

# The Evolution of the Gender Pay Gap: Lessons from Track and Field Athletics\*

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January 9, 2009

## Abstract

In the last 5 decades, the US gender pay ratio has followed a S-shape with a 18-year window of increase between 1973 and 1991. This paper shows that the gender world record marathon ratio exhibits a similar pattern with a 20-year window of increase between 1964 and 1984, a period marked by the authorization for women to participation at marathons. As participation of women increased, competition became tougher giving women participants incentives to invest more in training. I argue that as for Marathon running, the evolution of gender pay ratio is explained by the increased female

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\*First draft. The comments of Lex Borghans, Nabanita Datta Gupta, Didier Fouarge, Bart Golsteyn, Sol Polachek and Michael Sattinger are acknowledged.

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participation, following WWII and the women's liberation movement of the 60s and 70s. As expected participation increases, women's investments in human capital increases leading to a decrease in the gender pay gap.

*JEL Classification:* J16, J7, N32.

*Keywords:* Gender Pay Gap, Gender World Record Marathon Ratio, Human Capital investments, Participation.

# 1 Introduction

The gender pay Gap (GPG hereafter) ranks high on the political agenda of developed countries and its reduction has been targeted many times before. The GPG has therefore received a significant amount of attention in the (labor) economics literature and the debate is still very much open about the causes of the GPG: unobserved skills differences across gender or discrimination? Perhaps even more puzzling is the observation that the GPG has decreased significantly from the mid-70s to the mid-90s and leveled off thereafter. This raises the question of which factor(s) has been responsible for this pattern over time? Have women increased their investments in human capital following their increased (expected) participation in the labor market?<sup>1</sup> or have policies targeting gender discrimination been successful (at last)?

The aim of this paper is to answer these questions. To this aim, I argue that data from sports and especially Track and Field Athletics are particularly helpful. These data offer indeed a natural experiment in which i) a set of tasks is clearly defined and constant over time, ii) the productivity at these tasks is also clearly and accurately measurable and iii) there is no discrimination between men and women

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<sup>1</sup>In a recent paper, Polachek (2006) shows evidence in favor of the human capital explanation for the evolution of the gender pay gap over time. In the human capital view, expected participation increases human capital investment and hence productivity. As women participation increases, new cohorts of women face higher expected life-time work and hence invest more in human capital than earlier cohorts. At constant men's participation, the model predicts an increase in women's wages compared to men over time.

as they compete in different “markets”. Hence, comparing the performance of women to men over time in various sports (=tasks), one can derive the evolution of the gender performance gap over time. Differences between men and women in performance are then merely the result of differences in abilities to perform these tasks and not discrimination. It should be noted here that the ability to perform a task such as running the marathon is determined by the initial ability people were born with plus the result of investments in training prior to running the marathon, i.e. investments in human capital.

The key feature that makes sports like track and field suitable to identify the role of participation in explaining the gender pay gap via human capital investments, is that not all disciplines were introduced in major events, such as the Olympic games, at the same time for men and women. For instance, while sprint disciplines were introduced for women at the 1928 Olympic games, long distance running were not on the program of the Olympics for women before 1960 (800 meters) and 1984 (marathon). For disciplines such as long distances, the differential timing of introduction implies different patterns of participation for men and women over time. In turns, increase participation of women (relative to men), densifies competition among women (relative to men) and leads women participating in these disciplines to increase their investments in training (human capital).<sup>2</sup>

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<sup>2</sup>In a related paper, Munasinghe et al. (2001) find that the evolution of world record breaking in Track and Field is similar to the evolution of US record breaking arguably local records set with fixed population. Munasinghe et al. argue that this evidence stems for the prominent

For disciplines with differential timing of participation across gender, we should expect different patterns of human capital investments across gender and hence different patterns of world record over time. By comparing the patterns of gender world record ratio across disciplines, we can identify the impact of “participation” on the gender performance gap.

This paper shows evidence that the evolution of the Gender Pay Ratio (GPR hereafter) is similar to, and appears to follow by 10 years, the evolution of the Gender World Record Marathon Ratio (GWRMR hereafter). In fact, a 10% points increase in GWRMR five years ago leads to a 4.7% increase in the current GPR, a coefficient significant at the 1% level. Since the main force behind the evolution of the GWRMR is the increased participation of women at marathon leading to an increased competition between women and hence higher investments in terms of training, the relationship between GPR and GWRMR points towards female participation and women’s liberation movements following WWII as the explanation of the evolution of the GPR via higher human capital investments as suggested by Polachek (2006).

A simple model of human capital accumulation with two work activities (work

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role played by technological progress in the evolution of world record breaking as opposed to globalization. However, one can easily argue that 1) a significant share of world records in Track and Field are also US records and more important that 2) athletes breaking the US records are usually athletes competing at international competition (world championships, Olympics etc.) and therefore subject to increased competition among athletes following from the globalization and leading to increased human capital investments (increased training load, better nutrition, more massages, etc.), factors acknowledged in Munasinghe et al. as being part of the technological progress.

in the labor market and home production or marathon and sprint), each requiring a specific type of human capital for production, and social barrier leading to disutility to participate in one sector is developed. As the social barrier drops, the model predicts an increase of participation in that sector, an increase in investment in the associated type of human capital and hence an increase in productivity in that sector. Simple parametrization of the model show that productivity will increase according to a S-shape similar to the observed S-shape of the evolution of the GPR/GWRMR

The remaining structure of the paper is as follows. The next section presents the evolution of the US GPG over time and reviews the main candidates to explain this evolution. Section 3 shows the analogy between GPG and Track and Field Athletics. Section 4 presents a simple model of human capital accumulation and social barrier. Section 5 presents some robustness checks and section 6 summarizes and concludes.

