DISCUSSION PAPER SERIES

IZA DP No. 9268

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August 2015

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zur Zukunft der Arbeit
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Discussion Paper No. 9268
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ABSTRACT

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We analyze the economic consequences for less developed countries of investing in female health. In so doing we introduce a novel micro-founded dynamic general equilibrium framework in which parents trade off the number of children against investments in their education and in which we allow for health-related gender differences in productivity. We show that better female health speeds up the demographic transition and thereby the take-off toward sustained economic growth. By contrast, male health improvements delay the transition and the take-off because *ceteris paribus* they raise fertility. According to our results, investing in female health is therefore an important lever for development policies. However, and without having to assume anti-female bias, we also show that households prefer male health improvements over female health improvements because they imply a larger static utility gain. This highlights the existence of a dynamic trade-off between the short-run interests of households and long-run development goals. Our numerical analysis shows that even small changes in female health can have a strong impact on the transition process to a higher income level in the long run. Our results are robust with regard to a number of extensions, most notably endogenous investment in health care.

JEL Classification: O11, I15, I25, J13, J16

Keywords: economic development, educational transition, female health, fertility transition, quality-quantity trade-off

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1 Introduction

The interplay between gender (in)equality and economic development has received considerable attention in recent literature.[1] However, a key aspect of gender inequality has to do with health, and this has not yet been thoroughly examined.[2] Generally, four channels appear to matter: (i) Healthy women are more able to participate productively in the labor market with direct consequences for effective labor supply and hence the level and growth of economic output. (ii) Better health increases the returns to educational investments: This occurs both through lower morbidity, allowing for greater labor market participation at the intensive margin, and lower mortality, affecting labor market participation at the extensive margin (Jayachandran and Lleras-Muney, 2009; Albanesi and Olivetti, 2014). (iii) Better health of mothers directly affects the health of children through *in utero* effects and the mothers' ability to breastfeed and nourish their children in other ways (Field et al., 2009). Female health thereby improves development prospects over the long run through direct intergenerational transmission of human capital (cf. Bloom et al., 2014a). (iv) Better female health may lower fertility and thus youth dependency with a knock-on effect on female labor participation and educational investments (Bloom et al., 2009). Lower fertility may arise as a direct consequence of improved reproductive health through availability of contraceptives (Bailey, 2006), but it is also triggered indirectly as a response to changes in the female opportunity costs of child rearing and changes in the returns to education. The consequence is a swing in the quality-quantity trade-off toward the quality of children (e.g. Galor and Weil, 2000; Soares and Falcão, 2008; de la Croix and Vander Donckt, 2010).

In this paper we develop a micro-founded dynamic general equilibrium model that examines some of the mechanisms by which improvements in female health can stimulate economic development. Overlapping generations of families choose consumption, numbers of children, and educational investments in their children. Education in turn translates into the stock of human capital of the next generation. We integrate decision-making at the household level into a two-sector economy, in which effective labor is either combined with a fixed factor in the production of goods or employed within an education sector. We solve for the dynamic general equilibrium and study the macroeconomic repercussions of individual choices, and thereby the conditions under which the economy switches from a low-growth regime that corresponds to a poverty trap with high fertility and no educational investments into a modern sustained growth regime with declining fertility and increasing educational investments. Note that we do not analyze the historical take-off to sustained

[1] See for example Galor and Weil (1996), Knowles et al. (2002), Lagerlöf (2003), Abu-Ghaida and Klasen (2004), Lagerlöf (2005), Iyigun and Walsh (2007), Soares and Falcão (2008), Doepke and Tertilt (2009), Kimura and Yasui (2010), Schober and Winter-Ebmer (2011), Rees and Riezman (2012), Diebolt and Perrin (2013a), Diebolt and Perrin (2013b), Doepke and Tertilt (2014), Hiller (2014), and Prettner and Strulik (2014) for the role and evolution of gender inequality in economic development.

[2] See Stenberg et al. (2014) for the potential effects of female health on economic development. An extensive systematic review of the economic and noneconomic literature on female health and its role for development is presented in Iversen et al. (2014).

long-run growth that is associated with the industrial revolution in currently industrialized countries. Rather we focus on contemporaneously poor countries that can benefit from technological spillovers from the rest of the world (for an appropriate description of the historical evolution from stagnation to growth see Galor and Weil, 2000).[3]

Our particular focus lies in the role of female health, which affects female labor productivity and female labor force participation for any given level of education. Two findings motivate this focus: First, health is a crucial element of human capital and, as such, represents a central determinant of individual productivity (cf. Bloom et al., 2004; Bloom and Canning, 2005; Prettner et al., 2013). Second, while women face a longer life span than men, they experience higher productivity losses due to greater morbidity during their working lives (cf. Bonilla and Rodriguez, 1993; Vos et al., 2012). Case and Paxson (2005) recently made some advances in our understanding of this female-male health paradox by identifying the crucial role of differences in the distribution of conditions over the sexes during younger ages, when women suffer to a greater extent from chronic conditions that are objectively associated with higher morbidity. For any given condition, however, males are typically affected more severely, which explains higher rates of male mortality.

We examine how household choices vary with the level of female health and what the implications are for macroeconomic outcomes. Specifically, we seek to understand whether better female health contributes to higher rates of economic growth and an earlier transition from stagnation to sustained economic growth. As healthier females have better access to the labor market (and higher earnings), raising children incurs a higher opportunity cost even within the high-fertility regime. This tends to enhance economic growth from technology adoption although the distinction may be insubstantial until the take-off. More importantly, better female health facilitates the economic transition in that it lowers the earnings threshold at which educational investments in children become profitable. These investments then trigger both the educational and demographic transition that underlie economic development. While this suggests a decidedly positive role for female health in economic development, an offsetting tendency exists. This is because greater participation of healthy women in the labor market raises aggregate labor supply, which in turn depresses earnings in the low-growth regime and, thereby, the incentive for households to undertake investments in education. However, we show both analytically and numerically that despite this offsetting effect, female health unambiguously speeds up the economic transition.

We contrast these findings with the impact of improvements in male health alone, as well as with equiproportional improvements in the health of both sexes. By a pure income effect, male health improvements tend to increase fertility and, thereby, slow down economic growth and the progress toward economic transition. For equiproportional health improvements for both sexes, we find that economic growth during the low-growth regime

[3]The article by Galor and Weil (2000) laid the foundations of unified growth theory. For other contributions and extensive overviews see e.g. Kögel and Prskawetz (2001), Jones (2001), Hansen and Prescott (2002), Galor and Moav (2002), Galor (2005), Galor and Moav (2006), Galor (2011), Doepke (2004), Cervellati and Sunde (2005), Strulik and Weisdorf (2008), and Strulik et al. (2013).

remains unaffected, while it rises in the sustained growth regime. Strikingly, this finding mirrors the empirical results of Cervellati and Sunde (2011), who find that health improvements foster growth of per capita income after the demographic transition but not prior to it. Furthermore, we find that equiproportional health investments promote the transition from low growth to sustained growth, although not to the same extent that female health investments alone do.

Taken as a whole, our findings suggest a distinct role for development policies targeted at female, rather than male, health improvements. Potential policies that are targeted to female health might include the reduction of iodine deficiency, which, during pregnancy, has a more severe negative effect on the cognitive abilities of female children than of male children (cf. Field et al., 2009), and vaccination against human papilloma virus to prevent cervical cancer, which is the second deadliest cancer among women in the developing world (cf. Luca et al., 2014). While such policies may be based on female disadvantage regarding access to health care to begin with,[4] our analysis suggests an additional rationale on development grounds: targeting female health tends to lead economies out of poverty traps or at least to significantly accelerate progress towards an economic take-off. Furthermore, female health tends to foster long-run growth prospects as well. However, targeting female rather than male health comes at a lower instantaneous utility gain to the household. This highlights a conflict between the short-term interests of utility-maximizing households and long-run development goals (cf. Duflo, 2012).

While we understand health and differences in health across genders to be exogenous for much of our analysis, we show in subsection 6.2 that our results are robust when allowing for endogenous and gender-specific investments in health. Notably, we show that men may be advantaged in terms of health investments and health outcomes as a consequence of households seeking to maximize their net income. This result is notable insofar as we do not have to resort to tastes or social norms to explain discrimination against women in terms of health and health care. Adding elements of taste-based discrimination would only strengthen our findings.

Unlike previous work that has focused on partial equilibrium or stable growth paths, we are able to characterize the impact of gender-specific health on the full process of economic development. This allows us to highlight the role of general equilibrium repercussions and to explicitly calculate the timing of the economic transition. By emphasizing the role of female health in economic development, our model bears some resemblance to the theoretical analyses in Jayachandran and Lleras-Muney (2009), Albanesi and Olivetti (2014), de la Croix and Vander Donckt (2010), and Agénor et al. (2010). The first two of these articles examine how fertility and educational choices at the household level depend on maternal mortality but do not extend this analysis into a macroeconomic framework. de la Croix and Vander Donckt (2010) consider the impact of female health, modeled as more

[4]See e.g. Deaton (2008) and Molini et al. (2010) for evidence that the distribution in height and BMI is biased against women, Bhalotra (2010) and Baird et al. (2011) for disproportionate mortality of girls in the presence of economic crisis, and Bloom et al. (2001) and Self and Grabowski (2012) for evidence on difficulties for women to access health care when they lack autonomy.

life years lived in good health, on fertility and gender-specific educational investments in a collective household model with Nash bargaining. While they can conclude that female health contributes to a transition to a low-fertility regime with educational investments in both male and female children, de la Croix and Vander Donckt's macroeconomic environment consists of an exogenous increase in wages over time. Thus, they are abstracting from general equilibrium effects that modulate the transition. While our framework features a simpler model of the household (although one that gives rise to similar mechanics), its general equilibrium formulation allows a complete analysis of macroeconomic dynamics. Furthermore, our framework allows us to explicitly calculate how gender-specific health investments affect the timing of the economic transition.[5] Finally, Agénor et al. (2010) consider a complex household model within a general equilibrium framework. Their work highlights the role of public infrastructure for accessing health care, thus giving the analysis a somewhat different focus. Furthermore, they concentrate on balanced growth paths, whereas we are particularly interested in the transition process.

The remainder of the paper is organized as follows. Section 2 introduces the model, solves for optimal choices at the household level, and sets out the market equilibrium. Section 3 is devoted to the dynamics of the model and develops our main result regarding the impact of female and male health on the economic transition, while Section 4 considers policy implications. Section 5 numerically characterizes the impact of gender-specific health on the development process. Section 6 shows that our results are robust with respect to collective household decision making, endogenous health, and the inclusion of physical capital, and Section 7 concludes.

2 The model

In this section we develop a simple analytically tractable dynamic general equilibrium model of economic development, featuring differences in male and female health. Time evolves discretely, and in generation t the economy is populated by $N_t/2$ couples formed out of a pool of N_t individuals. We assume that males and females pair randomly after coming of age. Each couple jointly decides on consumption, the number of children, and the educational investments in each child. The last two decisions determine the population growth rate and the individual human capital level, respectively, which then jointly determine the available aggregate human capital stock of the economy in the next generation $t + 1$.

The aggregate human capital stock net of the time that is spent on child rearing can be employed in two sectors: goods production and education. Educational investments of parents determine employment in the education sector, while aggregate consumption

[5] While not analyzing explicitly the role of female health but rather the effects of a general increase in longevity, Soares and Falcão (2008) nevertheless highlight several similar channels through which health improvements foster the economic-demographic transition by altering female labor supply and fertility. Similar to de la Croix and Vander Donckt (2010), their model, too, remains a partial equilibrium/household level analysis.

determines employment in final goods production. The only input in the education sector is teachers $L_{t,E}$, while final goods are produced by using workers $L_{t,Y}$, natural resources of fixed supply X, and the technologies available to generation t, denoted by A_t (see Galor and Weil, 2000). It is assumed that less developed countries have no research sector for the development of new technologies, but rather adopt technologies developed in more advanced countries. For a justification of this assumption see Jones (2002), Keller (2002), and Ha and Howitt (2007), who show that the most developed industrialized countries almost exclusively drive the technological frontier of the world. Following Benhabib and Spiegel (2005), p. 941, we model the speed of technology adoption as being positively influenced by the technological gap between the less developed countries and the technology leaders and negatively influenced by the gap in human capital. The former can be justified by the notion that the adoption of new technologies is more likely to pay off when the incremental outputs that can be produced by using them are larger (cf. Howitt, 2000; Acemoglu et al., 2006), while the latter can be justified by the notion that handling new technologies requires a certain amount of skills (cf. Nelson and Phelps, 1966).

2.1 Household choices

Consider a less developed economy populated by male-female couples whose preferences are captured by the following utility function:

$$u = \log(c_t) + \gamma \log(n_t) + \delta \log(\bar{e} + e_t), \tag{1}$$

where c_t denotes joint adult consumption, n_t refers to the number of children, e_t denotes investment in the education of the offspring, and $\bar{e}$ represents the education level that children have without any educational investments by their parents (cf. Strulik et al., 2013). The rationale for $\bar{e} > 0$ is that children acquire knowledge during childhood by observing parents and peers. The parameters γ and δ measure the utility weight of the number of children and their education, respectively. The budget constraint of the couple is given by

$$\xi_m \widehat{w}_t + \xi_f \widehat{w}_t(1 - \psi n_t) = c_t + e_t n_t, \tag{2}$$

where $\widehat{w}_t = w_t h_t$ refers to the wage rate per unit of time, depending on the human capital of adults, h_t, and the wage rate per unit of human capital, w_t.[6] The parameters ξ_m and ξ_f are measures of male and female productivity as determined by factors other than education, in particular by gender-specific health, and ψ refers to the fraction of time that is required for giving birth to and caring for one child. Thus, household income on the left-hand side of the equation is composed of the husband's and the wife's earnings, both not only increasing in the (common) level of human capital but also in gender-

[6] Note that we abstract from politically, socially, and institutionally motivated gender-specific wage discrimination. Incorporating such an analysis would not change our central results as long as discrimination was not too severe such that women were prohibited from labor market participation. However, it would come at a substantial reduction in expositional clarity.

specific productivity as determined by gender-specific health. Because, for developing countries, time use patterns show that the contribution of mothers to child care dwarfs the contribution of fathers (cf. Duflo, 2012), we set the male contribution to zero and assume that women shoulder the full burden of child care. Thus, female earnings are lowered by the (full) amount of time ψn_t required for bearing and rearing n_t children. This means that the quality-independent child costs are represented by foregone female earnings. By contrast, the quality-dependent child costs are represented by total educational expenditure $e_t n_t$ on the right-hand side of Equation (2).

