, to age a.[6] Following the assumptions of section 2.1, we have that $p_1(a, c(\cdot)) = \exp\left(-\int_{t=a_1}^{a} \mu(c(t))\mathrm{d}t\right)$ or, alternatively, (cf.(1))

$$p_1(a_1, c(\cdot)) = 1,\ \dot{p}_1(a, c(\cdot)) = -p_1(a, c(\cdot))\mu(c(a)). \tag{6}$$

Then, the equilibrium mass of births b can be identified from the following energy balance equation:

$$b\int_{a=0}^{a_1} e^{-ra}p(a,\cdot)(-c(a))\mathrm{d}a + \int_{a=a_1}^{a_3} e^{-r(a-a_1)}p_1(a,\cdot)\left(y(a)-c(a)\right)\mathrm{d}a = bC_0. \tag{7}$$

The left-hand side of (7) is the net energy production of members of the cultural trait and their children, while the right-hand side is energy spent on new births.

The total mass of new recruits into the cultural type in question, via both vertical and

[6] If all cultural traits shared the same consumption path and survival rates, we would have $p_1(a, c(\cdot)) = \frac{p(a,c(\cdot))}{p(a_1,c(\cdot))}$. But because consumption paths of children are determined by their parents, and because new followers of a culture are recruited from multiple cultures, survival rates of new followers can be heterogenous and thus such formula is generally not correct.

oblique cultural transmission, is given by

$$u_1(c(\cdot), r) \equiv (1-q)be^{-ra_1}p(a_1, c(\cdot)) + qR\int_{a=a_1}^{a_3} e^{-r(a-a_1)}p_1(a, c(\cdot))\mathrm{d}a$$
$$\underbrace{=}_{cf.(7)}(1-q)\frac{e^{-ra_1}p(a_1, c(\cdot))\int_{a=a_1}^{a_3} e^{-r(a-a_1)}p_1(a, c(\cdot))\left(y(a)-c(a)\right)\mathrm{d}a}{C_0 + \int_{a=0}^{a_1} e^{-ra}p(a, c(\cdot))c(a)\mathrm{d}a}$$
$$+ qR\int_{a=a_1}^{a_3} e^{-r(a-a_1)}p_1(a, c(\cdot))\mathrm{d}a. \quad (8)$$

By earlier assumption,

$$u_1(c(\cdot), r) = 1 \quad (9)$$

in equilibrium. At the same time, maximization of the population growth rate r is equivalent to maximization of $u_1(c(\cdot), r)$ over $c(\cdot)$ for given r: if u was not maximized, a higher r would be feasible.

2.2.1. Child consumption problem

Apparently, optimal consumption paths for children $a \in [0, a_1)$ and for adults $a \in (a_1, a_3]$ can be calculated independently from each other. Indeed, according to (8), the optimal children's consumption path should maximize

$$\frac{e^{-ra_1}p(a_1, c(\cdot))}{C_0 + \int_{a=0}^{a_1} e^{-ra}p(a, c(\cdot))c(a)\mathrm{d}a} \quad (10)$$

over $c(\cdot)$. Intuitively, (10) is the number of children surviving to age a_1 at a representative time t_0 per unit of energy spent on children (including births and consumption) at the same moment of time. This objective does not depend on cultural transmission parameters q, R or on subsequent consumption path $c(a), a > a_1$.[7]

[7]Thus, the model fails to explain the empirical observation that parental investment into children increases with modernization (with increasing q in our context). To address the problem, the model can be modified to assume that birth of a child not only requires energy input C_0 but also excludes parents from being role

Proposition 1. *The optimal consumption path of children satisfies*

$$-\mu'(c(a))V_1(a) = 1, \tag{11}$$

where

$$V_1(0) = C_0, \dot{V}_1(a) = (\mu(c) + r)\, V_1(a) + c(a), a \in [0, a_1). \tag{12}$$

Moreover, given r, such consumption path is identical to that of the Homo sapiens children of section 2.1.

The proof of the proposition is in the appendix.

Denote by $B(r)$ the value of (10) under the optimal consumption path. By the envelope theorem, its full derivative with respect to r is equal to the partial derivative, equal to

$$B'(r) = -rB(r)\frac{C_0}{C_0 + \int_{a=0}^{a_1} e^{-ra}p(a)c(a)\mathrm{d}a} < 0. \tag{13}$$

2.2.2. Adult consumption problem

By substituting the optimal children's consumption path into (8), we can rewrite the optimal adults' consumption problem as maximization of

$$u_2(c(\cdot), r) \equiv (1-q)B(r)\int_{a=a_1}^{a_3} e^{-r(a-a_1)}p_1(a, c(\cdot))\,(y(a) - c(a))\,\mathrm{d}a + qR\int_{a=a_1}^{a_3} e^{-r(a-a_1)}p_1(a, c(\cdot))\mathrm{d}a \tag{14}$$

over $c(\cdot)$. This is a standard dynamic programming problem with the following solution (cf.(4,11)):

$$-\mu'(c(a))V_2(a) = 1, a \in (a_1, a_3], \tag{15}$$

models for non-relative followers for some period of time h. Then, because rising q increases returns to being such a role model, modernization increases the opportunity costs of giving birth, thus every child's life is more valuable and more investment is done to preserve life. The model presented in this paper essentially assumes $h = 0$ to simplify exposition of key results.

where (cf.(5,12))

$$V_2(a,Q) \equiv \frac{1}{p_1(a,c(\cdot))} \int_{t=a}^{a_3} e^{-r(t-a)} \left(y(t) - c(t) + Q\right) p_1(t,c(\cdot)) \mathrm{d}t, a \in [a_1, a_3], \tag{16}$$

is the updated value of life remaining beyond age a and where

$$Q \equiv \frac{q}{1-q} \frac{R}{B(r)}. \tag{17}$$

The parameter Q is *cultural productivity*, i.e. the rate of attraction of cultural followers from outside by a living adult, measured in the currency of energy surplus/deficit generated by the same adult. It is immediate to verify that the Homo sapiens of section 2.1 is a special case of this model with $q = Q = 0$.

We now state the key results of the model.