## **2 The GPG in the Economics Literature**

The traditional approach of economists to measure the GPG is to run (log) wage regressions relating individual wages to gender and productivity-related characteristics of men and women such as education, experience, occupation and industry, hours of work etc. The unexplained GPG is given by  $\delta$  the coefficient for gender.

Another way to express the difference in pay between men and women is the GPR, defined as the (log) wage of women relative to men, and calculated as  $1 - \delta$ . For the US,<sup>3</sup> the unexplained GPR was about 60% in the beginning of the 60s, meaning that women earned only 60 cents for every dollar that men earned, and 80% in the 00s. The evolution of the unexplained GPR, presented in Figure 1, is atypical and follow a S-shape with a 18- year window –1973; 1991– of increase between its two flat parts.<sup>4</sup> This also means that the determinant(s) of the GPR must have followed a similar evolution over time, either contemporaneous or prior to that of the GPR. The crucial feature to identify the determinant(s) of the GPR is this 18-year window between the two extremes of the GPR.

The question of the determinants of the evolution of the GPR has been addressed many times in the literature, see Blau and Kahn (2006) for instance. From this literature, two main candidates emerge: i) increased unobserved human capital, i.e. skills and/or traits, such as motivation, time preference and risk attitudes, and ii) decreased discrimination. Most of the literature has approached the problem with the premise that discrimination is the key factor behind unexplained GPR. This premise is also in line with the popular opinion and political attention.

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<sup>3</sup>Using the CPS march supplements from 1964 to 2005.

<sup>4</sup>These results are very much in line with Blau and Kahn (2007) although the sample selected and the control differ substantially. Note also that controlling only for (log) hours worked and race, the GPR shows a similar S-shape although it ranges from 50% in the 60s to 80% in the 90s –this figure is available upon request to the author–. I chose the unexplained GPR once controlled for education, occupation and industry to highlight the fact that investments in human capital have taken various forms and not been limited to higher educational achievement.

This group of studies has focused principally on the impact of institutional factors (see Blau and Kahn (2003)) affecting wage settings, such as minimum wage, or on hiring discrimination in specific sectors, i.e. symphony Orchestra (see Goldin and Rouse (2000)) or Philadelphia restaurants (see Neumark (1996)). Although wage settings have changed over time as shown by the evolution of the minimum wage and union membership over time in Figure 2, these changes have not followed a S-shape with 18-year window and therefore are unlikely to be the culprit to explain the evolution of the GPR over time. Regarding hiring discrimination, conclusion must be speculative as these studies are essentially cross-sectional and experimental in nature and therefore do not allow us to trace changes over time in hiring procedures. Nevertheless, even if one is willing to argue that hiring discrimination is the driving force behind the evolution of the GPR and hence has been S-shape with 18-year window over time, one would have to concede that either (hiring) discrimination explains only part of the GPR and the remaining 20% point have little to do with discrimination or, perhaps more pessimistic, that fighting against hiring discrimination has become harder and the investment in terms of policy interventions to get the GPR to 100% would have to be tremendously bigger to overcome the flattening of the GPR.

Not surprisingly, only few studies have viewed and approached the problem from the perspective of unobserved skills differences across gender as being the

source of the unexplained GPR by comparing the GPR to the Gender Productivity Ratio, see Hellerstein et al (1999) and Bayard (2003). The reason for this relatively unexplored area lies probably in the difficulty to obtain and construct labor market data in which i) individual productivity is measured accurately and ii) the set of tasks individuals perform is constant across gender. In the labor market, rare are the jobs for which productivity is measured in output units and not affected by the productivity of co-workers, either subordinates or managers, and even if there exist occupations for which both men and women are fairly represented, the set of tasks men and women deal with need not be exactly the same.

For such an exercise to work, one would need to have an experiment in which i) a set of tasks is clearly defined and constant over time, ii) the productivity at these tasks is also clearly and accurately measurable and iii) there is no discrimination between men and women. Then, one would simply assign women and men to these tasks, report measured productivity and derive the gender productivity gap associated. Differences between men and women would then be merely the result of differences in abilities to perform these tasks and not discrimination.

### **3 Analogy to Track and Field Athletics**

While requirements i), ii) and iii) are most likely never to be met in the labor market, many sports fulfill these requirements and for instance Track and Field

Athletics. Take the example of running marathon. The set of tasks is clearly defined and constant over time,<sup>5</sup> productivity is clearly measured by the time it takes to run the distance of 42.195 km and men and women compete in different “markets”.