The impact of health on productivity and therefore on earnings can be understood in two ways: First, ξ_m and ξ_f may represent health-dependent labor participation in the sense that only healthy time can be used for productive employment. According to data from the Global Burden of Disease Study, in 1990 males and females aged 30 live about 0.11 and 0.124 life years in disability (YLD), respectively (Institute for Health Metrics and Evaluation, 2013; Vos et al., 2012, p. 2184). Normalizing total time to unity, we would then obtain $\xi_m = 1 - YLD_m (= 0.89)$ and $\xi_f = 1 - YLD_f \ (= 0.876)$. Furthermore, case-study evidence indicates that the economic burden of disease (in terms of labor lost) at the household level primarily falls on females (cf. Bonilla and Rodriguez, 1993). We make the additional assumptions that child care has to be provided and that this can be done regardless of parental health status.[7] Given that child care is provided unconditionally, this implies that available working time is $1 - \psi n_t$, of which a share ξ_f is used effectively, whereas a share $1 - \xi_f$ is lost.[8]

Second, ξ_m and ξ_f may represent productivity at the work place, implying that (effective) wage rates are now given by $\xi_j \widehat{w}_t$, whereas male and female participation are given by 1 and $1 - \psi n_t$, respectively. Indeed, ample evidence shows that individual productivity increases with health.[9] While our analysis does not rely on *a priori* assumptions about the ordering of ξ_m and ξ_f, the literature on the male-female health gap suggests that $\xi_m \geq \xi_f$.[10] Lower female productivity may arise, for instance, due to iodine deficiency, a problem encountered in many developing countries, in particular in Sub-Saharan Africa. As Field et al. (2009) find from microeconometric evidence, insufficient iodine intake dur-

[7]This, obviously, rules out from our consideration very severe diseases. While we recognize that some acute infectious diseases may, indeed, debilitate women to the extent they cannot provide child care, several important chronic conditions (anemia, nonfatal malaria, cataract) are such that they are likely to depress female labor supply but not their ability to provide (at least basic) child care.

[8]One could argue that the provision of child care has negative utility for a woman who is sick. It can be checked that adding a term $-\phi\,(1-\xi_f)\,\psi n_t$ to the utility function does not change our results qualitatively as long as $\phi \in \left[0, \overline{\phi}\right]$.

[9]See for example Strauss and Thomas (1998), Schultz (2002), Shastry and Weil (2003), Schultz (2005), Bleakley (2007), Weil (2007), Bleakley (2010), Bleakley (2011), and Fink and Masiye (2012). The effects also include health impacts during childhood that reflect on adult productivity. Recent work by Bleakley (2007) and Bleakley (2010) identifies strong direct effects on adult productivity from childhood exposure to hookworms and malaria, respectively. Notably, productivity increases even for a given level of schooling. As Bleakley (2011) argues, better child health tends to raise, as a first-order effect, the quality of a given quantity of education, whereas ensuing (optimal) changes to the quantity of education only give rise to second-order effects.

[10]As noted previously, this is also mentioned in the literature on female disadvantage with regard to health and healthcare.

ing pregnancy lowers children's cognitive ability and subsequent educational attainment, in particular for girls. Notably this is true even when girls and boys receive the same amount of schooling. In this context, $\xi_m - \xi_f > 0$ could be interpreted as the extent to which maternal iodine deficiency impairs female productivity for a given quantity of education h_t (as would arise from educational spending e_t).

For fertility to be nonnegative and not to exceed the amount that would induce females to spend more time on child care than their available time budget allows, we assume that $\gamma \in (\delta, \xi_f/\xi_m)$ holds. Solving the couple's utility maximization problem then yields optimal consumption

$$c_t = \frac{(\xi_m + \xi_f)\widehat{w}_t}{1+\gamma}, \tag{3}$$

while optimal fertility and optimal human capital investments are given by

$$n_t = \begin{cases} \frac{\gamma(\xi_m+\xi_f)}{\xi_f\psi(1+\gamma)} & \text{for } \widehat{w}_t \leq \frac{\gamma\bar{e}}{\delta\xi_f\psi} \\ \frac{(\gamma-\delta)(\xi_m+\xi_f)\widehat{w}_t}{(1+\gamma)(\xi_f\psi\widehat{w}_t-\bar{e})} & \text{otherwise,} \end{cases} \tag{4}$$

$$e_t = \begin{cases} 0 & \text{for } \widehat{w}_t \leq \frac{\gamma\bar{e}}{\delta\xi_f\psi} \\ \frac{\delta\xi_f\psi\widehat{w}_t-\gamma\bar{e}}{\gamma-\delta} & \text{otherwise.} \end{cases} \tag{5}$$

At low levels of wages, $\widehat{w}_t \leq \gamma\bar{e}/(\delta\xi_f\psi)$, the couple divides household income between consumption c_t and fertility n_t alone, while educational investments e_t are zero. The reason is that parents prefer a corner solution in which children only learn incidentally because income is so low that the marginal utility from consumption and fertility outweighs the marginal benefit from educational investments over and above the basic level. However, once wages surpass the threshold $\widehat{w}_t = \gamma\bar{e}/(\delta\xi_f\psi)$, investing in their children's education such that e_t turns positive becomes optimal for parents (cf. Strulik et al., 2013). Notably, the threshold depends on female health alone. By raising the opportunity cost of child care, improved female health tends to skew the quality-quantity trade-off toward educational investments rather than the number of children.

For increasing income and human capital, the model replicates a transition from high to low fertility, that is, fertility converges from above to

$$\lim_{\widehat{w}_t\to\infty} n_t = \frac{(\gamma-\delta)(\xi_m+\xi_f)}{(1+\gamma)\xi_f\psi} < \frac{\gamma(\xi_m+\xi_f)}{\xi_f\psi(1+\gamma)}, \tag{6}$$

where the right-hand side represents fertility in the low-growth regime. Furthermore, as inspecting Equation (5) shows, once the income threshold for positive educational investments is surpassed, these investments rise with income, paving the way for mass education (cf. Galor, 2005, 2011; Strulik et al., 2013). With regard to the impact of gender-specific health on the household allocation we can now state the following[11]:

[11] Note that we operate under the assumption that the costs of health interventions are borne by foreign governments or development agencies and that no cost differentials exist between male and female health interventions. See Subsection 6.2 for an extension in which the household undertakes health investments.

Proposition 1. *Given the level of earnings, $\widehat{w}_t$,*

(i) consumption increases (symmetrically) with male (ξ_m) and female (ξ_f) health;

(ii) fertility increases (decreases) with male (female) health both in the low-growth and in the modern growth regime and in the long-run limit; and

(iii) educational investments in the modern growth regime increase with female health and are unaffected by male health.

Proof. Immediate from differentiation of (4), (5), and (6) with respect to ξ_f and ξ_m, respectively.

Improvements in male health yield an income effect that unambiguously leads to an expansion of both consumption and the number of children. By contrast, female health improvements yield both an income and a substitution effect. The income effect leads again to an unambiguous expansion of consumption, but this is no longer true with regard to the number of children. Here, the substitution effect, driven by the greater opportunity cost of children, leads to a reduction in the number of children. While this is true even in the low-growth regime, in the modern growth regime the reduction in fertility comes with greater educational investments. The effect that rising male income leads to higher fertility, while rising female income leads to lower fertility is well established empirically (cf. Butz and Ward, 1979; Bloom et al., 2009, with the former focusing on the United States). Note that spillover effects of female health on the human capital levels of other household members would only strengthen our results. Furthermore, note also that all our subsequent derivations hold true irrespective of whether households choose a fertility rate that is above or below the replacement rate for rising income and human capital. For models that describe an endogenous convergence toward replacement fertility in the long run, see Strulik and Weisdorf (2008) and Strulik et al. (2013).

2.2 Population development and labor force participation

Because each couple gives birth to n_t children at time t, the replacement rate of fertility is given by $n_t = 2$ and the adult population evolves according to

$$N_{t+1} = \frac{n_t}{2} N_t. \tag{7}$$

As far as labor market participation is concerned, we abstract from leisure and assume that individuals inelastically supply their available time net of child rearing. While interpreting ξ_m and ξ_f as health-dependent participation or as health-dependent productivity does not make any difference to the household analysis and will not make a difference to the key macroeconomic relationships summarized in the system of Equations (22)-(29), the subsequent intermediate analysis of employment in terms of workers (L_t) is based on the interpretation of ξ_m and ξ_f as health-dependent labor participation. Note that for this case human capital h_t is homogeneous across gender so that the wage rate, $\widehat{w}_t$, is gender neutral, while labor supply

$$L_t = \frac{N_t}{2} \left[\xi_m + \xi_f \left(1 - \psi n_t \right) \right] \tag{8}$$

depends on health in addition to the time that women allocate to child care.

Remark 1. *The productivity interpretation of ξ_m and ξ_f implies that the level of human capital $\xi_j h_t$ is gender specific. Hence, (i) the wage rate $\xi_j \widehat{w}_t$ is now gender specific, and (ii) labor demand and employment in terms of workers (L_t) will now depend on the gender composition, whereas (iii) labor supply in terms of workers is no longer health dependent. In this case, one would have to write out Equations (8), (10), (11), (14)-(16), and (18) in terms of aggregate human capital (H_t). Doing so, one can easily derive wages and earnings as (19) and (20) and the dynamic system (22)-(29), all of which apply regardless of the particular interpretation of ξ_m and ξ_f.*

2.3 Education sector

Once the income threshold for positive educational investments is surpassed, aggregate spending on formal education is given by education expenditures per couple ($e_t n_t$) multiplied by the number of couples ($N_t/2$), thus amounting to

$$e_t n_t \frac{N_t}{2} = \frac{\delta \xi_f \psi \widehat{w}_t - \gamma \bar{e}}{\xi_f \psi \widehat{w}_t - \bar{e}} \cdot \frac{(\xi_m + \xi_f)\widehat{w}_t}{1+\gamma} \cdot \frac{N_t}{2}. \tag{9}$$

Aggregate education spending is then used to employ $L_{t,E}$ teachers whose aggregate wage bill is given by $\widehat{w}_t L_{t,E}$. Thus, we can derive the equilibrium number of teachers as

$$L_{t,E} = \frac{e_t n_t}{\widehat{w}_t} \cdot \frac{N_t}{2} = \frac{\delta \xi_f \psi \widehat{w}_t - \gamma \bar{e}}{\xi_f \psi \widehat{w}_t - \bar{e}} \cdot \frac{\xi_m + \xi_f}{1+\gamma} \cdot \frac{N_t}{2}. \tag{10}$$

These teachers produce the human capital level of the next generation with a teaching productivity per unit of human capital of η. Because the human capital level of teachers is h_t and educational resources devoted to each child are given by $L_{t,E}/N_{t+1}$ with $N_{t+1} = n_t N_t/2$, we have the following equation of motion for individual human capital,

$$h_{t+1} = \begin{cases} \bar{e} & \text{for } \widehat{w}_t \le \frac{\gamma \bar{e}}{\delta \xi_f \psi} \\ \frac{\eta h_t L_{t,E}}{n_t N_t/2} + \bar{e} = \frac{\eta e_t}{w_t} + \bar{e} = \frac{\eta \delta \xi_f \psi \widehat{w}_t - \gamma \bar{e}}{(\gamma - \delta) w_t} + \bar{e} & \text{otherwise.} \end{cases} \tag{11}$$

In the infinite limit, the growth factor of human capital converges to

$$\lim_{\widehat{w}_t \to \infty} \frac{h_{t+1}}{h_t} = \frac{\eta \delta \xi_f \psi}{\gamma - \delta} \tag{12}$$

for rising income levels. The following result is immediate.

Proposition 2. *The long-run growth factor of human capital increases with female health but is unrelated to male health.*

2.4 Production sector

We follow Galor and Weil (2000) and assume that the production technology is given by

$$Y_t = H_{t,Y}^{\alpha} \left(A_t X\right)^{1-\alpha}, \tag{13}$$

where $H_{t,Y} = h_t L_{t,Y}$ refers to aggregate human capital employed in production, with $L_{t,Y}$ being the number of workers; $A_t \geq 1$ denoting the stock of technologies that a country has at its disposal; X denoting natural resources of fixed supply; and α denoting the elasticity of output with respect to human capital. This production function implies, *ceteris paribus*, that an increase in human capital employed in goods production and an increase in the technological sophistication of a country both raise output. Following Galor and Weil (2000) and assuming that no property rights are defined on the fixed resource X (such that its return is zero), gives the wage per unit of human capital as the average product of human capital, that is,

$$w_t = \frac{Y_t}{H_{t,Y}} = \left(\frac{A_t X}{h_t L_{t,Y}}\right)^{1-\alpha}. \tag{14}$$

The wage rate (per unit of time) is then given by

$$\widehat{w}_t = h_t w_t = h_t^{\alpha} \left(\frac{A_t X}{L_{t,Y}}\right)^{1-\alpha}. \tag{15}$$

As expected, it declines with labor supply and increases with human capital.