Theorem 1 ("Dead men tell no tales"). *For given r, R, consumption $c(\cdot)$ rises, and therefore mortality $\mu(c(\cdot))$ falls, with cultural openness q at every adult age $a \in (a_1, a_3]$.*

In words, rising return to "telling tales," i.e. to posing as a role model for external followers, makes individuals increase investment into survival as their capability to "tell tales" is less age-sensitive (in this stylized model, completely independent from age) than their capability to generate energy surplus. Such increasing interest in own survival makes individuals appear more focused on own consumption, consistently with the Homo economicus paradigm. Also, the theorem predicts that consumption rises with cultural openness q in the old age $a \in [a_2, a_3]$, where no more energy can be produced, meaning that old-age support is increasing. The proof of the theorem is analogous to that of theorem 2a in Robson and Kaplan (2003) who show that age-invariant increase in energy production increases consumption at all ages.

Proof. The cultural openness q affects decisions only via cultural productivity Q, with $\frac{\mathrm{d}Q}{\mathrm{d}q} > 0$. Because the consumption path $c(\cdot)$ is chosen to maximize the value of life at any

given age $a \in (a_1, a_3]$, we can apply the envelope theorem to conclude

$$\frac{\mathrm{d}V_2(a)}{\mathrm{d}Q} = \frac{\partial V_2(a)}{\partial Q} = \frac{1}{p_1(a, c(\cdot))} \int_{t=a}^{a_3} e^{-r(t-a)} p_1(t, c(\cdot)) \mathrm{d}t > 0.$$

But then, an increase in Q should be associated with a decrease in the absolute value of $\mu'(c(a))$ in (15), which is consistent with rising $c(a)$ due to the properties of $\mu(\cdot)$. ■

Next, we analyze the impact of changing cultural openness on the birth rate. Calculation of such rate according to the standard definition, new births relative to total population, is cumbersome because the total population depends on endogenous mortality rates. Instead, we use a modified definition of the birth rate as the number of new births to the population of age a_1, equal to $F(c(\cdot, Q)) = \frac{\int_{a=a_1}^{a_3} e^{-r(a-a_1)} p_1(a, c(\cdot, Q))(y(a) - c(a, Q)) \mathrm{d}a}{C_0}$, where $c(\cdot, Q)$ is the optimal consumption path given cultural productivity Q, while $p_1(a, c(\cdot))$ is determined by (6).

Theorem 2. *Given r, R, the birth rate $F(c(\cdot, Q(q)))$ falls as cultural openness q rises.*

Proof. Because $Q'(q) > 0$, we focus on proving that $F(c(\cdot, Q))$ decreases with Q. The problem of maximization of (14) is equivalent to maximization of $F(c(\cdot)) + QG(c(\cdot))$ over $c(\cdot)$, where $G(c(\cdot)) \equiv \frac{\int_{a=a_1}^{a_3} e^{-r(a-a_1)} p_1(a, c(\cdot)) \mathrm{d}a}{C_0}$. Consider two values of cultural productivity, $Q_1 < Q_2$. Theorem 1 proves that mortality strictly falls with Q, and therefore survival rates increase: $p_1(a, c(\cdot, Q_1)) < p_1(a, c(\cdot, Q_2)), a \in (a_1, a_3]$. But then $G(c(\cdot, Q_1)) < G(c(\cdot, Q_2))$.

Suppose the birth rate is non-decreasing with Q, $F(c(\cdot, Q_1)) \leq F(c(\cdot, Q_2))$. But then, when cultural productivity is Q_1, changing the consumption path from $c(\cdot, Q_1)$ to $c(\cdot, Q_2)$, which is feasible, improves the objective function:

$$F(c(\cdot, Q_2)) + Q_1 G(c(\cdot, Q_2)) > F(c(\cdot, Q_1)) + Q_1 G(c(\cdot, Q_1)),$$

which compromises optimality of $c(\cdot, Q_1)$ under Q_1. Therefore, we have that $F(c(\cdot, Q_1)) > F(c(\cdot, Q_2))$. ■

2.3. Oblique cultural transmission: aggregate effects

Increasing cultural openness affects lifetime decisions not only directly but also via the community population growth rate r and aggregate follower-role model ratio R which were considered exogenous in the previous section. This section studies steady growth paths in which all communities make rational decisions for cultural survival, endogenizes r and R, and confirms that the results of theorems 1 and 2 survive. Because r is now a variable, we add it as an argument to relevant functions.

All communities face the same value of R, which is the ratio of the measure of individuals of age a_1, normalized to unity, to the measure of individuals aged above a_1, equal to $C_0 G(c(\cdot, Q, r), r)$:

$$R(Q, r) \equiv \frac{1}{C_0 G(c(\cdot, Q, r), r)}. \tag{18}$$

All communities optimally follow identical consumption paths and have identical population growth rates r. It is useful to investigate how r affects the consumption path.

Proposition 2. *Given cultural productivity Q, higher aggregate population growth r causes consumption $c(a, Q, r)$ at every age $a \in (a_1, a_3]$ to decline.*

The proofs of this and the next propositions are in the appendix.

The equilibrium rate of population growth can be found from the following condition (cf.(3)): $B(r)C_0 F(c(\cdot, Q, r), r) \equiv 1$ or, in logarithmic terms,

$$M_r(Q, r) \equiv \ln B(r) + \ln C_0 + \ln F(c(\cdot, Q, r), r) \equiv 0. \tag{19}$$

In words, assuming the mass of individuals of age a_1 is unity and population grows at rate r, then survival to age a_1 per unit of energy, times total energy surplus produced by all adults, must be exactly equal to one.

Proposition 3. *Increasing cultural openness q causes population growth r to drop and cultural productivity Q to rise.*

Corollary 1. *The results of theorems 1,2 are valid at the aggregate level, i.e. when accounting for endogeneity of R and r.*

Proof. As q rises, consumption rises via increasing Q (theorem 1) and decreasing r (proposition 2). This proves theorem 1 at the aggregate level. Increasing Q also reduces fertility F by theorem 2, while (19) implies that reduced r, by increasing $B(r)$, must result in lower fertility F, as well. This proves theorem 2 at the aggregate level. ■

2.4. Celebrities

Some communities may adjust to increasing cultural openness q sooner than others. This section analyzes how such cultural invaders differ from the general population that lags behind.

Suppose cultural openness has recently increased from some q_1 to $q_2 > q_1$, but almost all population has culture adapted to the obsolete value q_1; specifically, the system (19,A.6) results in aggregate growth rate r and in (underestimated) cultural productivity Q_1 that both correspond to q_1. Note that, because cultural openness q does not directly affect population growth rate, only via chosen lifestyles, an increase in true q does not affect the true aggregate r. The aggregate follower-role model ratio is then (cf.(18)) $R(Q_1, r)$.