The evolution of the GWRMR is depicted in Figure 3. The GWRMR was about 68% until the 50s, dropped steadily to 63% by the mid-60s and started increasing sharply and steadily from 1964 to reach 90% by 1984. It has remained roughly constant since then. Not only its magnitude is strikingly close to the GPR but also its behavior over time: it follows a S-shape with a 20-year window of increase –1964;1984– between its two flat parts. In fact, the GPR seems to be lagging 10 years behind the GWRMR. As it turns out, a AutoRegressive Distributed Lag (ARDL) model fits the data accurately. The residuals of the model are indeed stationary as indicated by the Augmented Dickey Fuller (ADF) and Phillips Perron (PP) test statistics reported in Table 1 and the 10-year lagged value of the GWRMR explains significantly the current level of the GPR, i.e. a 10% points increase in the GWRMR leads to a 4.7% points increase in the GPR 10 years later.<sup>6</sup> Of course, unless one is willing to argue that employers decide

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<sup>5</sup>Training methods and running techniques are similar for both men and women. Although, since the training load is constrained by an individual’s physiological characteristics and men and women differ in their maximal oxygen uptake ( $VO_{2\max}$ ) by 10%, the training load of women must be lower than that of men.

<sup>6</sup>These results are robust to the inclusion of union membership and minimum wage –either current or 1,2,3,4 and 5-year lead as might be suspected from the series in Figure 2– in the model and the coefficients of these additional series are never significant at the 5% level. Note also that the trend parameter is not significant.

about how much to pay women relative to men based on the GWRMR 10 years ago, one has to look further at the confounding factor behind both the GWRMR and the GPR.

To answer this question, one needs to understand the driving force behind the evolution of the GWRMR over time. Remarkably enough, even though the current ratios of WR are about 10% in all distances, from the 100 meters to the marathon, a threshold that is understood in the Sports and Medicine literature as biological in nature (Cheuvront et al. (2005)), the evolution of the ratios of WR have been very different across distances as illustrated in Figure 9.<sup>7</sup> The reason for these different evolutions lies in the historical development of women's participation in Track and Field events. Although women's track and field events were beginning to be accepted in the 1920s, and in fact were introduced at the 1928 Olympic games for the first time, only short distances were allowed.<sup>8</sup> It is not until 1960 that women were allowed to run the 800 meters at the Olympics and the marathon was introduced for the first time in 1984. Also beyond the Olympic games, women had to wait until 1971 to be allowed to run the New York City marathon and one year later the Boston marathon. In fact, the women's liberation movement of the

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<sup>7</sup>The kink in the 80s for the 100 meters and the subsequent decrease to the 90% level has been attributed in the literature to the use of testosterone by athletes prior to the Ben Johnson scandal and the subsequent strengthening of the doping controls. Women have been shown to benefit more from testosterone doping than men, see Bahrke and Yesalis (2004).

<sup>8</sup>The 800 meters was on the program of the 1928 Olympics but 3 women collapsed during the race which led to a general masculine opinion that women could not safely run long distances.

60s and 70s that drove female participation in the labor market, see Figure 3, also contributed to a gradual participation of women at long distance events.

These results show a striking parallel between women and the labor market and women and marathon running. Although quantitative data about the number of women running marathon over time, i.e. competitiveness, is practically impossible to gather, qualitative information about the crucial dates at which women were first authorized to participate at various marathons (New York, Boston and Olympics) show a parallel to the female participation rate in the labor market. It is also striking to see that the GWRMR is a strong and significant predictor of the GPR, leading 10 years ahead and that the flattening of the GPR around 80% starting in 1991 corresponds to the contemporaneous flattening of the female participation around 60% and the flattening of the GWRMR around 90% starting 7 years earlier in 1984. It seems that the GPR has been driven by female participation in the labor market following WWII and the women's liberation movement in a similar way that the GWRMR has been driven by women's participation at marathons.

Moreover, one could speculate that since the flattening of the GWRMR at a level below 100% is attributed to biological differences, the flattening of the GPR observed since 1991 around the 80% could be attributed to differences in (unobservable) skills between men and women.<sup>9</sup>

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<sup>9</sup>In a recent paper, Ichino and Moretti (2007) show evidence that women's higher absenteeism at work compared to men is due to the menstrual cycle. This menstrual cycle induced absenteeism explains 11.8 percent of the gender pay gap.

## 4 A simple human capital model of participation and productivity

### 4.1 Model

Consider an economy where individuals live for  $A$  years. As in the standard human capital model, individuals invest full time in human capital early in their lives and then engage full time in consumption generating activities, i.e. sector 1 or 2. For the sake of the argument, when applied to the example of the GPG, sector 1 is the labor market and sector 2 is home production. When applied to Track and Field, sector 1 is marathon and sector 2 is either sprint or one of the early events opened to women or the labor market.

For simplicity, assume that the age at which individuals stop accumulating human capital is set exogenously at  $0 < \bar{a} < A$  and is the same for all individuals. Let individuals be born with endowed stock of human capital of two types, i.e.  $h_{10}$  and  $h_{20}$  and let the distribution of endowed human capital in the economy, defined as  $d(h_{10}, h_{20})$ , be constant over time and hence across cohorts. Let human capital of type  $j$  at age  $a$  be  $h_{ja}$ ,  $j = 1, 2$  and let  $s_{ja}$  be the time spent accumulating human capital of type  $j$  at age  $a$ . Since individuals are assumed to invest full time in human capital until age  $\bar{a}$  and engage in consumption generating activities thereafter, we have that  $s_{1a} + s_{2a} = 1$  for all  $a < \bar{a}$  and  $s_{ja} = 0$  for  $a \geq \bar{a}$ . The

accumulation of human capital of type  $j$  through study is given by  $g_j(h_{ja-1})s_{ja}$ . The evolution of the stock of human capital is not only driven by human capital investments but also by appreciation –early in life– and depreciation –late in life– over the life-cycle given by  $\alpha_j + \frac{\beta_j}{2}a$ . The change in the stock of human capital of type  $j$  is thus given by:

$$\dot{h}_{ja} = g_j(h_{ja-1})s_{ja-1} + \alpha_j + \frac{\beta_j}{2}a$$

Note that human capital depreciation  $\alpha_j + \frac{\beta_j}{2}a$  is specific to the type of ability.