2.5 Market clearing

Labor market clearing requires that labor is either employed in goods production or in the education sector such that $L_t = L_{t,E} + L_{t,Y}$, from which we obtain

$$L_{t,Y} = \frac{N_t}{2}\left[\xi_m + \xi_f\left(1-\psi n_t\right) - \frac{e_t n_t}{\widehat{w}_t}\right], \tag{16}$$

where the second term in square brackets adjusts female labor supply for productivity and child rearing and the third term in square brackets refers to employment in the education sector. Following Walras' Law, we can also determine the amount of human capital employed in production by recognizing that production of final goods has to equal aggregate consumption, that is, goods markets are cleared. Hence, production per capita $y_t = Y_t/N_t$ has to equal consumption per capita such that

$$y_t = \frac{c_t}{2} = \frac{(\xi_m + \xi_f)\widehat{w}_t}{2(1+\gamma)}. \tag{17}$$

Because $w_t = Y_t/H_{t,Y} = y_t/(H_{t,Y}/N_t)$, we obtain the following expressions for human capital and labor employment in final goods production, respectively,

$$H_{t,Y} = \frac{(\xi_m + \xi_f)h_t}{2(1+\gamma)} N_t \qquad \Rightarrow \qquad L_{t,Y} = \frac{\xi_m + \xi_f}{2(1+\gamma)} N_t. \tag{18}$$

The expression for $L_{t,Y}$ can be verified by substituting the optimal values of e_t and n_t into Equation (16) and simplifying the expression. Using Equations (14) and (15), we can recalculate wages as

$$w_t = \left[\frac{2(1+\gamma)A_t X}{h_t\,(\xi_m + \xi_f)\,N_t}\right]^{1-\alpha} \tag{19}$$

and

$$\widehat{w}_t = h_t^{\alpha}\left[\frac{2(1+\gamma)A_t X}{(\xi_m + \xi_f)\,N_t}\right]^{1-\alpha}, \tag{20}$$

respectively.

2.6 International technology diffusion

In specifying the diffusion of technologies from the technology leaders, i.e., countries that are advancing the world technological frontier according to Keller (2002), we follow Benhabib and Spiegel (2005), p. 941, and assume that

$$A_{t+1} = \max\left\{\frac{h_t}{\bar{h}_t}\left(\frac{\bar{A}_t}{A_t} - 1\right)A_t + A_t, \bar{A}_t\right\}, \tag{21}$$

where $\bar{A}_t$ and $\bar{h}_t$ refer to the technological frontier and the human capital level in the most advanced countries, respectively. In this formulation the gap between the average human capital of the less developed country and that of the technology leaders, $h_t/\bar{h}_t$, acts as a technology adoption barrier (cf. Parente and Prescott, 1994). The faster technological progress is in advanced countries, the faster it diffuses to less developed economies (*ceteris paribus*). This can be justified by the notion that adopting new technologies is more likely to pay off the larger the additional amount of output that can be produced by using them. A proxy for this additional output is given by the technological gap (cf. Howitt, 2000; Acemoglu et al., 2006). The role of the gap between human capital levels of developed and less developed countries as a technology adoption barrier can be justified by the idea of Nelson and Phelps (1966) that handling new technologies requires a certain amount of skill.

3 Dynamic behavior of the economy in general equilibrium

Combining our building blocks, we obtain the following dynamic system that describes our model economy in the low-growth regime:

$$A_{t+1} = \frac{h_t}{\bar{h}_t}\left(\frac{\bar{A}_t}{A_t} - 1\right) A_t + A_t, \tag{22}$$

$$h_{t+1} = \bar{e}, \tag{23}$$

$$N_{t+1} = \frac{\gamma(\xi_m + \xi_f)}{2\xi_f \psi(1+\gamma)} N_t, \tag{24}$$

$$w_{t+1} = \left[\frac{2(1+\gamma)A_{t+1}X}{(\xi_m + \xi_f)h_{t+1}N_{t+1}}\right]^{1-\alpha}, \tag{25}$$

while the modern growth regime is characterized by

$$A_{t+1} = \frac{h_t}{\bar{h}_t}\left(\frac{\bar{A}_t}{A_t} - 1\right) A_t + A_t, \tag{26}$$

$$h_{t+1} = \frac{\eta\delta\xi_f\psi\widehat{w}_t - \gamma\bar{e}}{(\gamma - \delta)\, w_t} + \bar{e}, \tag{27}$$

$$N_{t+1} = \frac{(\gamma-\delta)(\xi_m + \xi_f)\widehat{w}_t}{2(1+\gamma)(\xi_f\psi\widehat{w}_t - \bar{e})} N_t, \tag{28}$$

$$w_{t+1} = \left[\frac{2(1+\gamma)A_{t+1}X}{(\xi_m + \xi_f)h_{t+1}N_{t+1}}\right]^{1-\alpha}. \tag{29}$$

Note that the low-growth regime represents a locally stable steady-state equilibrium in which an economy is caught and cannot escape without technological progress that it imports from the rest of the world. In this sense the latent state variable that eventually induces a take-off is the stock of technologies in rich countries (cf. Galor and Weil, 2000, where the latent state variable is the population size). Consider now the development of the economy from some time t_0 onward, assuming that at t_0 the economy is in the low-growth regime. Specifically, we then have

$$h_{t_0} = \bar{e}; \quad n_{t_0} = \frac{\gamma(\xi_m + \xi_f)}{\xi_f\psi(1+\gamma)}; \quad e_{t_0} = 0; \quad w_{t_0} = \left[\frac{2(1+\gamma)A_{t_0}X}{(\xi_m + \xi_f)\bar{e}N_{t_0}}\right]^{1-\alpha} < \frac{\gamma}{\delta\xi_f\psi},$$

where the inequality implies $\widehat{w}_{t_0} < \gamma\bar{e}/(\delta\xi_f\psi)$ and thus fertility is high and no education investments are undertaken. One sufficient condition for sustained economic development is the ongoing growth of wages due to international knowledge diffusion. Using Equation (20) we can calculate the growth rate of wages as

$$g_t := \frac{\widehat{w}_{t+1}}{\widehat{w}_t} - 1 = \left(\frac{h_{t+1}}{h_t}\right)^{\alpha}\left(\frac{A_{t+1}/A_t}{n_t/2}\right)^{1-\alpha} - 1, \tag{30}$$

where $A_{t+1}/A_t = \max\left\{h_t/\bar{h}_t\left(\bar{A}_t/A_t - 1\right) + 1, 1\right\}$. It is sufficient for sustained wage growth ($g_t > 0$) that $h_{t+1}/h_t \geq 1$, i.e., human capital is nondecreasing, and $A_{t+1}/A_t \geq n_t/2$, i.e., technological progress does not fall short of population growth, implying that the wage rate is nondecreasing. We can then derive the following more specific sufficient conditions for a transition from low growth to modern growth and for sustained economic growth in the very long run.

Proposition 3. *The following holds for the occurrence of a transition and for its sustainability, respectively:*

(i) A transition from low growth to modern growth arises if

$$\frac{A_{t+1}}{A_t} > \frac{\gamma(\xi_m + \xi_f)}{2\xi_f \psi(1+\gamma)}, \tag{31}$$

with $A_{t+1}/A_t = \max\left\{\bar{e}_t/\bar{h}_t\left(\overline{A}_t/A_t - 1\right) + 1, 1\right\}$ *up until the point of transition.*

(ii) Sustained economic development in the very long run arises if

$$\ln\left(\frac{\eta\delta\xi_f\psi}{\gamma-\delta}\right) \geq \frac{1-\alpha}{\alpha}\ln\left[\frac{(\gamma-\delta)(\xi_m+\xi_f)}{2(1+\gamma)\xi_f\psi}\right]. \tag{32}$$

Proof. See Appendix A.

Within the low-growth regime the wage rate can only increase through a rising "baseline" wage per unit of human capital. This requires that technological growth A_{t+1}/A_t overcompensates population growth $n_t/2$ under high fertility. Given that, realistically, $n_t/2 > 1$ in these economies, this requires that technological growth is positive and sufficiently strong as by condition (31). Assuming that technological growth abates in the very long run, wages continue to increase unambiguously if human capital continues to outgrow the population by a sufficient amount. Thus, considering the long-run limits of human capital growth given in Equation (12) and fertility given in Equation (6), we find the sufficient condition (32) for sustained long-run growth.[12]

We can now identify the role of female health in sustained growth and in a transition to a modern growth regime. To this end, assume that the transition takes place at $\tau \geq t_0 + 1$ and that technology growth $A_{t+1}/A_t \simeq \widehat{A}$ is roughly constant over the interval $[t_0, \tau]$. Defining $\widehat{w}_\tau = \gamma\bar{e}/(\delta\xi_f\psi)$ as the wage level at which the transition occurs and combining this with the initial wage level

$$\widehat{w}_{t_0} = \bar{e}^{\alpha}\left[\frac{2(1+\gamma)A_{t_0}X}{(\xi_m+\xi_f)N_{t_0}}\right]^{1-\alpha} \tag{33}$$

and with the growth rate in the low-growth regime

$$g = \left[\frac{2\widehat{A}(1+\gamma)\xi_f\psi}{\gamma(\xi_m+\xi_f)}\right]^{1-\alpha} - 1, \tag{34}$$

[12]For a precipitous exogenous fall in the rate of technological progress immediately after the transition to the sustained growth regime, a fall back to the low-growth regime cannot be entirely ruled out. A closer investigation of this rather unrealistic case is available from the authors upon request.

we can use the relationship $\widehat{w}_\tau = (1+g_t)^{\tau - t_0}\, \widehat{w}_{t_0}$ to solve for the time to transition as a function of ξ_f and ξ_m

$$\Delta = \tau - t_0 = \frac{\ln \widehat{w}_\tau - \ln \widehat{w}_{t_0}}{\ln(1+g)}.$$

We then obtain

$$\frac{\partial \Delta}{\partial \xi_f} = \frac{1}{\xi_f \ln(1+g)}\left[-1 + (1-\alpha)\frac{\xi_f}{\xi_m+\xi_f} - (1-\alpha)\,\Delta \frac{\xi_m}{\xi_m+\xi_f}\right] < 0, \tag{35}$$

$$\frac{\partial \Delta}{\partial \xi_m} = \frac{(1-\alpha)(1+\Delta)}{(\xi_m+\xi_f)\ln(1+g)} > 0, \tag{36}$$

which allows us to state our main result.

Proposition 4. *Better female (male) health, that is, a higher* ξ_f *(*ξ_m*)*

(i) leads to faster (slower) wage growth in the low-growth regime and in the long-run limit and

(ii) speeds up (slows down) the transition to modern growth.

Proof. Part (i) follows immediately when inserting the low-growth and limiting values of n_t [cf. Equations (4) and (6)] and the limiting value of h_{t+1}/h_t [cf. Equation (12)] into (30) and taking the appropriate derivatives with respect to ξ_f and ξ_m, respectively. Part (ii) follows immediately from Equations (35) and (36), respectively.

Economies with better female health tend to experience faster wage growth during the low-growth regime and in the long-run limit. This is because they tend to exhibit less downward pressure on the wage rate for an expanding population and greater accumulation of human capital in the modern growth regime. While greater wage growth in the low-growth regime suggests that economic transition is taking place earlier, this is not a foregone conclusion. The reason is that while wages grow faster within economies with healthy females [the last term in (35)] and while these economies enter transition at a lower wage level [the first term in brackets in (35)], they are also starting at a lower wage level [the second term in (35)]. This is because greater female labor participation (or productivity) initially tends to depress wages. As it turns out, the economy with a healthier (and more productive) female labor force experiences economic take-off at an earlier time. We note from (35) that the impact of female health on the speed to transition decreases with the growth rate on the path to transition and increases with the time to transition. Finally, we note that the reduction in the transition threshold is a crucial factor. This is because when the time to transition is short, the impact of lower fertility on the growth rate is insufficient to offset the initial reduction in the wage rate.

All of this contrasts with the impact of male health, which, by raising fertility, tends to slow down economic development. Indeed, male health militates against an economic transition by lowering both the initial level of wages and their growth rate.

We show in Section 6 that our results are robust to extensions of the model taking account of collective household preferences, endogenous health investments, and physical capital in the production process.

4 Policy applications

From a development policy perspective, our main result in Proposition 4 implies that efforts toward health improvements should be targeted at women. Indeed, the model suggests that redistributing health care from men to women may be beneficial. The following result shows, however, that such a policy would create a conflict with the interests of the unitary household in the short run. This argument abstracts from the justification of the redistribution of healthcare opportunities to women based on an unequal distribution biased against women to begin with (cf. the literature referenced in the introduction).

Proposition 5. *Consider a redistribution of healthcare from men to women such that* $d\xi_f = -d\xi_m > 0$.

(i) Such a policy unambiguously raises economic growth rates throughout and speeds up the economic transition, but

(ii) for any given wage, $\widehat{w}_t$*, it unambiguously lowers household utility, both in the low-growth and in the modern growth regime.*

Proof. See Appendix A.

Thus, while enhancing economic growth and hastening economic transition, a redistribution of health also lowers household utility. This is true even where such a policy fosters educational investments in the modern growth regime or induces a transition. Indeed, this follows from a revealed preference argument: Noting from the budget constraint in Equation (2) that redistribution unambiguously lowers family income, it must be true that the household with better male health could always mimic the allocation chosen by a household with better female health and thereby do at least as well. Any deviation in the allocation (i.e., the choice of a larger number of children) must then be associated with even greater utility. We realize that this result depends on the assumption of unitary household decision making and may well change in the presence of collective decisionmaking. This notwithstanding, it highlights the scope for a conflict between the short-term interests of utility-maximizing households, which may favor male health improvements, and the long-term interests of development policies that favor female health improvements.