Suppose further that a small fraction of population ϵ has adapted to the new value of q. Because they are better adapted to the new environment, their community rate of growth should exceed that of the general population. This means that the new lifestyle gradually spreads to the general population; for this reason, we will denote these cultural invaders as celebrities. As the culture of celebrities spreads, the rate of population growth of both new and old cultures will decline and, as Proposition 3 shows, will eventually fall below the initial level of r.

How will their lifestyles differ from those of the general population? Analyzing time-varying population growth rates is a cumbersome task. Moreover, it is unlikely that random

cultural selection can perfectly adjust to future changes in r. For this reason, we will assume that celebrities behave as if their population growth was equal to r, which is an underestimate initially but an overestimate in the long run.

Then, the perceived cultural productivity of celebrities is $Q_2 = \frac{q_2}{1-q_2}\frac{R(Q_1,r)}{B(r)} > \frac{q_1}{1-q_1}\frac{R(Q_1,r)}{B(r)} = Q_1$. But then, theorems 1 and 2 can be directly applied to conclude that celebrities consume more, live longer, and have lower fertility. Section 3 verifies these theoretical predictions.

3. Empirical evidence

The lives of the two most frequently cited founding fathers of the Homo economicus concept, Adam Smith and John Stuart Mill,[8] match closely the properties of celebrities of section 2.4. Both had no children and lived fairly long lives by the standards of their time, 67 and 66 years, respectively. And they indeed became celebrities, as their views of human goals have spread to the extent that they became the standard of economics profession. Montagu (1994) studies life expectancy of famous men from antiquity, as listed by the Oxford Classical Dictionary. Dropping those who died from violent deaths, average lifespan of remaining celebrities is 72 years, which is equal with high degree of statistical confidence to that of their counterparts from the same dictionary who died between 1900 and 1950. de la Croix and Licandro (2015) study a rich dataset of 300000 famous individuals from the entire human history and conclude that their life expectancy has always been significantly higher than that of the general population and, moreover, started to increase at least a century before that of the general population. These observations confirm the idea that fame has always selected long-lived individuals, and that celebrities pioneered demographic change. This section verifies the key empirical predictions of section 2.4 with tests specifically designed for that purpose.

[8] E.g. as cited in the Wikipedia page about the Homo economicus.

We identify celebrities as those listed in the Pantheon 1.0 dataset (Yu et al., 2016). This dataset includes all individuals whose biographical Wikipedia pages were translated into at least 25 languages as of May 2013, totalling 11341 individuals. For each individual, the dataset provides the year and location of birth, gender, occupation, as well as some measures of their popularity on Wikipedia. To be able to test our hypotheses, we complement the data about celebrities with additional bot- and hand-collected information.

Due to the fact that each Wikipedia page is linked to an entry in Wikidata which harmonizes biographical information, much of additional data was collected through automated queries. In particular, for celebrities who died before July 2018, we automatically collect the year and location of death (Wikidata properties P570 and P20, respectively).

Because much of the analysis is country-level, we need to identify to which country each celebrity belongs. The original Pantheon dataset provides only birth data, which is not perfectly suitable for our purposes because celebrities often become influential far away from their place of birth.[9] Assuming that people tend to migrate to places where they have the best chance of becoming influential, we associate celebrities with their last known place of residence, if they were alive as of July 2018, and with their location of death otherwise.[10] The data on residence location is quite patchy so we used several Wikidata properties, as follows. The most preferred source was "location of residence" (Wikidata property P551), followed by "location of work" (P937), "empoyer" (P108), and "educated at" (P69). This process yielded 4060 distinct entities related to the lives of celebrities; of them, all but 285 were associated with a specific geographic coordinate. For the remaining missing coordinates, a manual search was conducted. Many entities were corporations, for which the headquarters location was used. Some were music bands (e.g. Metallica), in which case we used the

[9] E.g. Freddie Mercury was born in Tanzania.

[10] This method can still mislocate influential individuals, as some of them die in transport accidents away from home (Lech Kaczyński) or in exile (Napoleon). But manual verification shows that the margin of error is sufficiently small, while the cost of more accurate information is high.

"location of formation" property. Eventually, 245 entries were manually associated with a geographic location; the remaining 40 entries are mostly ancient states or regions which were not used in the analysis.

If the above procedure failed to link a celebrity to a specific geographic coordinate, the location of birth from the original Pantheon database was used. The collected location information was then used to associate each celebrity with a modern country.

3.1. Celebrities are different

This section tests whether fertility and mortality of celebrities differ from those of the general population. Because the celebrity status may be correlated with educational level which strongly affects both fertility and mortality, we studied biographies of celebrities to collect their educational data. Such data was collected in a three-stage process.

Degree information. First, for each celebrity the Wikidata information on "academic degree" was trawled (variable P512, either as separate property or as a qualifier for "educated at" property). We ended up with 133 distinct degrees, of which 9 were ignored as they did not provide conclusive information about the degree obtained (e.g. "physician", "student") while the remaining were manually classified into Bachelors, Masters and Doctorate educational levels. For celebrities with multiple degrees, the highest educational level was used.

School information. For the majority of celebrities, however, no degree data was available, which could mean either lack of tertiary education or, in most cases, omitted information. To fill the gaps, the have further collected the Wikidata information on schools which celebrities attended ("educated at" property, P69), which resulted in 1252 unique institutions. For each institution, we downloaded the school category ("instance of" property, P31); at least one entry is available in 97% of cases, and multiple entries are frequent. For example Hamburg University of Technology belongs to two categories, "institute of technology" and "public university". For the resultant 143 categories, we attempted to manually classify them

into those associated with three levels of education: primary, secondary and tertiary. For 45% of school categories, no such classification could be done ("school", "nonprofit organization"). Then, given the three-level classification of school categories, we attempt to associate each school with one of the three educational levels, with manual verification whenever different categories of the same school provided conflicting educational levels. As a result, 85% of schools were matched to one of educational levels. Finally, for each celebrity without degree information, we impute their educational level from the level of the school they are known to have attended.