Productivity in sector  $j$  is assumed to depend only on human capital of type  $j$ . Let  $t_a^j$  be the time spent working in sector  $j$  at age  $a$  with  $t_{1a} + t_{2a} = 1$  if  $a \geq \bar{a}$  and  $t_{1a} = t_{2a} = 0$ . Assume that individuals derive no intrinsic utility from accumulating human capital and let an individual's utility<sup>10</sup> at age  $a$  be  $U_a = (f_1(h_{1a}) - B_1)t_{1a} + (f_2(h_{2a}) - B_2)t_{2a}$  where  $f_j(x)$  is the (per unit of time) productivity/consumption of workers with level  $x$  of type  $j$  and  $B_j$  is a positive constant indicating (per unit of time) social barrier leading to disutility of working in sector  $j$ . For the sake of simplicity and without loss of generality assume that  $B_2 = 0$ . At each age, utility maximizing individuals will therefore specialize and

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<sup>10</sup>Any convex function of  $(f_1(h_{1a}) - B_1)t_{1a}^1$  and  $(f_2(h_{2a}) - B_2)t_{2a}$  will yield a corner solution  $t_{ja} = 1$  and  $t_{ka} = 0$ ,  $j \neq k$ .

engage full time in either producing in sector 1 or 2 depending on  $U_{1a} \stackrel{\geq}{\leq} U_{2a}$ .

The problem for an individual born with human capital  $h_{10}$  and  $h_{20}$  is therefore to choose  $s_{ja}$  and  $t_{ja}$ ,  $j = 1, 2$  for all  $a$  to maximize life-cycle utility. Formally the problem reads as:

$$\max_{s_{ja}, t_{ja}} \int_{\bar{a}}^A e^{-\rho t} U_a da$$

so that :

$$\begin{aligned} U_a &= (f_1(h_{1a}) - B_1) t_{1a} + f_2(h_{2a}) t_{2a} \\ t_{1a} &= t_{2a} = 0 \text{ if } a < \bar{a} \\ t_{1a} + t_{2a} &= 1 \text{ if } a \geq \bar{a} \\ s_{1a} + s_{2a} &= 1 \text{ if } a < \bar{a} \\ t_{1a} &= t_{2a} = 0 \text{ if } a \geq \bar{a} \\ \dot{h}_{ja} &= g_j(h_{ja-1}) s_{ja} + \alpha_j + \frac{\beta_j}{2} a \end{aligned}$$

where  $\rho$  is the discount rate.

The solution to this problem can be obtained using optimal control techniques although, even for this simple model, general closed form solutions are unlikely to exist. However, the essence of the model and its application to the GPR and the GWRMR is best understood with further simplifications. First, assume that the stock of human capital of each type depreciates at the same rate so that  $\alpha_1 = \alpha_2 = \alpha$  and  $\beta_1 = \beta_2 = \beta$ . This means that if the stock of human capital

of type  $j$  is larger than the stock of human capital of type  $k$  at  $\bar{a}$ ,  $k \neq j$ , it will remain so until age  $A$ . Second, assume that  $f_1(x) = f_2(x)$  for all  $x$ . This means that the productivity-age profiles of each type are parallel to each other and hence either never cross each other or are equal to each other.

From the first assumption we have that if  $h_{1\bar{a}} > h_{2\bar{a}}$  then  $h_{1a} > h_{2a}$  for all  $a$ . From both assumptions we have that if  $h_{1\bar{a}} > h_{2\bar{a}}$ , then  $f_1(h_{1a}) > f_2(h_{2a})$  for all  $a \geq \bar{a}$ . This also means that if  $f_1(h_{1\bar{a}}) - B_1 > f_2(h_{2\bar{a}})$  then  $f_1(h_{1a}) - B_1 > f_2(h_{2a})$  for all  $a \geq \bar{a}$ .

Define  $\bar{h}_{ja}$  ( $\underline{h}_{ja}$ ) as the stock of human capital at age  $a$  if one invests full time in ability of type  $j$  (respectively  $k$ ), that is, if  $s_{ja} = 1$  (respectively 0) for all  $a < \bar{a}$ . The two assumptions above imply that individuals will invest full time in accumulating human capital of type 1 if  $f_1(\bar{h}_{1\bar{a}}) - B_1 > f_2(\bar{h}_{2\bar{a}})$  or type 2 if  $f_1(\bar{h}_{1\bar{a}}) - B_1 \leq f_2(\bar{h}_{2\bar{a}})$  and then work full time in sector 1 or 2 respectively until they die at age  $A$ .<sup>11</sup> Note that this choice depends on the initial endowments of the two types  $h_{10}$  and  $h_{20}$ , the speed of human capital accumulation through investments  $g_1$  and  $g_2$ , the productivity-age profiles  $f_1$  and  $f_2$  and the magnitude of the social barrier  $B_1$ .