In many instances, health policies are not targeted at particular individuals within the household. One may wonder then what the implications are for the pace of economic development if women and men both benefit equally from a particular health policy.

Proposition 6. *Consider an increase in the health of both sexes by a common factor* $\lambda > 1$. *Such a policy* *(i) leaves the growth rate unaffected in the low-growth regime and raises the growth rate in the long-run limit and*

(ii) speeds up economic transition.

Proof. See Appendix A.

Given the opposing effects of male and female health on growth and development it is unclear *a priori* whether health improvements that affect both sexes alike promote development. Indeed, to some extent this depends on the economic regime itself. While a proportional increase in the health of both males and females promotes growth by lowering fertility and raising education in the modern growth regime, this is not true in the low-growth regime. In the absence of educational investments, proportional health improvements do not reduce fertility and thereby leave the growth rate unaffected. This result echoes the finding of Cervellati and Sunde (2011) that the impact of health on economic growth depends on whether the demographic transition has occurred or not. According to their analysis, health improvements, as measured by increases in life expectancy, tend to reduce fertility after the demographic transition to the extent that population growth slows down and per capita income growth increases. Before the transition, however, health improvements raise life expectancy but do not reduce fertility, which may even increase slightly. Consequently, population growth increases, which in turn compromises per capita income growth. Although the health effects in our model work through morbidity/productivity rather than mortality/life expectancy, the impact is very similar: In the presence of a quality-quantity trade-off, female health improvements raise educational investments, and the ensuing increase in the cost of child care is enough to offset the positive income effect of male health on fertility, which is unambiguously reduced. By contrast, before the transition, the income effect, calling for an increase in fertility, exactly cancels the effect from greater female opportunity cost. Whether fertility increases or decreases ultimately depends on the distribution of health gains in the household. Thus, it is easy to conceive that if males benefit to a larger extent, fertility does, indeed, increase. What our analysis also shows is that health improvements common to men and women do, however, facilitate a take-off toward sustained economic development, albeit more slowly.

5 Numerical analysis

We now illustrate the analytical results with a numerical example based on the parameter values given in Table 1. Specifically, we consider two exercises: First, we examine the impact of gender-specific health on the time to transition, seeking to assess the size of the effect; second, we simulate the dynamic system as given by Equations (22) to (29), seeking to assess the impact of gender-specific health on the overall development process. With respect to health we rely on the data of Vos et al. (2012) reporting that at the global level and for the year 1990 males and females aged 30 live about $YLD_m = 0.11$

and $YLD_f = 0.124$ life years in disability. In terms of labor participation, this implies $\xi_f = 0.876$ and $\xi_m = 0.89$ (i.e., 45.6 and 46.3 weeks per year). We use these values for the baseline scenario and then assess the impact of a percentage point increase in female health in Scenario 1, a percentage point increase in male health in Scenario 2, and a percentage point increase in the health of both sexes in Scenario 3. Note that a percentage point increase in female and male health amounts to an increase of healthy time of a little more than three days per year.

Table 1: Parameter values for simulation

Parameter	Value	Parameter	Value
δ	0.4660	α	2/3
γ	0.5200	g_h (foreign)	0.45% p.a.
ψ	0.1591	g_A (foreign)	3.85% p.a.
ξ_f	0.8760	ξ_m	0.8900
$\bar{e}$	4.2500	η	1.000
period length t	25 yrs.		

Table 2 presents for the baseline case and the three scenarios the pretransition outcomes in terms of fertility, female labor force participation, economic growth, and the time to transition. Fertility is around 4.3 children per household, a value that is reasonably well in line with empirical evidence for developing economies. Female labor force participation amounts to 0.272, broadly corresponding with the female participation rates reported for India or Turkey (cf. International Labour Organization, 2012). The growth rate of 5.6% over a time span of 25 years amounts to annual growth in the order of 0.2% and thus to an almost stagnating economy.[13] In consequence, for our baseline economy, the (latent) time to transition amounts to 52.6 years. The percentage point improvement in female health (Scenario 1) lowers this time by some 5 years and 4 months, which is enough to trigger a transition after 50 years (i.e., with the third generation) rather than after 75 years (i.e., with the fourth generation) as in the baseline. In contrast, a percentage point increase in male health (Scenario 2) raises the time to transition by about 2 and a half years. Given our assumption of a period length of 25 years, this does not have a bearing on the transition process. Finally, an improvement by one percentage point in the health of both sexes reduces the time to transition by about 3 years and 1 month, which again is enough to induce an earlier transition.

A period length of 25 years leads to rather extreme impacts of changes in health on the transition process as it is modeled. Changes in the latent time to transition of similar and sizable magnitude (as for example those for Scenarios 2 and 3) may either trigger no effect (as for Scenario 2) or a change in the timing of transition by 25 years (as for

[13] We assume for this experiment constant technology adoption of about 3.8% per year. In our simulation later, technology adoption is specified according to the flexible form of Equation (21), giving rise to an average on the same order.

Scenario 3). In that regard, changes in the latent time to transition are a more realistic measure of the likely impact of health care on the transition process. Moreover, a long period length is associated with a second problem: whether or not a health improvement advances or delays economic transition (by a generation) is very sensitive to the level of the initial wage $\widehat{w}_{t_0}$ and therefore depends crucially on the assumptions about the initial state of the economy.

In light of these concerns we can arrive at a more robust statement about the role of health for economic take-off by considering the following stochastic setting. Suppose the initial conditions of the economy $\{A_{t_0}, N_{t_0}, X\}$ are randomly drawn from a set of values G so that they generate an initial wage $\widehat{w}^b_{t_0} \in \left[\underline{w}^b, \overline{w}^b\right]$ for which transition arises after three periods (and three periods only) in the baseline scenario (b).[14] Clearly, the range of initial wages $\left[\underline{w}^1, \overline{w}^1\right]$ for which transition arises after 3 periods in Scenario 1 satisfies $\underline{w}^1 < \underline{w}^b$ and $\overline{w}^1 < \overline{w}^b$ (i.e., the range is shifted "downward"). Intuitively this is due to the fact that better female health reduces the threshold wage for economic take-off.

Furthermore, for any given $\{A_{t_0}, N_{t_0}, X\} \in G$, the initial wage in Scenario 1 will satisfy $\widehat{w}^1_{t_0} \in \left[\left(\widehat{w}^1_{t_0}/\widehat{w}^b_{t_0}\right)\underline{w}^b, \left(\widehat{w}^1_{t_0}/\widehat{w}^b_{t_0}\right)\overline{w}^b\right]$ with $\widehat{w}^1_{t_0}/\widehat{w}^b_{t_0} < 1$. This is because of the greater effective labor supply associated with better female health in Scenario 1. Nevertheless, an interval exists $\left[\overline{w}^1, \left(\widehat{w}^1_{t_0}/\widehat{w}^b_{t_0}\right)\overline{w}^b\right]$ such that a draw $\widehat{w}^1_{t_0} \in \left[\overline{w}^1, \left(\widehat{w}^1_{t_0}/\widehat{w}^b_{t_0}\right)\overline{w}^b\right]$ will induce a transition after three periods in the baseline case but a transition after two periods in Scenario 1. The probability of such a draw, $\pi_{b1} = \left[\left(\widehat{w}^1_{t_0}/\widehat{w}^b_{t_0}\right)\overline{w}^b - \overline{w}^1\right]\left[\left(\widehat{w}^1_{t_0}/\widehat{w}^b_{t_0}\right)\left(\overline{w}^b - \underline{w}^b\right)\right]^{-1}$, can now be read as the probability that the improvement in female health in Scenario 1 advances the economic transition by one period (i.e., by 25 years). For our numerical example we obtain $\pi_{b1} = 0.22$, which is of sizable magnitude.[15]

In our second exercise, we graph the development paths for human capital, population, and income, embracing both pre- and post-transition periods. The impact of female health improvements is shown in Figure 1. The solid blue line refers to the baseline case, whereas the dashed red line refers to Scenario 1, i.e., an economy that experienced at the initial time (1950) a percentage point increase in female healthy time. Both economies start with the same population size, the same state of technology, and the same land endowment. They follow the same path until around the year 2000 when they are still in a low-growth regime without the accumulation of human capital [see panels a) and b)] and very sluggish income growth [see panel f)]. The sole reason that wages grow at all is that the technological frontier in the rest of the world grows at a constant rate such that the distance to the frontier increases, leading to more intense technology adoption (cf. Howitt, 2000; Acemoglu et al., 2006). Meanwhile, the human capital level in the rest

[14] More specifically, $\underline{w}^b := \gamma\bar{e}/\left[\delta\psi\xi^b_f\left(1+g^b\right)^3\right]$ and $\overline{w}^b := \gamma\bar{e}/\left[\delta\psi\xi^b_f\left(1+g^b\right)^2\right]$ with g^b as defined by Equation (34). Thus, the lower (upper) bound corresponds to the baseline threshold wage discounted by the growth over three (two) periods. If $\widehat{w}^b_{t_0} < \underline{w}^b$, the transition would occur after four periods; if $\widehat{w}^b_{t_0} > \overline{w}^b$, the transition would occur after two periods.

[15] Similarly, we obtain $\pi_{b3} = 0.126$ as the probability that an equiproportional increase of health for both genders advances economic take-off by one generation, and (in an analogous way) we obtain $\pi_{b2} = 0.121$ as the probability that an improvement in male health delays take-off by one generation.

Table 2: Impact of health on pretransition outcomes and time to take-off

	Baseline	Scenario 1	Scenario 2	Scenario 3
Health parameters				
ξ_f	0.8760	0.8848	0.8760	0.8848
ξ_m	0.8900	0.8900	0.8989	0.8989
Pretransition outcomes				
Fertility n	4.3349	4.3131	4.3567	4.3348
Participation $\xi_f\,(1-\psi n)$	0.2718	0.2776	0.2688	0.2745
25-yr. growth rate g	0.0557	0.0574	0.0539	0.0557
Time to transition (yrs.)	52.623	47.313	55.100	49.538
Yrs. gained on baseline	–	5.310	−2.477	3.085

of the world also grows persistently such that the gap between the human capital level of the country under consideration and the rest of the world widens. This acts as a barrier to technology adoption and prevents an economic take-off from occurring (cf. Nelson and Phelps, 1966; Parente and Prescott, 1994; Benhabib and Spiegel, 2005). At the point of take-off (for the baseline scenario this is the year 2025 and for Scenario 1 this is the year 2000), per capita income surpasses the value at which it becomes optimal for individuals to invest in the education of their offspring. From then on parents choose to have fewer children but to educate them better. Consequently, a fertility transition sets in and the rate of population growth declines [see panel d)]. The resulting increase in human capital helps to close the gap between the human capital level of the country under consideration and the rest of the world. This in turn leads to faster technology adoption and an increase of per capita income growth [see panels e) and f)].

In comparison with the baseline scenario we see that the benefits from female health improvements materialize only over time, but then in an accelerating way. This is due to diverging growth rates of human capital and income in the modern growth regime, implying that an initial advantage is magnified. Interestingly, little perceivable difference exists between the two economies in the "immediate" aftermath of the early transition (i.e., over the years 2000–2025). Thus, female health improvements appear to create only a small initial advantage in terms of slightly higher growth rates at a slightly earlier point in time, but this effect is vastly magnified over the subsequent 50 years.

In Figure 2 we hold female health constant and simulate an increase in male health by 1 percentage point (Scenario 2). In this case, both economies take off in the year 2025. Nevertheless, even under the modern growth regime, the higher fertility level in Scenario 2 places a drag on income growth and the growth of human capital, causing these economies to diverge as well. Finally, in Figure 3, we simulate an equiproportional

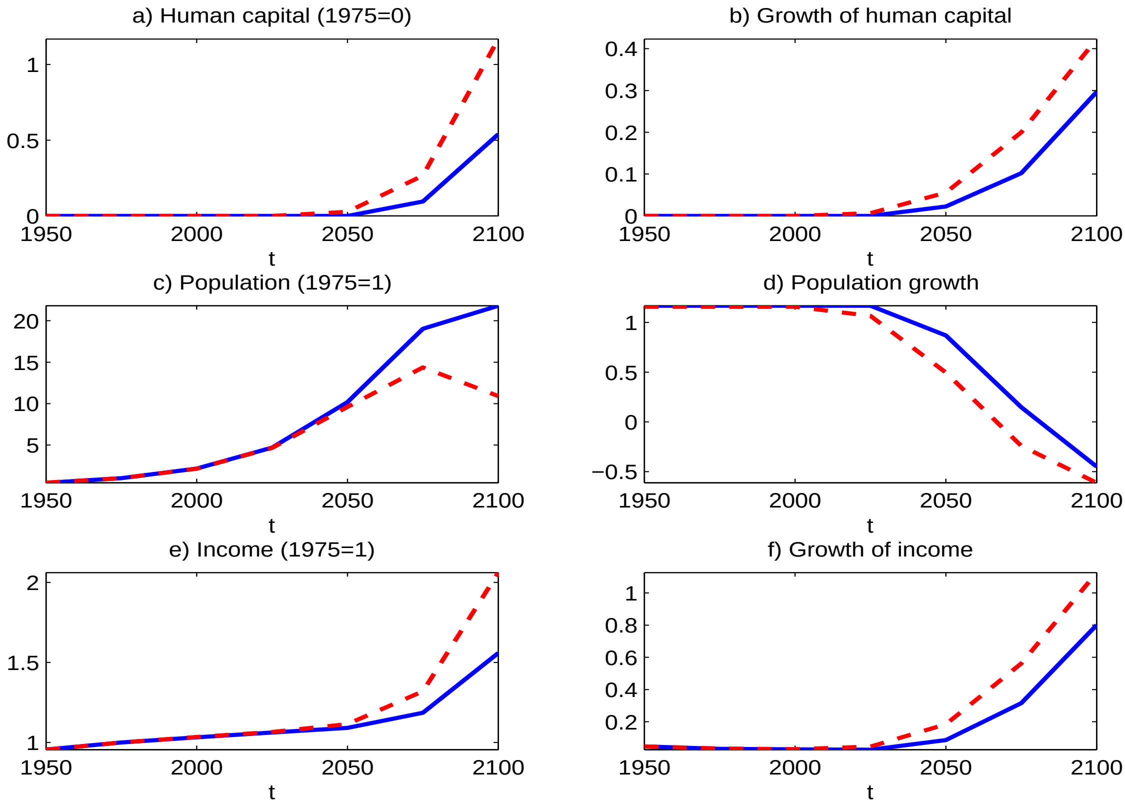

Figure 1: Illustration of the differential take-off in Scenario 1. The baseline simulation is reflected by the solid blue line. The dashed red line refers to a simulation with similar parameter values except that female health increases by 1 percentage point as compared with the baseline simulation.

increase in health of both sexes (Scenario 3). Despite the earlier take-off of the economy with better health, the difference in post-transition growth rates is rather limited, implying that these economies do not follow dramatically divergent development paths.