Hand-collected information. After two previous stages of data collection, for many celebrities educational information was still unavailable. Moreover, bot-collected data can both underestimate (if some information is not available in Wikidata) and overestimate (if a celebrity attended but dropped out of a school, e.g. Julia Roberts) the educational level. For this reason, we manually searched biographical information on education of celebrities of interest, i.e. of those to be compared against the general population, as detailed below.

First, we studied educational backgrounds of all 387 celebrities whose data was used in education-controlled fertility comparisons. In 43 cases, bot-collected educational level was downgraded, in 4 cases upgraded, in 105 cases, unspecified tertiary education was replaced by a specific degree, and in 125 cases, missing educational information was filled. For 9 celebrities, no educational information could be found (e.g. Sophia Loren, Martha Argerich); the author's best guess about their educational background, based on their biographical data, was used.

For education-controlled mortality comparisons, we did not verify bot-collected data, and studied manually only celebrities without any such data, 116 individuals total. As the previous paragraph suggests, bot-collected data tends to somewhat overstate education of celebrities, as many of those related to show business drop out of college. Such measurement error can only reinforce the conclusions of this study, as overstated education will take away

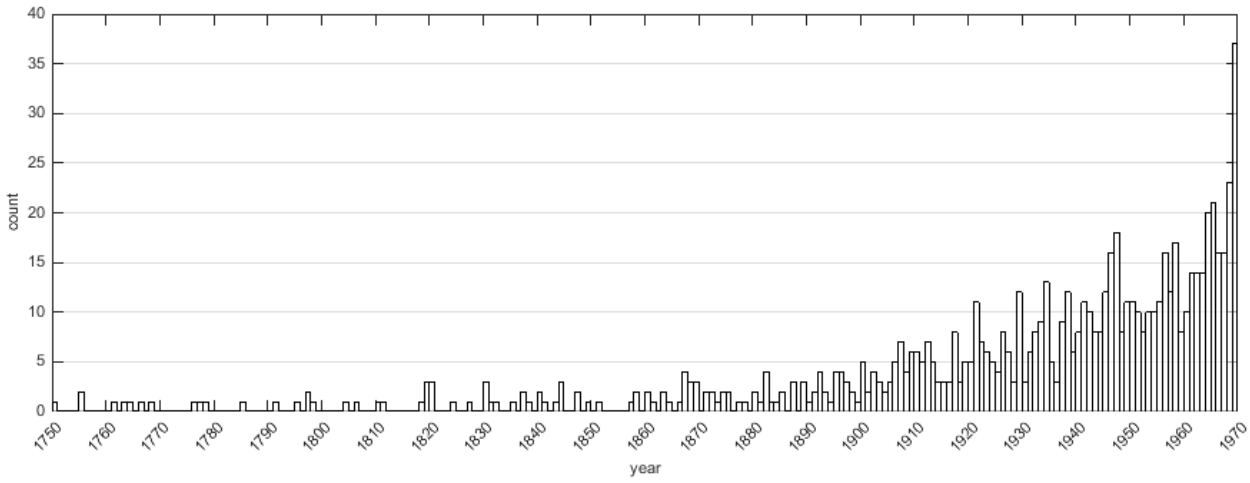

Figure 1: Celebrity women by year of birth

part of true correlation between fame and mortality.

3.1.1. Fertility

Data. The theory of section 2.4 predicts that celebrities have lower fertility. To test the hypothesis, we collect the data on the number of biological children born by 760 women from the Pantheon dataset who were themselves born between 1750 and 1970 and lived 45 years or more. The focus on women is due to lower error in measurement of the number of children, as well as due to the assumption that fertility choices of men may simply crowd in/out other men rather than affect the total number of births. The focus on age 45+ is because younger women may have not completed their fertility. Women born before 1750 were dropped due to poor information on both celebrities and their general-population counterparts. We will refer to the 760 women as the fertility subsample. Figure 1 displays the distribution of their birth years.

While Wikidata has the "number of children" entry (P1971), the information is often missing or incorrect. For this reason, we studied the biography of each of 760 women and recorded the most credible information on the number of live births.[11]

[11]For each observation, the url of the information source was recorded and is available on request.

Number of children	Count
None	239
1	175
2	186
3	89
4	33
5 or more	38
Total	760

Table 1: Celebrity women by number of children

Table 1 visualizes the distribution of the number of children in the fertility subsample. A casual observation of the data is consistent with the low-fertility hypothesis. Out of ten women whose Wikipedia pages were available in 100+ languages as of 2013, four (Angela Merkel, Frida Kahlo, Mother Teresa, Lila Downs) had no biological children at all, while another four (Sarah Bernhardt, Marlene Dietrich, Hillary Clinton, Hebe Camargo) had only one.

Uncontrolled comparisons. The first formal test we conduct is to calculate the difference between the number of children of each celebrity and average number of children in the matching general population. For each celebrity in the fertility subsample, define the *control group* as women born in the same year and living in the same country. The primary source of control group fertility information is the Human Fertility Database[12] which provides an unbalanced panel of yearly cohort fertility rates (CFR) for about 30 countries, starting from birth year 1876. For other countries, we use the UN "World fertility data 2012"[13] which provides estimates of "children ever born" for women from all world countries, with 3-5 observations per country beginning from survey year 1960. To fill observations that were still missing, we used the Total Fertility Rate (TFR) estimate as provided by Gapminder

[12]Human Fertility Database. Max Planck Institute for Demographic Research (Germany) and Vienna Institute of Demography (Austria). Available at www.humanfertility.org.

[13]United Nations, Department of Economic and Social Affairs, Population Division (2013). World Fertility Data 2012 (POP/DB/Fert/Rev2012).

Region	# of countries	Relative fertility	# of observations
United States	1	-1.00(-11.07)	345
Other North America	5	-2.37(-4.81)	18
United Kingdom	1	-0.83(-4.59)	87
France	1	-0.97(-5.28)	69
Germany	1	-0.55(-1.14)	24
Italy	1	-1.17(-2.83)	20
Switzerland	1	-0.67(-1.53)	19
Russia	1	-2.10(-3.96)	19
Other Europe	24	-0.93(-4.82)	81
Asia	15	-2.67(-9.73)	38
Australia, New Zealand	2	-0.42(-0.86)	12
Africa	7	-3.83(-6.18)	11
Argentina, Brazil, Peru	3	-2.54(-4.45)	8
World	63	-1.15(-17.17)	751

Table 2: Celebrity fertility, relative to general population, by region of residence. t-statistic for zero relative ferility hypothesis in parentheses.

dataset,[14] assuming that the TFR in year t corresponds to CFR for women born in year $t - 32$.[15] Eventually, for 751 out of 760 celebrities a control group data could be found. Table 2 visualizes relative fertility, i.e. the average difference between celebrity fertility and that of the control group, for multiple regions of the world, and tests the hypothesis that such relative fertility is zero. For most parts of the world and for the world overall, the hypothesis is rejected at a high confidence level.