For the sake of the argument, suppose that social barriers are initially very large so that every individuals accumulate type 2 human capital and select sector

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<sup>11</sup>If  $f_1(\bar{h}_{1\bar{a}}) - B_1 = f_2(\bar{h}_{2\bar{a}})$  individuals are indifferent. Without loss of generality, I assume that individuals will invest in 2 in this case.

2, i.e.  $B_1 > f_1(\bar{h}_{1\bar{a}}) - f_2(\bar{h}_{2\bar{a}})$  for all individuals. It is important to note that some individuals with relatively high endowed ability of type 1 compared to type 2 are still more productive in sector 1 than in sector 2,  $f_1(\underline{h}_{1a}) > f_2(\bar{h}_{2a})$  but choose sector 2 because of the intrinsic disutility derived from the social barrier  $B_1$ . Suppose then that  $B_1$  drops suddenly (unanticipated) to 0 at a point in time say  $T$ . Define cohorts of individuals by their age at  $T$  say  $a_T$ . Of all individuals of cohorts  $a_T > \bar{a}$ , those with relatively high endowed ability of type 1, i.e. with  $f_1(\underline{h}_{1a}) > f_2(\bar{h}_{2a})$  will switch from sector 2 to sector 1. The productivity of these individuals at sector 1, though limited since they did not invest in human capital of type 1 ever, will be the reference in sector 1 and set the reference level for younger cohorts. In the meantime, some individuals from cohort  $a_T = \bar{a} - 1$ , that invested full time in type 2 human capital up until  $T$ , i.e. age  $\bar{a} - 1$ , will find it profitable to dedicate their last year of study to type 1 human capital. These individuals of cohort  $a_T$  will then select sector 1 at  $T + 1$ , i.e. age  $\bar{a}$ , and move on a higher productivity-age profile than their older cohorts with same endowed human capital simply because of their higher investment in human capital of type 1. Similarly, those individuals of cohort  $a_T = \bar{a} - j$  with  $f_1(\underline{h}_{1a}) > f_2(\bar{h}_{2a})$ , will dedicate their last  $j$  years of study to investment in human capital of type 1 and select sector 1 when they turn  $\bar{a}$  years old. For each new cohort, those individuals with similar endowed human capital and with  $f_1(\underline{h}_{1a}) > f_2(\bar{h}_{2a})$  will move on a

higher productivity-age profile than similar individuals from the previous cohort thanks to their additional year of investment in type 1 human capital. For all cohorts  $a_T$  younger than 0, those individuals with similar endowed human capital and with  $f_1(\bar{h}_{1a}) > f_2(\bar{h}_{2a})$  will have invested full time full years in type 1 human capital and hence move on the productivity-age profile  $f_1(\bar{h}_{1\bar{a}})$ .

This process indicates that holding initial human capital constant, the mean productivity of new cohorts will increase. Moreover, suppose that productivity levels off at age  $a^* > \bar{a}$ , i.e.  $\arg \max_a f_1(h_{1a}) = a^*$ . The above process implies that, holding endowed human capital of type 1 constant, the highest productivity measured in sector 1 will move up from  $f_1(\underline{h}_{1a^*})$  at  $T$  to  $f_1(\bar{h}_{1a^*})$  at  $T + a^*$ . Will it increase constantly over time? Not necessarily. It will depend on  $h_{10}$ ,  $g_1$  and the slope of  $f_1$ . In general the additional human capital accumulated by cohort  $a_T = \bar{a} - 1$  will be so that  $f_1(\underline{h}_{1\bar{a}-1} + g_1(\underline{h}_{1\bar{a}-1}) + \alpha + \frac{\beta}{2}\bar{a}) < f_1(\underline{h}_{1a^*})$ . In which case, the highest productivity will be  $f_1(\underline{h}_{1a^*})$  at  $T + 1$  too. Similarly, if the additional human capital accumulated by cohort  $a_T = \bar{a} - 2$  is not large enough and if the productivity of cohort  $a_T = \bar{a} - 1$  has not yet increased enough between  $T + 1$  and  $T + 2$ ,  $f_1(\underline{h}_{1a^*})$  will still be the highest productivity. However, at some point in time, the productivity of younger cohorts will be larger than  $f_1(\underline{h}_{1a^*})$ . It might be cohort  $a_T = \bar{a} - 1$  who first outperforms the older cohorts but it might also be younger cohorts at younger age.

## 4.2 Illustration

To illustrate the main prediction of the model, I use the following parametrization:

$$g_j(h_{ja}) = 0.035h_{ja-1} - 0.003h_{ja-1} \text{ for } j = 1, 2$$

$$\dot{h}_{ja} = g_j(h_{ja-1}) + 0.5a - 0.015a^2$$

$$f_j(h_{ja}) = h_{ja}$$

$$B_1 = 3$$

$$\bar{a} = 18$$

The human capital-age profiles and productivity-age profiles for individuals with  $h_{10} = 4$  and  $h_{20} = 3$  are plotted on Figure 4. If these individuals invest full time in type 1 human capital their stock of human capital of type 1 at age  $a$  is given by the blue-square line and their stock of type 2 human capital is given by the black-triangle line. If they invest full time in type 2 human capital, their stock are given by the red-circle line and the green-star line respectively. If there were no social barrier, these individuals would invest full time in type 1 human capital and work in sector 1, moving on the blue-square line to maximize life-time utility. However, with social barrier  $B_1 = 3$ , the situation in utility terms is given by Figure 5. These individuals will prefer to move on the green-star line and thus

invest full time in type 2 human capital and work in sector 2.