We should mention that the path of development is not invariant to the sequencing of events. If female health is improved earlier (later) than male health, the economy ends up on a higher (lower) income trajectory. This suggests that targeted health interventions for women are more effective for economic development the earlier they occur. In other words, failing to act now on improving female health is likely to raise the future cost of interventions for any given outcome.

6 Extensions and robustness of the results

In this section we investigate three extensions of the model and analyze whether our results are robust to these alternative specifications. Subsection 6.1 relaxes the assumption of unitary household preferences in favor of collective preferences, Subsection 6.2 analyzes the implications of endogenous investments in health, and Subsection 6.3 sheds light on

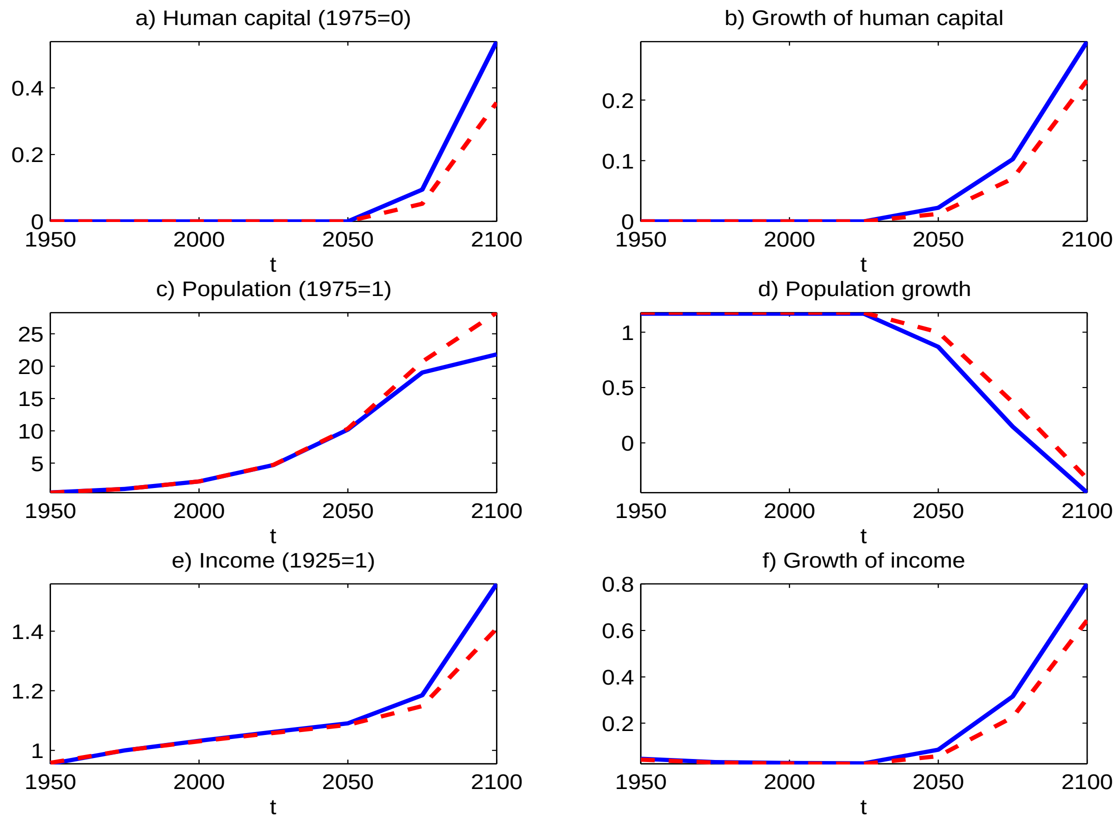

Figure 2: Illustration of the differential take-off in Scenario 2. The baseline simulation is reflected by the solid blue line. The dashed red line refers to a simulation with similar parameter values except that male health increases by 1 percentage point as compared with the baseline simulation.

the effects of physical capital accumulation and foreign direct investment (FDI).

6.1 Collective household preferences

Frequent arguments hold that household allocations are (empirically) better represented by models of collective rather than unitary preferences.[16] To illustrate the robustness of our main results, this section derives the allocation under collective household preferences and sketches out the implications of (female) health improvements. Thus, consider collective preferences of the form

$$\begin{aligned} u &= \widehat{\theta}\left[\log\left(c_t^m\right) + \gamma_m \log\left(n_t\right) + \delta_m \log\left(\bar{e} + e_t\right)\right] \\ &\quad + \left(1 - \widehat{\theta}\right)\left[\log\left(c_t^f\right) + \gamma_f \log\left(n_t\right) + \delta_f \log\left(\bar{e} + e_t\right)\right], \end{aligned} \tag{37}$$

[16]See Browning and Chiappori (1998) for a general characterization and de la Croix and Vander Donckt (2010), Rees and Riezman (2012), and Prettner and Strulik (2014) for applications to the economic-demographic transition.

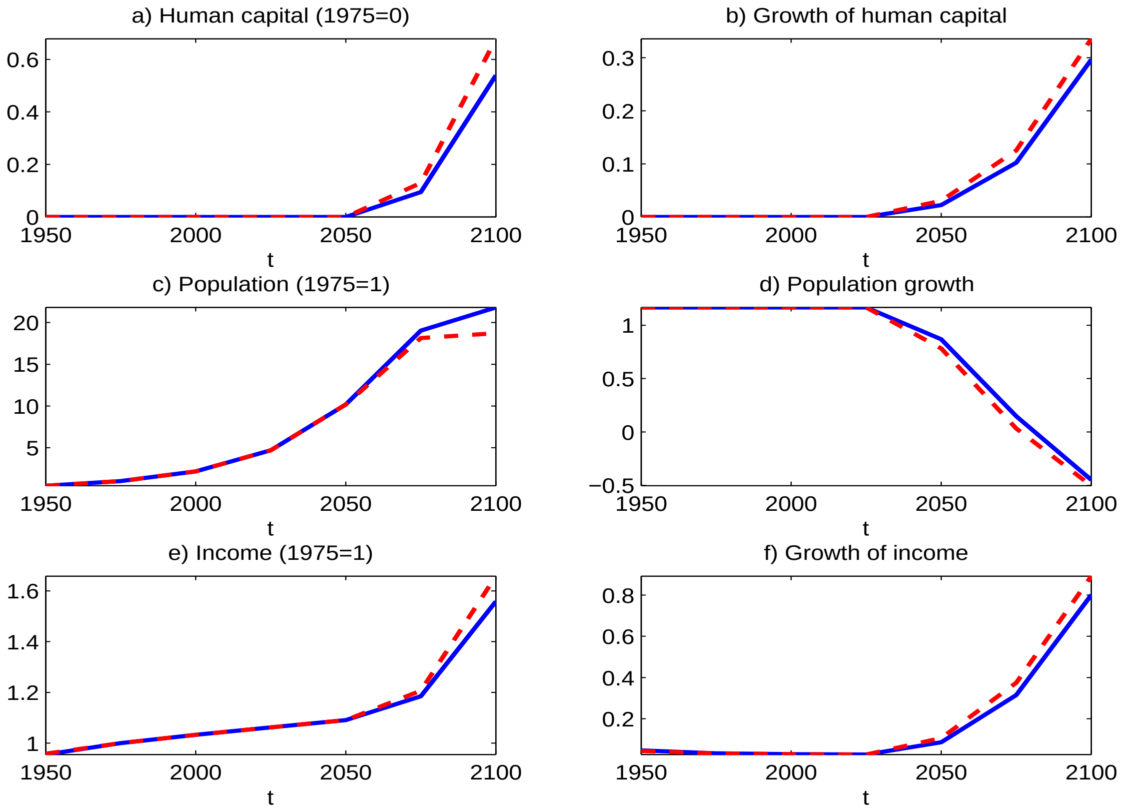

Figure 3: Illustration of the differential take-off in Scenario 3. The baseline simulation is reflected by the solid blue line. The dashed red line refers to a simulation with similar parameter values except that health increases equiproportionally by 1 percentage point for males and females as compared with the baseline simulation.

according to which each partner $j = m, f$ derives utility from private consumption c_t^j and from the number of children and their education, the latter two being public goods within the household. The distribution function $\widehat{\theta} = \theta(\xi_m, \xi_f)$ is assumed to depend on the distribution of health. This can be viewed as a reduced form of the more common representation, where $\widehat{\theta}$ depends on the income distribution within the household. Naturally, we have $\partial\theta/\partial\xi_m = \theta_m \geq 0 \geq \theta_f = \partial\theta/\partial\xi_f$, implying that better female (male) health tends to increase (decrease) women's bargaining power. We allow that partners differ in their preferences over children and their education. Similar to Rees and Riezman (2012) we follow empirical evidence that men tend to have a stronger preference for private consumption and the number of children as opposed to education (see e.g. Schultz, 1990; Thomas, 1990) such that we assume $\delta_m < \delta_f \leq \gamma_f \leq \gamma_m$. Solving the utility maximization problem subject to the original budget constraint in Equation (2) we obtain

$$c_t^m = \frac{\widehat{\theta}(\xi_m + \xi_f)\widehat{w}_t}{1 + \widehat{\gamma}}; \qquad c_t^f = \frac{\left(1 - \widehat{\theta}\right)(\xi_m + \xi_f)\widehat{w}_t}{1 + \widehat{\gamma}} \tag{38}$$

for male and female consumption and

$$n_t = \begin{cases} \frac{\widehat{\gamma}(\xi_m+\xi_f)}{\xi_f \psi(1+\widehat{\gamma})} & \text{for } \widehat{w}_t \leq \frac{\widehat{\gamma}\bar{e}}{\widehat{\delta}\xi_f\psi} \\ \frac{(\widehat{\gamma}-\widehat{\delta})(\xi_m+\xi_f)\widehat{w}_t}{(1+\widehat{\gamma})(\xi_f\psi\widehat{w}_t-\bar{e})} & \text{otherwise,} \end{cases} \tag{39}$$

$$e_t = \begin{cases} 0 & \text{for } \widehat{w}_t \leq \frac{\widehat{\gamma}\bar{e}}{\widehat{\delta}\xi_f\psi}, \\ \frac{\widehat{\delta}\xi_f\psi\widehat{w}_t-\widehat{\gamma}\bar{e}}{\widehat{\gamma}-\widehat{\delta}} & \text{otherwise,} \end{cases} \tag{40}$$

for fertility and education with $\widehat{\gamma} = \widehat{\theta}\gamma_m + \left(1-\widehat{\theta}\right)\gamma_f$ and $\widehat{\delta} = \widehat{\theta}\delta_m + \left(1-\widehat{\theta}\right)\delta_f$, respectively. Thus, the allocation follows the same principles as for the unitary household, the only differences being that (i) aggregate household consumption c_t is now split according to the distribution rule and (ii) fertility and education as household public goods now depend on the weighted sums $\widehat{\gamma}$ and $\widehat{\delta}$ of individual preferences. Noting that $sgn(\partial\widehat{\gamma}/\partial\xi_j) = sgn\left[(\gamma_m - \gamma_f)\,\theta_j\right] = sgn(\theta_j)$ and $sgn(\partial\widehat{\delta}/\partial\xi_j) = \left[(\delta_m - \delta_f)\,\theta_j\right] = -sgn(\theta_j)$, deriving the following result is straightforward.

Proposition 7. *Given the wage rate $\widehat{w}_t$,*

(i) aggregate consumption at the household level increases with female health (ξ_f), but responds ambiguously to male health (ξ_m);

(ii) fertility increases (decreases) with male (female) health both in the low-growth and in the modern growth regime and in the long-run limit;

(iii) educational investments in the modern growth regime increase (decrease) with female (male) health;

(iv) the transition threshold decreases (increases) with female (male) health.

The direct impact of health on the household's choices is now modified by the impact of health on the household distribution of bargaining power. For female (male) health improvements this implies that the preference weight on the number of children is reduced (increased), whereas the weight on education is increased (reduced). In most cases this simply leads to a reinforcement of the effects found for the unitary household model. In particular, female health improvements tend to lower fertility and raise education (in the modern regime) both directly and through the greater emphasis on education rather than the number of children in household decision making. But two notable changes occur: First, male health improvements now have an ambiguous impact on household consumption. This is because the positive income effect is offset by a greater emphasis on fertility. Second, in the modern growth regime, male health now has a negative impact on education, because of the lower weight on education in household decision making.