Controlling for education. Much of correlation between fame and fertility can be due to education which is strongly correlated with both. We now test whether the relationship survives the inclusion of education as a control variable.[16] The aggregate data on fertility by educational level is generally unavailable, so we turn to nationally representative micro-level data to construct matching general-population control group for each celebrity. Specifically,

[14]Free data from www.gapminder.org.

[15]Such formula is the best fit between CFR and TFR for country-year pairs with both measures available.

[16]Personal income is strongly correlated with celebrity status, but its effect on fertility is believed to be either weakly positive or zero (Clark, 2005), thus not a threat to our empirical conclusions. Moreover, the data on celebrity income is generally unavailable. For these reasons, we do not control for income.

Educational level	Relative fertility	# of observations
Primary	-1.07(-2.17)	24
High school	-0.78(-5.65)	126
College	-0.32(-3.51)	217
Total	-0.53(-6.62)	367

Table 3: Fertility of celebrity women, relative to general population, by educational level. t-statistic for zero relative fertility hypothesis in parentheses.

Celebrity year of birth	Relative fertility	# of observations
1892-1910	-1.30(-4.17)	37
1911-1920	-0.50(-1.79)	32
1921-1930	-0.50(-2.03)	38
1931-1940	-0.64(-2.65)	37
1941-1950	-0.08(-0.33)	68
1951-1960	-0.51(-3.40)	55
1961-1970	-0.54(-4.44)	100

Table 4: Fertility of celebrity women, relative to general population, by year of birth. t-statistic for zero relative fertility hypothesis in parentheses.

we use Integrated Public Use Microdata Series database which aggregates and harmonizes 321 census samples from 90 countries (Minnesota Population Center, 2018), as well as the US Current Population Survey (CPS, Flood et al. (2018)). For each celebrity from our own fertility subsample born in year t, we defined the control group as women from these two databases who resided in the same country, had the same educational level, and were born within the interval $[t-5, t+5]$.[17] Overall, we were able to construct a control group with at least one observation for 367 celebrities from 21 countries, born between 1892 and 1970, of which 314 are from the United States. Table 3 displays relative fertility by educational level, proving that celebrities have lower fertility regardless of their education. Table 4 shows education-controlled fertility differences by celebrity year of birth; no specific time trend can be seen.

Because the CPS database has more detailed educational information, with a specific

[17]Thus, the control group includes women as young as 40 years old who did not yet complete their fertility; such measurement error reinforces our empirical conclusions.

Academic degree	Relative fertility	# of observations
Primary education	0.77(0.58)	7
High school	-0.54(-3.63)	84
Bachelor's degree	-0.31(-1.74)	83
Master's degree	-0.50(-2.12)	26
Doctorate degree	-0.50(-2.91)	24
Total	-0.40(-4.01)	224

Table 5: Fertility of celebrity women, relative to general population, by academic degree. t-statistic for zero relative fertility hypothesis in parentheses.

tertiary degree, we can analyze celebrity fertility controlling for such degree. A total of 224 US-based celebrity women with degree data born between 1926 and 1970 had a matching control group from the CPS database; table 5 demonstrates education-controlled fertility comparisons. Celebrity status seems to have a uniform negative impact on fertility, regardless of academic degree.

To summarize, we found a strong and robust negative relationship between celebrity status and fertility, in line with theoretical prediction of Section 2.4.

3.1.2. Mortality

Section 2.4 predicts that celebrities live longer. To test this relationship, controlling for individual characteristics, it is necessary to observe life histories of not only celebrities but also those of the general population. For that purpose, we use the US Panel Study of Income Dynamics (PSID), due to large number of celebrities from the United States and long time span of the PSID data.

Because education is an important predictor of mortality and is strongly correlated with the celebrity status, it must be controlled for. PSID collects detailed educational data beginning from 1985, so we look at individual survival beginning from that year. We focus on individuals aged 50+ as younger individuals have negligible mortality.

Our empirical strategy is to divide the lifespan of each qualified individual in both PSID and Pantheon 1.0 samples into 6-year periods, beginning from age 50 or year 1985 (whichever

	Full sample	Tertiary education only
	6-year mortality	
celebrity	-0.149***(-3.58)	-0.116*(-2.08)
age	-0.0878***(-6.92)	-0.149***(-5.96)
age squared	0.00107***(11.47)	0.00152***(8.36)
female	-0.254***(-9.77)	-0.113(-1.80)
tertiary education	-0.381***(-10.62)	
year	-0.00865***(-5.80)	-0.00991**(-3.09)
Constant	17.48***(5.68)	21.56**(3.28)
Observations	20187	6210

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 6: Predictors of mortality: probit regression.

happened later), and run a probit regression that explains 6-year mortality outcomes by celebrity status, age, education, gender, and the time trend. Because the last PSID dataset is from 2015, the last such period begins in 2009.

For most of PSID history, detailed educational information was collected only for household heads and their wives, so we have to drop individuals who have never been in such status. We believe that the resultant bias is small because most individuals acquire such status by age 50. We also drop the Latino subsample of PSID, because its short data span makes it unsuitable for mortality studies. Eventually, 16510 person-period observations from 8053 PSID individuals were used in the analysis. Of these individuals, 54% were women, 18% had tertiary education; the oldest was born in 1887 and the youngest in 1959.

For most qualified celebrities, educational information was bot-collected and often did not include a specific tertiary degree. At the same time, for PSID individuals for whom such information is available, a hypothesis that people with different tertiary degrees have equal mortality cannot be rejected, so we proxy education by a tertiary degree dummy. Overall, 3677 person-period observations from 1223 celebrity individuals were used. Among them 17% were women, 83% had tertiary degree; the birthyear range is identical to that of the PSID sample.

The first column of table 6 displays the regression output for the entire sample. All regressors are significant and have the expected sign. Consistently with theory of section 2.4, celebrities have significantly lower mortality.