The situation for individuals with the same endowed stock of type 1 human capital, i.e.  $h_{10} = 4$ , but lower endowed stock of type 2 human capital ( $h_{20} = 2$ ) is depicted in Figure 6. For them too the social barrier is too large so that they investment in type 2 human capital and then work in sector 2 will maximize life-time utility. However, while individuals with  $h_{10} = 4$  and  $h_{20} = 3$  would still choose for sector 2 if the social barrier were to drop to 0 at the time they already turned  $\bar{a} = 18$ , individuals with  $h_{10} = 4$  and  $h_{20} = 2$  would maximize life-time utility by working in sector 1. Indeed, even though individuals  $h_{10} = 4$  and  $h_{20} = 2$  never invested in type 1 human capital, they are more productive at sector 1 (red-circle line) than at sector 2 (green-star line).

As individuals  $h_{10} = 4$ ,  $h_{20} < h_{10}$  younger than  $\bar{a} = 18$  at  $T$  start investment in type 1 human capital during their remaining years after having invested full time in type 2 human capital until  $T$ , the highest productivity of workers with  $h_{10} = 4$  in sector 1 will progressively increase over time. Figure 8 shows this evolution of the highest productivity in sector 1 for workers with endowed stock of type 1 human capital  $h_{10} = 4$  after that social barrier drops from  $B_1 = 3$  to 0 at  $T = 0$ . Given the parametrization above, this evolution is S-shape with a 19-year window. This shows that the simple human capital model depicted above is rich enough to reproduce the evolution of the US gender pay ratio and the gender world record

ratio observed in the data.

## 5 Robustness checks

To assess the robustness of the above results, I plot in Figure 9 and 10 the evolution of the Gender World Record in other disciplines and other sports (Swimming and Speed skating). The figures clearly shows two groups of series. One group, plotted on Figure 9, including Track and Field events, 100 meters, high jump and to some extent long jump,<sup>12</sup> swimming events covering the 100 meters and 1500 meters free style and speed skating event 500 meters, is characterized by a slowly upward sloping gender world record ratio over time and consists of the early events officially opened to women at major competitions (Olympics and/or world championships). The second group, plotted on Figure 10 consists of marathon, triple jump and pole vault and is characterized by a S-shape gender world record ratio with windows of increase of respectively 20 years, 1964–1984, 13 years, 1982–1995,<sup>13</sup> and 21 years, 1987–2008. The events in this second group belong to the later events opened

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<sup>12</sup>It should be noted that the trend for long jump is "biased" by the surrealistic jump performed by Bob Beamon at the 1968 Mexico Olympics. The WR mark increased by 6% points that day and hence the Gender ratio decreased by 6% points that very same day.

<sup>13</sup>It could easily be argued that the faster transition observed for triple jump, i.e. 15-year window, and the fact that it started a bit ahead of the authorization for women to participate, is due to the fact that a significant number of athletes that started participating to the triple jump events came from long jump. The most well-known examples being Inessa Kravets (Ukraine) the first Olympic champion in Atlanta 1996 who also won the silver medal at the long jump event in Barcelona 1992 and Tatyana Lebedeva (Russia) who won the silver medal at the triple jump event in 2000 and 2008 and the bronze medal in 2004 and won the gold medal at the long jump event in 2004.

to women, i.e. triple jump and pole vault were only ratified by the International Association of Athletics Federations in 1990 and 1992 respectively and appeared at the Olympics for the first time in 1996 and 2000 respectively. Figure 10 shows clearly the similarity between the evolution of the GPR and the gender world record ratio in marathon, triple jump and pole vault.

As for the GWRMR, I run separate ARDL regressions of GPR on the gender world record triple jump ratio and the gender world record pole vault ratio. The residuals of both models are stationary (ADF and PP tests are significant at the 1% level for both regressions) and the coefficient for the 5-year lead of the gender world record triple jump ratio is 0.39 and significant at 1% and the coefficient for the 14-year lead of the gender world record pole vault is 0.55 and significant at 1%. This means that a 10% points increase in the gender world record triple jump ratio 5 years from now leads to a 3.9% points increase in the current GPR. Similarly a 10% points increase in the gender world record pole vault ratio 14 years from now leads to a 5.5% increase in the current GPR.

One might wonder whether world records capture adequately the evolution of performance over time. An alternative way to look at the evolution of women's performance relative to men. Yet, this method would still not account for the fact that WR record or year best performances are more often than not established at different events and hence under different conditions for men and women. To

account for this unequal conditions, one could compare the women's winning time to men's winning time at the Boston marathon (one of the oldest and most competitive marathon of the world). Figure 11 plots the gender year best performance ratio and the gender winning time at the Boston marathon ratio together with the GWRMR. The evolution of the three ratios is extremely similar and reinforce the results presented above.

## 6 Conclusion

To conclude, this paper shows evidence that the evolution of the GPR is similar to, and appears to follow by 10 years, the evolution of the GWRMR. Since the main force behind the evolution of the GWRMR is the increased participation of women at marathon leading to an increased competition between women and hence higher investments in terms of training, the relationship between GPR and GWRMR points towards female participation and women's liberation movements following WWII as the explanation of the evolution of the GPR. This is perfectly in line with Polachek (2006)'s human capital model that predicts a smaller GPR, due to a relative increase in human capital investments, as male-female lifetime work expectations become more similar. After all, the human capital model is also at work in Track and Field.