The implications for the process of economic development follow in a straightforward way. Note first that the threshold for economic development $[\widehat{\gamma}\bar{e}/(\widehat{\delta}\xi_f\psi)]$ unambiguously decreases with female health. This occurs both directly and indirectly through the shift in household preferences toward the quality rather than the quantity of children. Furthermore, the economic growth rates both in the low-growth and modern growth regimes increase with female health due to the reduction in fertility. The converse applies to male health, where the transition threshold itself now increases with male health. It then follows by analogy to Proposition 4 that improvements in female (male) health unambiguously hasten (slow) the process of economic take-off.[17]

6.2 Endogenous health

Consider a setting in which male and female health depend on gender-specific investments in health improvements. We conceptualize this by modifying the budget constraint

$$\xi_{m,t}\widehat{w}_t + \xi_{f,t}\widehat{w}_t(1-\psi n_t) = c_t + e_t n_t - (i_m + i_f), \tag{41}$$

where health-dependent participation $\xi_{j,t} = \overline{\xi}_j + \widehat{\xi}_j(i_{j,t})$ for $j = f, m$ is now composed of an exogenous part $\overline{\xi}_j$ and a part $\widehat{\xi}_j(i_{j,t})$ that is amenable to health investments $i_{j,t}$. We also assume $\widehat{\xi}'_j(i_{j,t}) \geq 0$ and $\widehat{\xi}''_j(i_{j,t}) \leq 0$ for $j = f, m$. Maximizing utility as given by the original utility function (1) subject to the budget constraint (41) we obtain household consumption as

$$c_t = \frac{(\xi_{m,t} + \xi_{f,t})\widehat{w}_t - i_{m,t} - i_{f,t}}{1+\gamma}, \tag{42}$$

and fertility and education as, respectively,

$$n_t = \begin{cases} \frac{\gamma(\xi_{m,t}+\xi_{f,t})\widehat{w}_t - i_{m,t} - i_{f,t}}{\xi_{f,t}\widehat{w}_t\psi(1+\gamma)} & \text{for } \widehat{w}_t \leq \frac{\gamma\bar{e}}{\delta\xi_{f,t}\psi} \\ \frac{(\gamma-\delta)(\xi_{m,t}+\xi_{f,t})\widehat{w}_t - i_{m,t} - i_{f,t}}{(1+\gamma)(\xi_{f,t}\psi\widehat{w}_t - \bar{e})} & \text{otherwise,} \end{cases} \tag{43}$$

$$e_t = \begin{cases} 0 & \text{for } \widehat{w}_t \leq \frac{\gamma\bar{e}}{\delta\xi_{f,t}\psi}, \\ \frac{\delta\xi_{f,t}\psi\widehat{w}_t - \gamma\bar{e}}{\gamma-\delta} & \text{otherwise.} \end{cases} \tag{44}$$

In addition, we find the optimal health investments described by $\widehat{\xi}'_m(i_{m,t})\widehat{w}_t = 1$ and $\widehat{\xi}'_f(i_{f,t})\widehat{w}_t(1-\psi n_t) = 1$, according to which the marginal return in terms of greater earnings is equilibrated with the marginal unit of investment (=1). From the first-order conditions we obtain the following result.

Proposition 8. *For a gender-neutral health production function $\widehat{\xi}_m(i) = \widehat{\xi}_f(i)$, it is optimal for the household to invest more in male health if $n_t > 0$.*

The result follows in a straightforward way as the returns to health investments in terms of additional household earnings are greater for men than they are for women due to their lower rate of labor participation. Notably, this finding provides a productivity-based explanation for why women are discriminated against in terms of health investments (cf. the references in footnote 4), i.e., it does not rely on a preference bias against women.

[17] A proof is available from the authors on request.

Consumption and fertility now depend on the optimal health investments in men and women, while education depends on the optimal health investments in women. This additional channel implies that, in contrast to the baseline model, the fertility rate now depends on the wage rate. The same applies to the transition threshold, which depends on the wage rate through changes in female health investments. The following can be shown:[18]

Lemma 1. *(i) Male health investments increase with the wage rate,* $\partial i_{m,t}/\partial \widehat{w}_t > 0$*. (ii) Ceteris paribus, female health investments decrease with fertility,* $\partial i_{f,t}/\partial n_t < 0$*, and increase with the wage rate,* $\partial i_{f,t}/\partial \widehat{w}_t > 0$*. (iii) If* $\gamma < \xi_{f,t}/\xi_{m,t}$*, female health investments increase with the wage rate when taking into account the optimal fertility response,* $di_{f,t}/d\widehat{w}_t = \partial i_{f,t}/\partial \widehat{w}_t + (\partial i_{f,t}/\partial n_t)(dn_t/d\widehat{w}_t) > 0$.

While the positive impact of the wage rate on the incentive to invest in male health is readily apparent, for women this is not entirely clear, because fertility itself now responds to wages and may, indeed, increase with the wage rate. This notwithstanding, it can be shown that as long as women participate in the labor market (as is implied by $\gamma < \xi_{f,t}/\xi_{m,t}$), female health investments respond positively to an increase in the wage rate.[19]

With these dependencies settled, it is straightforward to see that exogenous changes to health essentially have the same impact on the household allocation and the process of economic development as in the model without endogenous health investments. Consider an exogenous increase in female health. While this has no impact on male health investments, the reduction in fertility triggers complementary female health investments, $di_{f,t}/d\bar{\xi}_f > 0$. Overall, this magnifies the impact of female health on economic growth and the speed toward economic take-off. However, by raising fertility, an exogenous increase in male health depresses female health investments, $di_{f,t}/d\bar{\xi}_m < 0$, implying even lower wage growth and a greater delay in reaching transition.

We conclude this extension by noting that endogenous health investments tend to accelerate or dampen the process toward economic transition. Thus, considering an economy that at time t_0 has not yet reached the point of economic take-off, i.e., $\widehat{w}_{t_0} < \gamma\bar{e}/(\delta\xi_{f,t_0}\psi)$, and defining $\eta_t = \eta(\xi_{f,t}, i_{f,t}) \times \eta(i_{f,t}, \widehat{w}_t)$ as the product of the elasticity of female health with respect to health investments, $\eta(\xi_{f,t}, i_{f,t}) = \widehat{\xi}'_f i_{f,t}/\xi_{f,t}$, and the (partial) elasticity of female health investments with respect to the wage rate $\eta(i_{f,t}, \widehat{w}_t) = (\partial i_{f,t}/\partial \widehat{w}_t)(\widehat{w}_t/i_{f,t})$, we propose the following.

Proposition 9. *The following holds for the low-growth (pretransition) regime* $t \in [t_0, \tau]$*:*

(i) Fertility decreases with the wage rate, if $\eta_t \geq (i_{m,t} + i_{f,t})/c_t$ *holds for* $t \in [t_0, \tau]$.

(ii) If this is true, then for any given $\widehat{A} = A_{t+1}/A_t > n_{t_0}/2$*, the economy accelerates toward an earlier transition.*

[18] Proofs of Lemma 1 and the subsequent Proposition 9 are available from the authors on request.

[19] Note that the equilibrium wage is now only implicitly defined by $\widehat{w}_t = h_t^{\alpha}\{2(1+\gamma)\widehat{w}_t A_t X/N_t[(\xi_{m,t} + \xi_{f,t})\widehat{w}_t - (i_{m,t} + i_{f,t})]\}^{1-\alpha}$. Verifying that this equation has a unique solution at $\widehat{w}_t \in (0,1)$ is straightforward.

We only provide the intuition here (a formal proof is available upon request). According to (i), the impact of a wage increase on fertility is ambiguous. This is unsurprising because both male and female health investments increase with the wage rate. While the former drives up fertility, the latter tends to depress it. If, and only if, the impact of the wage increase on female health, as measured by the compound elasticity η, is sufficiently strong, does fertility decrease with the wage rate. This is more likely the lower aggregate health investments are in relation to consumption. An underdeveloped economy for which technology growth exceeds initial population growth such that wages grow at $g_t > 0$ [cf. Equation (30)] will then accelerate toward the point of take-off, τ. This is because health improvements (for males and females) along the development path ultimately work toward a reduction in fertility, which in turn boosts wage growth. In addition, the improvement in female health over time continues to lower the transition threshold, implying a further advance of the time of take-off. Conversely, if female health responds poorly to the wage rate, health improvements along the development path may increase fertility and, thereby, slow the transition process.

It is often argued that utility itself depends on health (see for example Grossman, 1972; Ehrlich and Chuma, 1990; Hall and Jones, 2007; Kuhn et al., 2015; Bloom et al., 2014b; Dalgaard and Strulik, 2014). We could capture some aspects of the utility-enhancing effect of health investments by adding a term to the utility function that increases with the gender-specific health levels. In the absence of cross-effects with the marginal utility of consumption, fertility, and/or educational investments, this would have no impact on our results. The presence of cross-effects in the utility function would, however, certainly complicate the interactions between health investments and the other endogenous variables. While there is no reason to think that this would change our central results, the explicit modeling of this would be complicated beyond the point of analytical tractability.

6.3 Physical capital and FDI

We follow Galor and Weil (2000) in disregarding physical capital as an input in production [cf. Equation (13)]. Indeed, we believe the assumption that most households do not hold substantial amounts of savings is reasonable for developing countries. While capital may play a role in the production process, such capital is then predominantly owned either by a small class of capitalists within the country or by foreign investors. Focusing on the latter, however, shows an interesting relationship between (productivity-related) health improvements within a developing economy and FDI.[20]

We can examine this in a straightforward way by considering a production function

$$Y_t = H_{t,Y}^{\alpha} \left(A_t X_t\right)^{1-\alpha},$$

[20]Considering a fully-fledged multi-country open economy framework that allows for a detailed analysis of capital and trade flows would complicate the model considerably. For the sake of clarity, we therefore restrict ourselves to sketching out the main channels by which health might affect FDI flows in this section.

where X_t is now the supply of physical capital in period t.[21] Assuming that the price of capital is equal to the world-market interest rate, r, and that inputs are paid according to their marginal product, we then obtain immediately

$$\begin{aligned} X_t &= \left[\frac{(1-\alpha)\, A_t^{1-\alpha}}{r}\right]^{\frac{1}{\alpha}} H_{t,Y} \\ &= \left[\frac{(1-\alpha)\, A_t^{1-\alpha}}{r}\right]^{\frac{1}{\alpha}} h_t \left[\xi_m + \xi_f \left(1-\psi n_t\right)\right] \frac{N_t}{2} \end{aligned}$$

as the stock of physical capital. Assuming for the sake of simplicity that capital is not depreciated, we obtain a growth rate of capital equal to

$$g_t^X = \frac{X_{t+1}}{X_t} - 1 = \widehat{A}^{\frac{1-\alpha}{\alpha}} \frac{h_{t+1}}{h_t} \cdot \frac{n_t}{2} \cdot \frac{\xi_m + \xi_f \left(1-\psi n_{t+1}\right)}{\xi_m + \xi_f \left(1-\psi n_t\right)} - 1.$$

For the case of pretransition growth where $h_{t+1} = h_t = \bar{e}$ and $n_{t+1} = n_t$, these expressions simplify to

$$\begin{aligned} X_t &= \left[\frac{(1-\alpha)\, A_t^{1-\alpha}}{r}\right]^{\frac{1}{\alpha}} \frac{\gamma(\xi_m + \xi_f)}{1+\gamma} \frac{N_t}{2}, \\ g_t^X &= \widehat{A}^{\frac{1-\alpha}{\alpha}} \frac{n_t}{2} = \widehat{A}^{\frac{1-\alpha}{\alpha}} \frac{\gamma(\xi_m + \xi_f)}{2\xi_f \psi (1+\gamma)}. \end{aligned}$$

The following is then easily verified.[22]

Proposition 10. *For the low-growth (pretransition) regime $t \in [t_0, \tau]$, it holds that*

(i) the level of capital (FDI) in each period increases with both female health (ξ_f) and male health (ξ_m);

(ii) the growth rate of capital (the growth rate of FDI), increases with male health, but decreases with female health.

By increasing effective labor supply, better health, regardless of whether it is enjoyed by females or males, raises the marginal product of capital and, therefore, triggers a greater investment level. This result is consistent with the empirical findings of Alsan et al. (2006). Before the transition, the growth rate of the capital stock is determined by the rate of technical progress within the developing country and the rate of population growth. Thus, unsurprisingly, the absolute rate of capital growth increases with male health but decreases with female health. Given $\widehat{A} > 1$, the same holds for the per capita rate of capital growth. Thus, in contrast to many of our earlier findings, female health improvements compromise capital accumulation in the pre-transition regime.

[21] We realize that this interpretation of our production function implies that technical change A_t is capital augmenting. However, for our purposes this is not a crucial assumption. In fact, any specification $Y_t = A_t^{\beta} H_{t,Y}^{\alpha} X_t^{1-\alpha}$ with $\beta > 0$ would lead to a similar outcome.

[22] Note that a low-growth regime obtains if the wage rate reported in Equation (45) is sufficiently low. This is always true for A_t being sufficiently low.

In a world in which the returns on capital do not contribute to the income of the population under study (because they accrue abroad or to a population of negligible size) the measure to focus on is the full wage rate, which in the model with capital is given by

$$\widehat{w}_t = h_t w_t = h_t \alpha \left[\frac{(1-\alpha) A_t^{1-\alpha}}{r} \right]^{\frac{1-\alpha}{\alpha}}. \tag{45}$$

Accordingly, wage growth follows as

$$g_t^w = \frac{\widehat{w}_{t+1}}{\widehat{w}_t} - 1 = \frac{h_{t+1}}{h_t} \widehat{A}^{\frac{(1-\alpha)^2}{\alpha}}.$$

Noting that $h_{t+1} = h_t = \bar{e}$ before the transition and recalling Equation (12), the following is then easy to verify.