A potential threat to this result is omitted income variable, which is generally unavailable for celebrities. One might expect that celebrities have higher incomes, and if income reduces mortality, the regression results may be spurious. The study of mortality literature reveals that the relationship between income and mortality is quite weak for those in the upper social strata (Backlund et al. (1996),Backlund et al. (1999)), thus the potential omitted variable bias can be minimized by focusing on those with higher education. The second column of table 6 reports the results. Although the effect of celebrity status is reduced, it still remains significant at the 95% level. The results of the regression imply that a typical college-educated male who was born in 1925 and survived until 1985 was expected to live another 24.1 years, while his celebrity counterpart lived 1.5 years more. Also note that, due to data limitations, this analysis was focused on mortality 150 years after the onset of the demographic transition, by which time, as theory predicts, a typical lifestyle should have largely converged to that of celebrities.

To summarize, this section finds evidence that celebrities indeed live longer than the general population.

3.2. Celebrities are influential

Section 2.4 predicts that a larger initial number of celebrities should lead to a faster spread of their values to the general population, thus should be associated with lower birth and death rates at some later point in time. This section looks for empirical evidence in support of this hypothesis. Because it is not known exactly who was influenced by which

celebrity,[18] our analysis is based on very loose assumptions about such influence and is therefore subject to large measurement error in the main explanatory variable.

Modern empirical literature usually identifies the effect of A on B by seeking an exogenous variation in A. In case of celebrity influence, there is no such thing as exogenous variation in the number of celebrities, because the celebrity status of a person cannot be identified ex-ante and is only observed after the person becomes popular. We also cannot use previous generations of celebrities as an instrument, because their influence can be long-lived and have a direct effect on present outcomes. This section is limited to Granger-type causality, i.e. to verification whether higher number of celebrities per capita precedes demographic changes.

I assume that influence has certain geographic and time limits; then, within these limits we create per-capita measures of the number of influential celebrities, and study whether the variation in this influence measure can explain variation in birth and death rates.

The geography of influence is assumed to be limited to national borders. This assumption is justified by the idea that country borders often separate different ethnicities whose cultural contact with each other is restricted by linguistic barriers. Geographic limits of influence were especially tight before the advent of television which dramatically reduced the cost of cultural influence; we therefore hypothesize that the country-level density of celebrity population was more strongly correlated with subsequent aggregate outcomes before 1950, i.e. before television became available.

The time span of influence is assumed to be different for birth- and death rates. Specifically, I assume that a celebrity can influence birth rates within her country of residence, during 100 years beginning from age 30.[19] For death rate influence, a similar interval was

[18] A hypothetical data allowing to study this question would be a survey which explicitly asks respondents to identify their role models.

[19] While some celebrities indeed remain influential for a longer time period, their influence is more likely to spread across national borders and therefore less likely to be identified by our analysis.

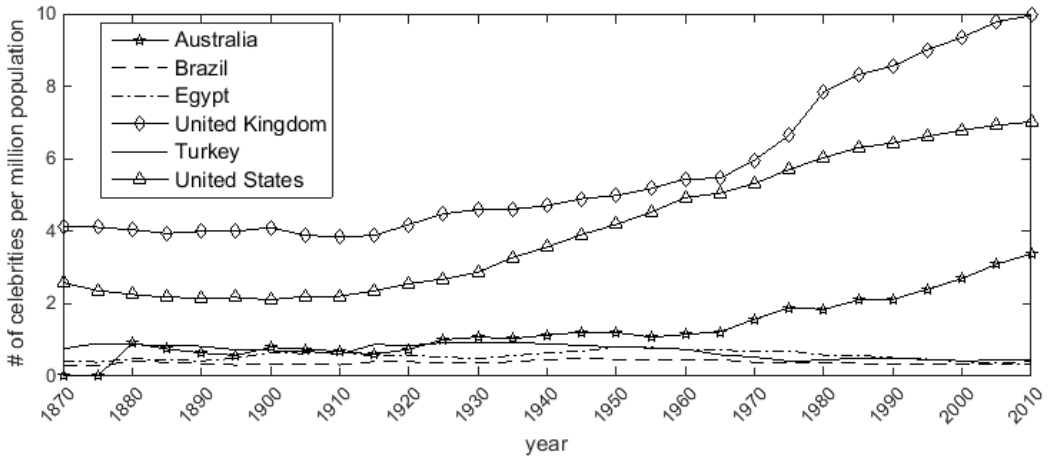

Figure 2: Overall birthrate influence for selected countries

used but starting from age 50. Due to such loose assumptions about the timing of influence, we cannot identify the effects of influence from within-country variation alone, and therefore cannot use country fixed effects in the regressions. Random-effects models were used instead.

For a per capita measure of influence, population data was primarily taken from the Maddison dataset (Bolt et al., 2018), complemented by census data from Iceland, Luxembourg, Russia, and from the Gapminder dataset. Eventually, we end up with three balanced panels of influence: overall and female influence for birth rates (to test whether female celebrities have a different effect), as well as both-gender influence for death rates. Each panel is for 166 modern countries of the world, with the time span from 1870 until 2010 with 5-year intervals. In 1870, 57 countries had positive measures of overall influence for birth rates, 19 had positive female influence for birth rates, and 52 had positive influence for death rates. In 2010, the respective numbers are 158, 72, and 154. Figure 2 illustrates the dynamics of overall birthrate influence for selected countries.

In our regressions, we control for aggregate levels of education and income. The education is measured by total years of schooling, population aged 15-64, as provided by Barro and Lee (2013). This is a balanced panel of 111 countries, with gender-specific observations every 5 years from 1870 to 2010. Income is GDP per capita as measured by the Maddison dataset

	1870-1950	1870-1950	1955-2010	1955-2010
	Crude birth rate			
Influence, both genders	-0.656**(-3.19)	-0.613***(-3.46)	-0.210(-1.45)	0.0695(0.80)
Influence, women	0.555 (0.42)		1.197*(2.41)	
Log GDP per capita	1.656*(1.97)	1.666*(1.99)	-0.970**(-3.14)	-0.980**(-3.17)
Total years of schooling	-2.430***(-8.52)	-2.433***(-8.57)	-2.471***(-19.33)	-2.501***(-19.62)
Observation year	-0.0365*(-2.30)	-0.0365*(-2.32)	-0.0410**(-3.01)	-0.0358**(-2.66)
Constant	96.40**(3.26)	96.37**(3.27)	132.7***(4.98)	122.5***(4.65)
Observations	571	571	1211	1211

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 7: Celebrity influence on birth rates. Country random effects included.