In addition, one is tempted to push further the comparison between Sports

and the labor market and following the literature on Sports and Medicine that explains the flattening of the GWRMR around the 90% level in terms of biological differences between men and women, e.g. Chevront et al. (2005), to attribute the remaining 20% gap in pay observed since 1991 to differences in unobservables (to the econometrician) characteristics between men and women. These skills differentials are themselves the result of lower human capital investments (not only in terms of education but in terms of investments in a wide range of (unobserved) skills and traits) that follow from the yet still lower labor market participation of women compared to men, i.e. labor market participation rate is 59.3% for women in 2007 compare to 73.2% for men.

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Table 1: Autoregressive Distributed Lag fit of the gender pay ratio on the gender world record marathon ratio.

$GPR_t$	Coefficients	Standard errors
$GPR_{t-1}$	0.349 ***	0.1287
$Trend$	-0.026	0.0547
$GWRMR_{t-10}$	0.470 ***	0.1041
$Constant$	61.096	104.27381
$R_{adj}^2$	0.981	
$N$	41	

	ADF with drift (lag 1)	PP with drift (lag 1)
$GPR_t$	-1.885 (0.66)	-1.88 (0.67)
$GWRMR_t$	-1.61 (0.79)	-1.58 (0.80)
$Residuals_t$	-4.04 (0.01)	-5.62 (0.00)

Note: ADF is the Augmented Dickey-Fuller test for unit root

PP is the Phillips-Perron test for unit root

\*\*\* sig at 1%

p-values between ().

$Residuals = GPR_t - (0.349 \times GPR_{t-1} - 0.026 \times Trend + 0.470 \times GWRMR_{t-10} + 61.096)$

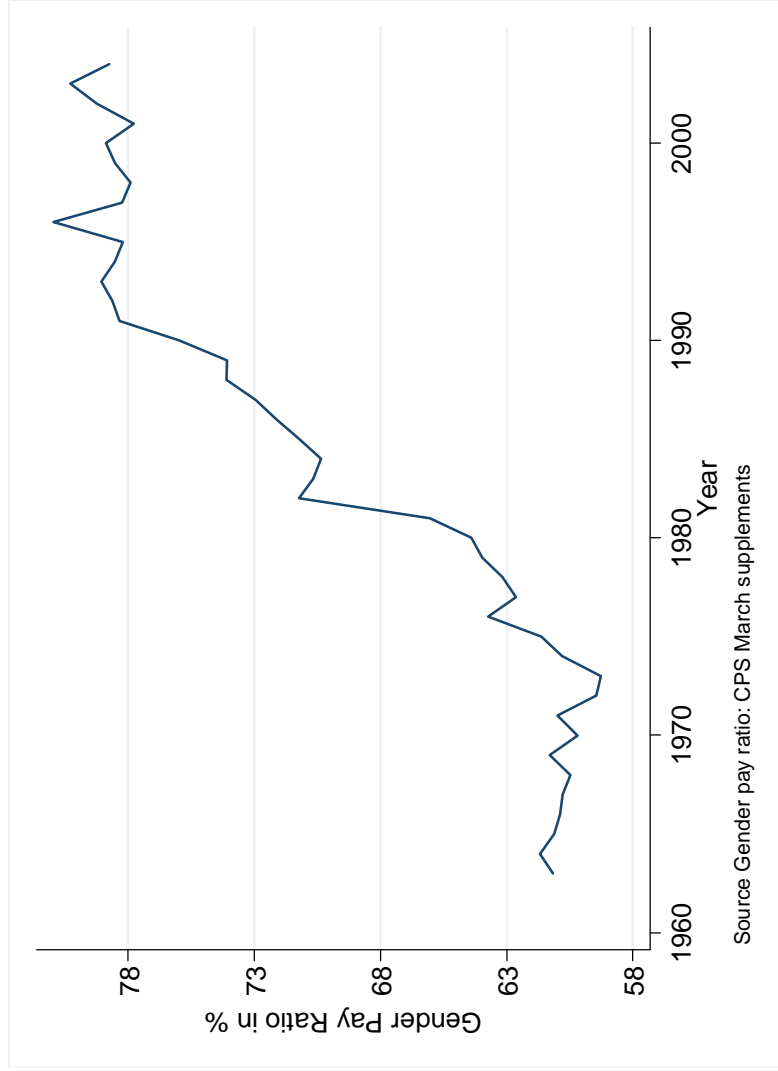


Figure 1: US Gender Pay Ratio over time. Note: the Gender pay ratio is  $1-\delta$  where  $\delta$  is the coefficient of gender in a regression of log hourly earnings on gender, controlling for college education, occupation and industry, race and hours. The sample includes those with hourly earnings above one half of minimum wage. Topcoded earnings are adjusted following Katz and Murphy (1992).