Proposition 11. *As long as households do not receive capital income,*

(i) male health (ξ_m) has no impact on the growth and level of wages both before the transition and in the long-run limit;

(ii) female health (ξ_f) has no impact on the growth and level of wages before the transition but enhances them in the long-run limit; furthermore, it speeds up the economic transition.

Thus, in the presence of externally held capital, male health loses its role in the development process up to the economic transition. This result may come as a surprise, given that health has an impact on the process of capital accumulation. With the wage rate now determined exclusively by the state of technology and the international interest rate, it does not affect the development process as long as most households do not participate in the growing returns to capital. After the transition, male health improvements slow the process of wage growth by stifling human capital growth although this effect vanishes in the long-run limit. Similarly, female health has no impact on the level and growth of wages before the transition takes place. Nevertheless, by lowering the transition threshold, it still contributes to acceleration of the economic take-off. By increasing the accumulation of human capital after the transition, female health continues to contribute to economic growth even in the long-run.[23]

7 Discussion and conclusions

We have studied the impact of female versus male health investments on productivity within a dynamic general equilibrium model of economic development with endogenous consumption, education, and fertility. We solved the model and studied the conditions

[23] We should caution, of course, that one would expect that at some point after the transition, households would participate in the accumulation of capital, implying a change in the mechanics of growth before the long-run limit.

under which the economy switches from a low-growth regime with high fertility and no educational investments to a modern growth regime with declining fertility and increasing educational investments. By raising female labor participation/productivity and thus the opportunity cost of children, greater female health has a direct negative impact on fertility. While this moderately enhances earnings growth during the low-growth phase, which is otherwise driven by technology adoption, it also has important level effects: on the one hand, it lowers the earnings threshold that must be met in order to initiate educational and demographic transitions; on the other hand, it lowers the wage level. As it turns out, however, starting from the same initial condition, an economy with better female health will always take off at an earlier date. In contrast, by raising income at the household level, male health improvements tend to increase fertility and thereby slow growth, the progress toward demographic and economic transition, and the resulting economic take-off. These analytical results are reflected in our numerical analysis as well.

From a development policy perspective, a case exists for health improvements to be targeted at women (e.g., by reducing iodine deficiency or vaccinating against the human papilloma virus). While this may also be justified on intra-household equity grounds, male health improvements are more effective in promoting household utility in the short run. This is because in societies in which males supply a greater share of their time in the labor market, household income increases by more if men rather than women benefit from a health-related increase in their earnings. Thus, a conflict may exist between the short-term interests of the household with a stronger emphasis on male health and long-term development goals with a stronger emphasis on female health. When health improvements benefit both sexes alike, growth is only promoted when an economic-demographic transition has already taken place. Only then will the increase in educational investments associated with better female health lead to an increase in the cost of children that over-compensates for the positive income effect on fertility. Nevertheless, economic take-off is still sped up as long as health improvements are not disproportionately enjoyed by men. Our main conclusion, that female health is more conducive to economic development, is robust with respect to the introduction of collective rather than unitary household preferences, the endogeneity of health investments within the household, and the inclusion of physical capital in the production function (FDI).

To keep the model analytically tractable and for the sake of clarity, we abstracted from several issues that would increase the realism of the model. Apart from collective household preferences, endogenous health investments, and FDI, where we showed that our results are robust with respect to their inclusion, additional extensions may include i) utility itself depends on health; ii) reductions in fertility bring about endogenous increases in maternal health; iii) politically, socially, and institutionally motivated gender-specific discrimination exists; iv) better male and female health comes with positive spillover effects on other household members, contemporaneously and over time; v) in the long run, the quality-quantity preferences might be endogenous to economic development; and vi) health interventions do not only reduce morbidity but also mortality. However, we have no reason to believe that relaxing the model's assumptions to incorporate those aspects would invalidate any of our results. Additional utility from health would raise the benefits of health investments on top of their effect on economic development, while maternal health improvements due to reductions in fertility would further reinforce our results. We do not consider discrimination against women in the labor market or within the household but find that discrimination against women in terms of health and health care may result from the maximization of net household income. We do not wish to imply that we perceive such an outcome to be desirable, or that preference-based discrimination against women is not an issue. But taking into account additional sources of discrimination would only reinforce our arguments unless it is so severe that it prevents female labor force participation altogether. Positive spillover effects of gender-specific health on other household members would change the results only if the spillover effects of male health were greater than the spillover effects of female health, which is unlikely. Finally, the endogenous evolution of preferences toward higher quality of children as opposed to quantity would speed up the transition and reinforce our results.

One last limitation of our model is that it only examines the impact on labor participation, productivity, and economic growth of variations in morbidity (as opposed to mortality). While such a channel has been identified as empirically relevant (e.g., Field et al., 2009), it is by no means the only one. As Jayachandran and Lleras-Muney (2009) and Albanesi and Olivetti (2014) show, reductions in maternal mortality also serve as a trigger by fostering investments in female education, which ultimately translate into greater labor participation and lower fertility. An examination of this channel would call for an extension of our model to incorporate gender-specific educational investments. While such modeling may provide further insights, we speculate that this would not alter dramatically the mechanics or the results. To some extent, the sole effect of reductions in maternal mortality is to alter the sequence of events: In this case, investments in female education increase before female labor participation increases. By contrast, in our case, reductions in morbidity trigger greater female participation before they trigger greater educational investments. In both cases, however, the joint increase in education and participation comes with a reduction in fertility, which sets off the virtuous cycle of development. That said, reductions in male mortality may also turn out to be conducive to economic development. As Soares and Falcão (2008) show, greater educational investments in children with higher life expectancy, regardless of their gender, trigger a fertility decline. However, this does not contradict our finding that by raising the opportunity cost of children, female health improvements exert additional leverage on economic development.

Altogether, we believe that our theoretical framework could provide guidance on household-level empirical analyses with respect to the relations between female health and development and between female health and household income. This offers as a promising avenue for further research.

Acknowledgments

We would like to thank Hendrik Jürges, Alyssa Lubet, Elizabeth Mitgang, Alexia Prskawetz, Christa Simon, Katharina Werner, Joshua Wilde, and Maria Winkler-Dworak for valuable comments and suggestions. We are grateful to the Norwegian Agency for Development Cooperation for funding this study under grant number QZA-0408-QZA-12/0628.

Appendix A

Proof of Proposition 3. Part (i): Because $h_{t+1} = h_t = \bar{e}$ in the low-growth regime, Equation (30) simplifies to

$$g_t = \left(\frac{A_{t+1}/A_t}{n_t/2}\right)^{1-\alpha} - 1.$$

A transition from low growth to modern growth occurs if $g_t > 0$ for all $t \geq t_0$. As is readily checked, this holds if and only if $A_{t+1}/A_t > n_t/2$. Substituting from Equation (4), the low-growth level of fertility gives the condition in Equation (31). Part (ii): Assume that $A_{t+1}/A_t = 1$ in the very long run, where the economy has reached the technological boundary. Substituting the limit values from Equations (12) and (6) into the condition $g_t \geq 0$ and taking logarithms gives the condition in Equation (32).

Proof of Proposition 5. Part (i) follows immediately from Proposition 4.

Part (ii): As is readily verified from Equations (3)-(5), the redistribution $d\xi_f = -d\xi_m = z > 0$ leaves optimal consumption c_t unaffected. Referring by $\{u_t, n_t, e_t\}$ and $\{u_t', n_t', e_t'\}$ to pre- and postredistribution levels of utility, fertility, and education, respectively, we then obtain from Equation (1) that

$$u_t > u_t' \Leftrightarrow \gamma \left[\log(n_t) - \log\left(n_t'\right)\right] + \delta \left[\log(\bar{e} + e_t) - \log\left(\bar{e} + e_t'\right)\right] > 0. \qquad (.1)$$

Consider now in turn the three cases, where (a) the low-growth regime arises both pre- and postreform, i.e., the case where $\widehat{w}_t = h_t w_t < \gamma\bar{e}/\delta\xi_f\psi$; (b) the modern growth regime arises both pre- and postreform, i.e., the case where $\widehat{w}_t > \gamma\bar{e}/\delta\xi_f\psi$; and (c) the case where for $\widehat{w}_t \in \left[\gamma\bar{e}/\left[\delta\left(\xi_f + z\right)\psi\right], \gamma\bar{e}/\delta\xi_f\psi\right]$ the regime switches from low growth to modern growth.

Case (a): As is readily checked from Equations (4) and (5), we have $n_t > n_t' = \gamma(\xi_m + \xi_f)/\left[(1+\gamma)\left(\xi_f + z\right)\psi\right]$ and $e_t = e_t' = 0$, implying immediately that the second equality in Equation (.1) holds.

Case (b): Substituting from Equations (4) and (5) the modern growth values n_t and e_t together with

$$n_t' = \frac{(\gamma - \delta)(\xi_m + \xi_f)\widehat{w}_t}{(1+\gamma)\left[\left(\xi_f + z\right)\psi\widehat{w}_t - \bar{e}\right]} \qquad (.2)$$

$$e_t' = \frac{\delta\left(\xi_f + z\right)\psi\widehat{w}_t - \gamma\bar{e}}{\gamma - \delta}, \qquad (.3)$$

we can rewrite the second inequality in Equation (.1) as

$$(\gamma - \delta)\left\{\log\left[(\xi_f + z)\,\psi\widehat{w}_t - \bar{e}\right] - \log\left(\xi_f\psi\widehat{w}_t - \bar{e}\right)\right\} > 0,$$

which holds because the term in curly braces is positive and $\gamma > \delta$ by assumption.

Case (c): Substituting from Equations (4) and (5) the value n_t from the low-growth regime and $e_t = 0$ together with n_t' and e_t' as from Equations (.2) and (.3), we can rewrite the second inequality in (.1) as

$$G(\widehat{w}_t) = \left\langle \begin{array}{c} \gamma\left\{\log(\gamma/\xi_f\psi) - \log(\gamma-\delta) + \log\left[(\xi_f+z)\,\psi - \bar{e}/\widehat{w}_t\right]\right\} \\ +\delta\left\{\log(\bar{e}/\delta) - \log\left[(\xi_f+z)\,\psi\widehat{w}_t - \bar{e}\right] + \log(\gamma-\delta)\right\} \end{array} \right\rangle > 0.$$

$G_{\widehat{w}_t} < 0$ for $\widehat{w}_t \in \left[\gamma\bar{e}/\left[\delta\left(\xi_f+z\right)\psi\right], \gamma\bar{e}/\delta\xi_f\psi\right]$can be verified, implying that

$$\begin{aligned} G(\widehat{w}_t) &\geq G(\gamma\bar{e}/\delta\xi_f\psi) \\ &= \left\langle \begin{array}{c} \gamma\left\{\log(\gamma/\xi_f\psi) - \log(\gamma-\delta) + \log\left\{(\psi/\gamma)\left[\gamma z + (\gamma-\delta)\,\xi_f\right]\right\}\right\} \\ +\delta\left\{\log(\bar{e}/\delta) - \log\left\{(\bar{e}/\delta\xi_f)\left[\gamma z + (\gamma-\delta)\,\xi_f\right]\right\} + \log(\gamma-\delta)\right\} \end{array} \right\rangle \\ &= (\gamma-\delta)\left\{\log\left[\gamma z + (\gamma-\delta)\,\xi_f\right] - \log(\gamma-\delta) - \log(\xi_f)\right\} \\ &> (\gamma-\delta)\left\{\log\left[(\gamma-\delta)\,\xi_f\right] - \log(\gamma-\delta) - \log(\xi_f)\right\} = 0, \end{aligned}$$

where the second inequality follows for $z > 0$. Hence, $u_t > u_t'$ for $\widehat{w}_t \in \left[\gamma\bar{e}/\left[\delta\left(\xi_f+z\right)\psi\right], \gamma\bar{e}/\delta\xi_f\psi\right]$, which completes the proof.

Proof of Proposition 6. Part (i) follows immediately when recalling from Equation (30) that the growth rate declines with n_t in all regimes and increases with e_t in the long-run limit and then noting from Equations (4), (6), and (12) that n_t is independent of λ, whereas $\lim_{w_t h_t \to \infty} h_{t+1}/h_t$ increases with λ. Part (ii) follows in analogy to Part (ii) of the proof of Proposition 4 with the time to transition given by

$$\Delta = \frac{\ln(\widehat{w}_\tau/\lambda) - \ln\left(\widehat{w}_{t_0}/\lambda^{1-\alpha}\right)}{\ln(1+g)}$$

with $\widehat{w}_\tau = \gamma\bar{e}/\delta\xi_f\psi$, and $\widehat{w}_{t_0}$ and g as defined in Equations (33) and (34), respectively. We then have $\partial\Delta/\partial\lambda = -\alpha\lambda^{-1}\left[\ln(1+g)\right]^{-1} < 0$.

References

Abu-Ghaida, D. and Klasen, S. (2004). The costs of missing the Millennium Development Goal on gender equity. *World Development*, Vol. 32(No. 7):1075–1107.

Acemoglu, D., Aghion, P., and Zilibotti, F. (2006). Distance to frontier, selection, and economic growth. *Journal of the European Economic Association*, Vol. 4(No. 1):37–74.

Agénor, P.-R., Canuto, O., and da Silva, L. P. (2010). On gender and growth: the role of intergenerational health externalities and women's occupational constraints. Policy Research Working Paper 5492. The World Bank, Washington, D.C.