(Bolt et al., 2018).

3.2.1. Birth rate

To study whether celebrities impact fertility, we use crude birth rate as the dependent variable. The data from 1960 onward was taken from World Development Indicators. Otherwise, we use the National Center for Health Statistic for the US birth rates, and Gapminder data (which aggregates multiple sources) for other countries. Finally, we end up with 2588 non-missing birthrate observations, with data availability increasing from 21 countries in 1870 to all 166 countries in 2010. For education, we use data for females only, as it is believed to impact fertility more strongly.

Table 7 reports the results of a random-effects panel regression of birth rate on measures of influence, education, income, and time trend. To verify that influence was more local before the television era, we run separate regressions for years 1870-1950 (with data for 51 countries) and 1955-2010 (106 countries). The effect of female celebrity density has unexpected sign but is insignificant, which can be explained by small number of celebrity females in the sample and therefore large measurement errors in their per-capita density. The effect of overall influence from both genders is negative and significant before 1950, in line with theory of Section 2.4: according to the second column of table 7, one extra celebrity

born within $[30, 130]$ years prior to year $t \in [1870, 1950]$, per million population in year t, reduced the birthrate in year t by 0.613 children per 1000 population. In other words, the life of each celebrity results in roughly 613 unborn children per year, within the time span of celebrity influence. After 1950, such effect becomes insignificant, which can be explained by increasing globalization of influence as detailed above.

3.2.2. Death rate

To analyze the effect of celebrities on death rates, we use the Human Mortality Database[20] which provides age- and gender-specific mortality rates at 5-year intervals for 40 countries, from 1750 to 2015. We focus on ages 40-90, as younger individuals have negligible death rates, while older population is too thin and thus the death rate measures are subject to large error. Overall, we have 54468 country-year-age-gender observations from 31 countries with non-missing data. We regress the logarithm of death rates on the measure of celebrity influence, gender-specific education (also including gender-education interaction), log GDP per capita, as well as age-gender fixed effects and observation year fixed effects. Country random effects were also included. We run separate regressions for years before and after 1950, to address the hypothesis that country-level effect was stronger before the television era. The total number of countries is 22 before year 1950 and 31 thereafter. To check for robustness of results, we also run the regressions for death rates at two specific ages, 50 and 75. Table 8 reports the results.

Consistently with the theory, the estimated effect of celebrity influence on death rates is negative and robust across regression specifications. After year 1950, the nation-level effect is three times as low, presumably because it becomes increasingly international. According to column 1 of table 8, one extra celebrity per million population reduced the aggregate

[20]Human Mortality Database. University of California, Berkeley (USA), and Max Planck Institute for Demographic Research (Germany). Available at www.mortality.org or www.humanmortality.de (data downloaded on October 17, 2018).

	Ages 40-90, 1870-1950	Age 50, 1870-1950	Age 75, 1870-1950	Ages 40-90, 1955-2010
		Log death rate		
Celebrity influence	-0.0271***	-0.0251***	-0.0121**	-0.00696***
	(-18.07)	(-3.68)	(-2.59)	(-10.28)
Total years of schooling	0.0333***	0.0353**	0.0180*	0.0570***
	(13.21)	(2.87)	(2.19)	(37.71)
(Schooling)x(Female)	-0.0130***	-0.00559	-0.0168***	-0.0172***
	(-12.56)	(-0.97)	(-4.62)	(-21.91)
Log GDP per capita	0.0824***	0.0341	0.0722**	-0.269***
	(10.81)	(0.91)	(2.91)	(-54.67)
Age-gender fixed effect	yes			yes
Female		-0.258***	-0.0598***	
		(-8.98)	(-3.30)	
Year fixed effect	yes	yes	yes	yes
Observations	20400	400	400	34068

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 8: Celebrity influence on death rates. Country random effects included.

death rate by 2.71% before year 1950. For example, in USA in 1930 where the aggregate death rate was 11.3 per 1000 population, the above finding implies that the influence from each celebrity resulted in $11300 \times 0.0271 \approx 306$ fewer deaths.

4. Conclusion

This paper explains the evolution in human lifecycle decisions, and apparent shift in preferences, by changing patterns of cultural transmission. In the Malthusian era with culturally isolated communities, humans focus on population growth, and their behavior fits the model or Robson and Kaplan (2003): high donations to young population, modest consumption of adults, and no support of old age. Rising cultural openness favors new cultural traits which induce their hosts to attract cultural followers from outside own family by posing as influential role models. As this new channel of cultural "reproduction" is less sensitive to age than physical reproduction, new cultural traits prescribe their hosts to reduce

fertility and invest more in own longevity by consuming more and making arrangements for the old age.

Individuals who embrace new cultural traits sooner become *celebrities* as their way of life is copied by many. The empirical part of the paper finds a negative relationship between celebrity status, on the one hand, and fertility and mortality, on the other. We also find evidence that a higher number of celebrities per capita in a country is associated with lower birth and death rates in the future, in line with the theory that their way of life spreads to the general population.

At the same time, the existing data is not well-suited for studies of cultural transmission among non-relatives. Conducting surveys which directly ask respondents to identify their role models would be the best practice for empirical studies of the phenomenon.

On the policy side, reducing of the cost of oblique cultural transmission can be instrumental in reducing global population growth and increasing life expectancy. A better connection of poor nations to the Internet may become a cheap and effective method to increase people's focus on health and economic prosperity.