Albanesi, S. and Olivetti, C. (2014). Maternal health and the baby boom. *Quantitative Economics*, Vol. 5(No. 2):225–269.

Alsan M., Bloom D. E., and Canning D. (2006) The effect of population health on foreign direct investment inflows to low- and middle-income countries. *World Development*, Vol. 34(No. 4):613-630.

Bailey, M. J. (2006). More power to the pill: the impact of contraceptive freedom on women's life cycle labor supply. *The Quarterly Journal of Economics*, Vol. 121(No. 1):289–320.

Baird, S., Friedman, J., and Shady, N. (2011). Aggregate income shocks and infant mortality in the developing world. *Review of Economics and Statistics*, Vol. 93(No. 3):847–856.

Benhabib, J. and Spiegel, M. M. (2005). Human capital and technology diffusion. In *Handbook of Economic Growth, Volume 1A*, Elsevier, Amsterdam, 935–966.

Bhalotra, S. (2010). Fatal fluctuations? Cyclicality in infant mortality in India. *Journal of Development Economics*, Vol 93:7–19.

Bleakley, H. (2007). Disease and development: evidence from hookworm eradication in the American south. *Quarterly Journal of Economics*, Vol. 122(No. 1):73–117.

Bleakley, H. (2010). Malaria eradication in the Americas: a retrospective analysis of childhood exposure. *American Economic Journal: Applied Economics*, Vol. 2(No. 2):1–45.

Bleakley, H. (2011). Health, human capital, and development. *Annual Review of Economics*, Vol. 2:280–310.

Bloom, D. E. and Canning, D. (2005). Health and economic growth: reconciling the micro and macro evidence. Center on Democracy, Development and the Rule of Law Working Papers.

Bloom, D. E., Canning, D., and Fink, G. (2014a). Disease and development revisited. *Journal of Political Economy*, Vol. 122(No. 6):1355–1365.

Bloom, D. E., Canning, D., Fink, G., and Finlay, J. E. (2009). Fertility, female labor force participation, and the demographic dividend. *Journal of Economic Growth*, Vol. 14(No. 2):79–101.

Bloom, D. E., Canning, D., and Moore, M. (2014b). Optimal retirement with increasing longevity. *Scandinavian Journal of Economics*, Vol. 116(No. 3):838–858.

Bloom, D. E., Canning, D., and Sevilla, J. (2004). The effect of health on economic growth: a production function approach. *World Development*, Vol. 32(No. 1):1–13.

Bloom, S. S., Wypij, D., and Gupta, M. D. (2001). Dimensions of women's autonomy and the influence on maternal health care utilization in a north Indian city. *Demography*, Vol. 38(No. 1):67–78.

Bonilla, E. and Rodriguez, A. (1993). Determining malaria effects in rural Colombia. *Social Science and Medicine*, Vol. 37(No. 9):1109-1114.

Browning, M. and Chiappori, P.-A. (1998). Efficient intra-household allocations: a general characterization and empirical tests. *Econometrica*, Vol. 96(No. 6):1241–1278.

Butz, W. P. and Ward, M. P. (1979). The emergence of countercyclical U.S. fertility. *The American Economic Review*, Vol. 69(No. 3): 318–328.

Case, A. and Paxson, C. H. (2005). Sex differences in morbidity and mortality. *Demography*, Vol. 42(No. 2):189–214.

Cervellati, M. and Sunde, U. (2005). Human capital formation, life expectancy, and the process of development. *American Economic Review*, Vol. 95(No. 5):1653–1672.

Cervellati, M. and Sunde, U. (2011). Life expectancy and economic growth: the role of the demographic transition. *Journal of Economic Growth*, Vol. 16(No. 2):99–133.

Dalgaard, C.-J. and Strulik, H. (2014). Optimal aging and death: understanding the Preston curve. *Journal of the European Economic Association*, Vol. 12(No. 3):672–701.

Deaton, A. (2008). Height, health, and inequality: the distribution of adult heights in India. *American Economic Review*, Vol. 98(No. 2):468–474.

de la Croix, D. and Vander Donckt, M. (2010). Would empowering women initiate the demographic transition in least developed countries? *Journal of Human Capital*, Vol. 4(No. 2):85–129.

Diebolt, C. and Perrin, F. (2013a). From stagnation to sustained growth: the role of female empowerment. *American Economic Review*, Vol. 103(No. 3):545–549.

Diebolt, C. and Perrin, F. (2013b). From stagnation to sustained growth: the role of female empowerment. Association Française de Cliométrie (AFC) Working Paper 4, Restinclières, France.

Doepke, M. (2004). Accounting for fertility decline during the transition to growth. *Journal of Economic Growth*, Vol. 9(No. 3):347–383.

Doepke, M. and Tertilt, M. (2009). Women's liberation: What's in it for men? *Quarterly Journal of Economics*, Vol. 124(No. 4):1541–1591.

Doepke, M. and Tertilt, M. (2014). Does female empowerment promote economic development? NBER Working Paper 19888, Cambridge, Massachusetts.

Duflo, E. (2012). Women empowerment and economic development. *Journal of Economic Literature*, Vol. 50(No. 4):1051–1079.

Ehrlich, I. and Chuma, H. (1990). A model of the demand for longevity and the value of life extension. *Journal of Political Economy*, Vol. 98(No. 4):761–82.

Field, E., Robles, O., and Torero, M. (2009). Iodine deficiency and schooling attainment in Tanzania. *American Economic Journal: Applied Economics*, Vol. 1(No. 4):140–169.

Fink, G. and Masiye, F. (2012). Assessing the impact of scaling-up bednet coverage through agricultural loan programmes: evidence from a cluster-randomized controlled trial in Katete District, Zambia. *Trans R Soc Trop Med Hyg*, Vol. 106(No. 11):660–667.

Galor, O. (2005). From stagnation to growth: unified growth theory. *Handbook of Economic Growth*, Elsevier, Amsterdam, 171–293.

Galor, O. (2011). *Unified growth theory.* Princeton University Press, Princeton, New Jersey.

Galor, O. and Moav, O. (2002). Natural selection and the origin of economic growth. *Quarterly Journal of Economics*, Vol. 117(No. 4):1133–1191.

Galor, O. and Moav, O. (2006). Das human-kapital: a theory of the demise of the class structure. *The Review of Economic Studies*, Vol. 73(No. 1):85–117.

Galor, O. and Weil, D. N. (1996). The gender gap, fertility, and growth. *The American Economic Review*, Vol. 86(No. 3):374–387.

Galor, O. and Weil, D. (2000). Population, technology, and growth: from Malthusian stagnation to the demographic transition and beyond. *The American Economic Review*, Vol. 90(No. 4):806–828.

Grossman, M. (1972). On the concept of health capital and the demand for health. *Journal of Political Economy*, Vol. 80(No. 2):223–255.

Ha, J. and Howitt P. (2007). Accounting for trends in productivity and R&D: a Schumpeterian critique of semi-endogenous growth theory. *Journal of Money, Credit and Banking*, Vol. 39(No. 4):733–774.

Hall, R. E. and Jones, C. I. (2007). The value of life and the rise in health spending. *Quarterly Journal of Economics*, Vol. 122(No. 1):39–72.

Hansen, G. D. and Prescott, E. C. (2002). Malthus to Solow. *American Economic Review*, Vol. 92(No. 4):1205–1217.

Hiller, V. (2014). Gender inequality, endogenous cultural norms, and economic development. *Scandinavian Journal of Economics*, Vol. 116(No. 2):455–481.

Howitt, P. (2000). Endogenous growth and cross-country income differences. *American Economic Review*, Vol. 92(No. 4):502–526.

International Labour Organization (2012). Global employment trends for women. Geneva.

Institute for Health Metrics and Evaluation (2013). Global Burden of Disease Study 2010. India Global Burden of Disease Study 2010 (GBD 2010) Results 1990-2010, Institute for Health Metrics and Evaluation, 2013: Seattle.

Iversen, J. H., Onarheim, K. H., and Bloom D. E. (2015). Economic benefits of investing in womens' health: A systematic review. Working Paper, Boston Massachusetts.

Iyigun, M. and Walsh, R. P. (2007). Endogenous gender power, household labor supply, and the demographic transition. *Journal of Development Economics*, Vol. 82(No. 1):138–155.

Jayachandran, S. and Lleras-Muney, A. (2009). Life expectancy and human capital investments: evidence from maternal mortality declines. *The Quarterly Journal of Economics*, Vol. 124(No. 1):349–397.

Jones, C. I. (2001). Was an industrial revolution inevitable? Economic growth over the very long run. *Advances in Macroeconomics*, Vol. 1(No. 2):1–43.

Jones, C. I. (2002). Sources of U.S. economic growth in a world of ideas. *American Economic Review*, Vol. 92(No. 1):220–239.

Keller, W. (2002). Geographic localization of international technology diffusion. *The American Economic Review*, Vol. 92(No. 1):120–142.

Kimura, M. and Yasui, D. (2010). The Galor–Weil gender-gap model revisited: from home to market. *Journal of Economic Growth*, Vol. 15(No. 4):323–351.

Knowles, S., Lorgelly, P. K., and Owen, P. D. (2002). Are educational gender gaps a brake on economic development? Some cross-country empirical evidence. *Oxford Economic Papers*, Vol. 54(No. 1):118–149.

Kögel, T. and Prskawetz, A. (2001). Agricultural productivity growth and escape from the Malthusian trap. *Journal of Economic Growth*, Vol. 6(No. 4):337–357.

Kuhn, M., Wrzaczek, S., Prskawetz, A., and Feichtinger, G. (2015). Optimal choice of health and retirement in a life-cycle model. *Journal of Economic Growth*, Vol. 158:186–212.

Lagerlöf, N.-P. (2003). Gender equality and long-run growth. *Journal of Economic Growth*, Vol. 8(No. 4):403–426.

Lagerlöf, N.-P. (2005). Sex, equality, and growth. *The Canadian Journal of Economics*, Vol. 38(No. 3):807–831.

Luca D. L., Iversen J. H., Lubet A. S., Mitgang E., Onarheim K. H., Prettner K., and Bloom D. E. (2014). Benefits and costs of the womenâ€s health targets for the post-2015 development agenda. Copenhagen Consensus Center Working Paper.

Molini, V., Nube, M., and den Boom, B. V. (2010). Adult BMI as a health and nutritional inequality measure: applications at macro and micro levels. *World Development*, Vol. 38(No. 7):1012–1023.

Nelson, R. and Phelps, E. (1966). Investment in humans, technological diffusion, and economic growth. *American Economic Review*, Vol. 61(No. 1/2):69–75.

Parente, S. T. and Prescott, E. C. (1994). Barriers to technology adoption and development. *The Journal of Political Economy*, Vol. 102(No. 2):298–321.

Prettner, K., Bloom, D. E., and Strulik, H. (2013). Declining fertility and economic well-being: do education and health ride to the rescue? *Labour Economics*, Vol. 22(June 2013):70–79.

Prettner, K. and Strulik, H. (2014). Gender equity and the escape from poverty. cege Discussion Paper 216, Göttingen.

Rees, R. and Riezman, R. (2012). Globalization, gender, and growth. *Review of Income and Wealth*, Vol. 58(No. 1):107–117.

Schober, T. and Winter-Ebmer, R. (2011). Gender wage inequality and economic growth: is there really a puzzle?—a comment. *World Development*, Vol. 39(No. 8):1476–1484.

Schultz, T. P. (1990). Testing the neoclassical model of family labour supply and fertility. *Journal of Human Resources*, Vol. 25(No. 4):599–634.

Schultz, T. P. (2002). Wage gains associated with height from health human capital. *American Economic Review*, Vol. 92(No. 2):349–353.

Schultz, T. P. (2005). Productive benefits of health: evidence from low-income countries. In G. López-Casasnovas, B. Rivera, and L. Currais (Eds.), *Health and Economic Growth: Findings and Policy Implications*, (257–286), Cambridge, MA: Massachusetts Institute of Technology.

Self, S. and Grabowski, R. (2012). Female autonomy and health care in developing countries. *Review of Development Economics*, Vol. 16(No. 1):185–198.

Shastry, G. K. and Weil, D. N. (2003). How much of cross-country income variation is explained by health? *Journal of the European Economic Association*, Vol. 1(No. 3-4):387–396.

Soares, R. R. and Falcão, B. L. S. (2008). The demographic transition and the sexual division of labor. *Journal of Political Economy*, Vol. 116(No. 6):1058–1104.

Stenberg, K. et al. (2014). Advancing social and economic development by investing in women's and children's health: a new Global Investment Framework. *The Lancet*, Vol. 383(No. 9925):1333–54.

Strauss, J. and Thomas, D. (1998). Health, nutrition, and economic development. *Journal of Economic Literature*, Vol. 36(No. 2):766–817.

Strulik, H., Prettner, K., and Prskawetz, A. (2013). The past and future of knowledge-based growth. *Journal of Economic Growth*, Vol. 18(No. 4):411–437.

Strulik, H. and Weisdorf, J. (2008). Population, food, and knowledge: a simple unified growth theory. *Journal of Economic Growth*, Vol. 13(No. 3):195–216.

Thomas, D. (1990). Intra-household resource allocation: an inferential approach. *Journal of Human Resources*, Vol 25(No. 4):635–664.

Vos, T. et al. (2012). Years lived with disability (YLDs) for 1160 sequelae of 289 diseases and injuries 1990-2010: a systematic analysis for the Global Burden of Disease Study 2010. *The Lancet*, Vol. 380(No. 9859):2163–2196.

Weil, D. (2007). Accounting for the effect of health on economic growth. *The Quarterly Journal of Economics*, Vol. 122(No. 3):1265–1306.