Appendix A. Proofs

Proof of proposition 1

Denote $s(a) \equiv \frac{p(a,c(\cdot))}{p(a_1,c(\cdot))}, a \in [0, a_1)$. It satisfies

$$s(a_1) = 1, \dot{s}(a) = -\mu(c(a))s(a), a \in [0, a_1). \tag{A.1}$$

Maximization of (10) is equivalent to minimization of the following:

$$C_0 s(0) + \int_{a=0}^{a_1} e^{-ra} s(a) c(a) \mathrm{d}a, \tag{A.2}$$

subject to (A.1). The Hamiltonian of the minimization problem reads $\mathcal{H}(s(\cdot),\lambda(\cdot),c(\cdot)) = e^{-ra}s(a)c(a) - \lambda(a)\mu(c(a))s(a)$. Optimal consumption is found from $\frac{\partial \mathcal{H}}{\partial c} = 0$, i.e. from

$$e^{ra}\lambda(a)\mu'(c(a)) = 1. \tag{A.3}$$

The costate function $\lambda(\cdot)$ is found from the following:

$$-\dot{\lambda}(a) = \frac{\partial \mathcal{H}}{\partial s} = e^{-ra}c(a) - \lambda(a)\mu(c(a)) \tag{A.4}$$

with the initial condition $\lambda(0) = -C_0$. By comparing (12) and (A.4), it is straightforward to verify that $V_1(a) \equiv -\lambda(a)e^{ra}$; but then, (11) is identical to (A.3), which proves the first sentence of the Proposition. Furthermore, from (2,3,5) it follows that $V_0(0) = C_0 = V_1(0)$, while differentiation of (5) with respect to a yields the same result as in (12). Therefore, $V_0(a) \equiv V_1(a), a \in [0, a_1)$, which, by comparison of (4) and (11), means the consumption path is identical to that of Section 2.1.■

Proof of proposition 2

From (15), consumption at age a, $c(a,Q,r)$, increases monotonically with the value of life $V_2(a,Q,r)$. Because this value is maximized over $c(\cdot)$ at every age,

$$\frac{\mathrm{d}V_2(a,Q,r)}{\mathrm{d}r} = \frac{\partial V_2(a,Q,r)}{\partial r} = -\frac{1}{p_1(a,c(\cdot))}\int_{t=a}^{a_3}(t-a)z(t,r)\mathrm{d}t, \tag{A.5}$$

where $z(t,r) \equiv e^{-r(t-a)}\left(y(t) - c(t) + Q\right)p_1(t,c(\cdot))$. The integral in (A.5) can be rewritten as $w_1z_1 + w_2z_2$, where $z_1 = \int_{t=a}^{a^\star} z(t,r)\mathrm{d}t$ for arbitrary $a^\star \in (a,a_3)$, $z_2 = \int_{t=a^\star}^{a_3} z(t,r)\mathrm{d}t$, and where $0 < \frac{\int_{t=a}^{a^\star}(t-a)z(t,r)}{z_1} \equiv w_1 < w_2 \equiv \frac{\int_{t=a^\star}^{a_3}(t-a)z(t,r)}{z_2}$. Notice that $\frac{z_1+z_2}{p_1(a)} = V_2(a,Q,r)$ and therefore $z_1+z_2 > 0$. Likewise, $\frac{z_2}{p_1(a^\star)} = V_2(a^\star,Q,r)$ and therefore $z_2 > 0$. Multiplying z_1+z_2 by $w_1 > 0$ and adding to $(w_2-w_1)z_2 > 0$, we obtain $w_1z_1 + w_2z_2 > 0$ and therefore (A.5) is negative. Thus, higher r lowers $V_2(a,Q,r)$, which lowers $c(a,Q,r)$.■

Proof of proposition 3

The cultural productivity is equal to (cf.(17,18)) $Q \equiv \frac{q}{1-q}\frac{1}{B(r)C_0G(c(\cdot,Q,r),r)}$ or, in logarithmic terms,

$$M_Q(Q,r) \equiv \ln B(r) + \ln Q + \ln C_0 + \ln G(c(\cdot,Q,r),r) \equiv \ln q - \ln(1-q). \tag{A.6}$$

The system (19,A.6) defines Q, r as an implicit function of q; the derivatives $\frac{\mathrm{d}Q}{\mathrm{d}q}$ and $\frac{\mathrm{d}r}{\mathrm{d}q}$ can be found from this system as follows:

$$\begin{pmatrix} M_{rr} & M_{rQ} \\ M_{Qr} & M_{QQ} \end{pmatrix} \begin{pmatrix} \mathrm{d}r \\ \mathrm{d}Q \end{pmatrix} = \begin{pmatrix} 0 \\ \frac{1}{q(1-q)} \end{pmatrix} \mathrm{d}q. \tag{A.7}$$

Here $M_{rr} = \frac{\mathrm{d}M_r}{\mathrm{d}r} = \frac{B'(r)}{B(r)} + \frac{1}{F(\cdot)}\frac{\mathrm{d}F(c(\cdot,Q,r),r)}{\mathrm{d}r}$, where $B'(r) < 0$ by (13). The direct effect of r on $F(c(\cdot,Q,r),r)$ is negative while the indirect, via $c(\cdot,Q,r)$, is positive for $Q > 0$:[21] higher r decreases consumption (proposition 2) which reduces life expectancy but increases fertility. The overall effect is generally non-monotone, but $F(c(\cdot,Q,r),r)$ obviously converges to zero as r goes to infinity, thus $\frac{\mathrm{d}F}{\mathrm{d}r} < 0$ for large enough r. We will assume the equilibrium rate r is within such range, thus $M_{rr} < 0$.

The signs of other elements in (A.7) are more straightforward. $M_{rQ} = \frac{\mathrm{d}M_r}{\mathrm{d}Q} = \frac{1}{F(\cdot)}\frac{\mathrm{d}F(\cdot)}{\mathrm{d}Q} < 0$ by theorem 2; $M_{Qr} = \frac{\mathrm{d}M_Q}{\mathrm{d}r} = \frac{B'(r)}{B(r)} + \frac{1}{G(\cdot)}\frac{\mathrm{d}G(\cdot)}{\mathrm{d}r} < 0$ because higher r decreases consumption at every age (proposition 2), thus decreases survival to any given age; $M_{QQ} = \frac{\mathrm{d}M_Q}{\mathrm{d}Q} = \frac{1}{Q} + \frac{1}{G(\cdot)}\frac{\mathrm{d}G(\cdot)}{\mathrm{d}Q} > 0$ by theorem 1.

[21] The indirect effect is zero for the Homo sapiens ($Q = 0$), because in this case consumption is chosen to maximize fertility.

But then, the effects of q on Q, r are found from (A.7) as follows:

$$\begin{pmatrix} \frac{\mathrm{d}r}{\mathrm{d}q} \\ \frac{\mathrm{d}Q}{\mathrm{d}q} \end{pmatrix} = \frac{1}{M_{rr}M_{QQ} - M_{rQ}M_{Qr}} \frac{1}{q(1-q)} \begin{pmatrix} -M_{rQ} \\ M_{rr} \end{pmatrix} \begin{matrix} < 0 \\ > 0 \end{matrix} . \tag{A.8}$$

■

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