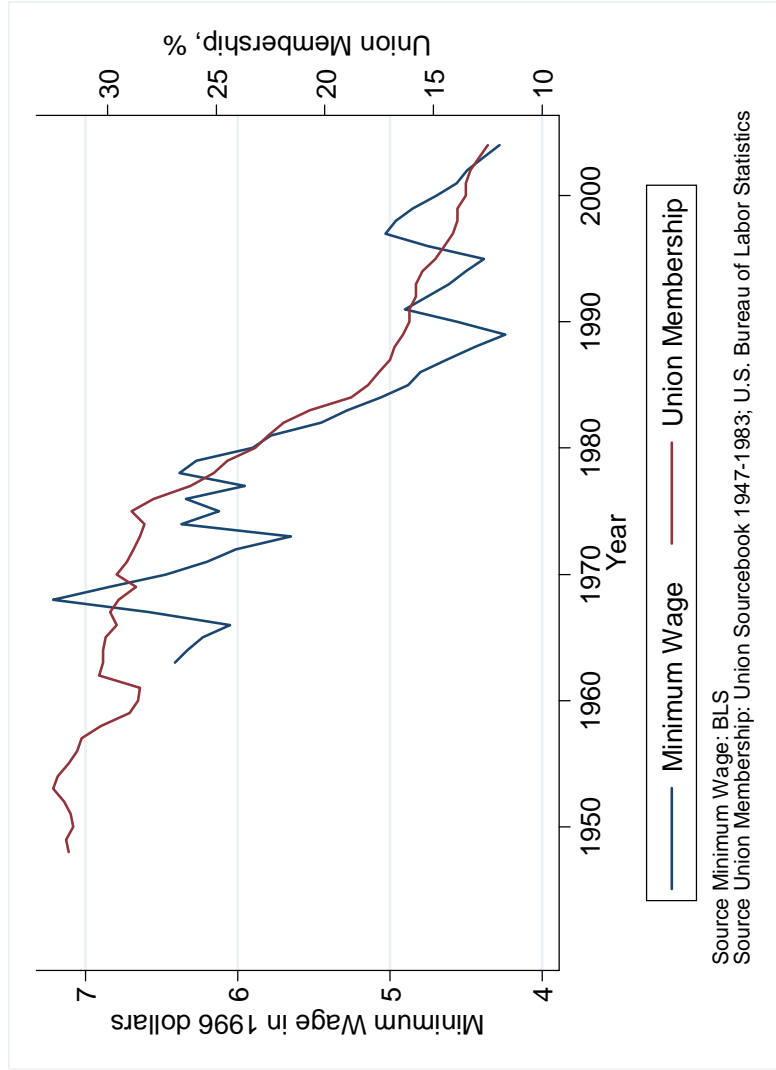


Figure 2: US minimum hourly wage and union membership over time.

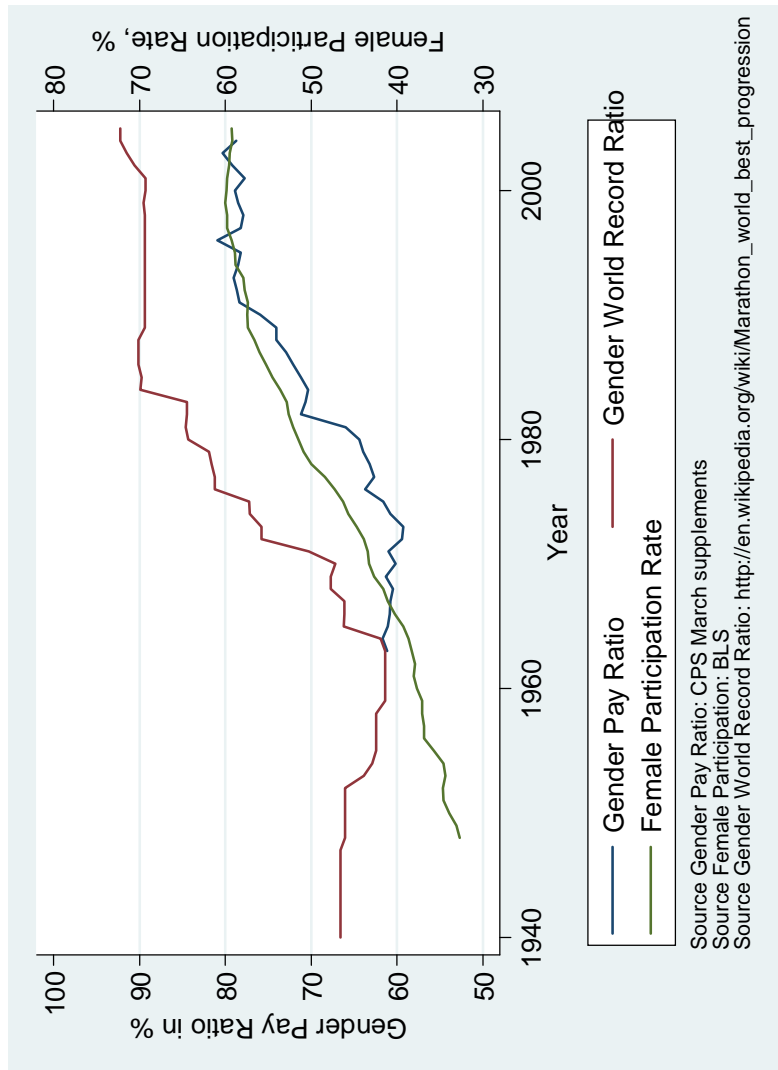


Figure 3: Gender Pay Ratio and Gender World Record Marathon Ratio. Gender pay ratio is  $1-\delta$  where  $\delta$  is the coefficient of gender in a regression of log hourly earnings on gender, controlling for college education, occupation and industry, race and hours. The sample includes those with hourly earnings above one half of minimum wage. Topcoded earnings are adjusted following Katz and Murphy (1992).

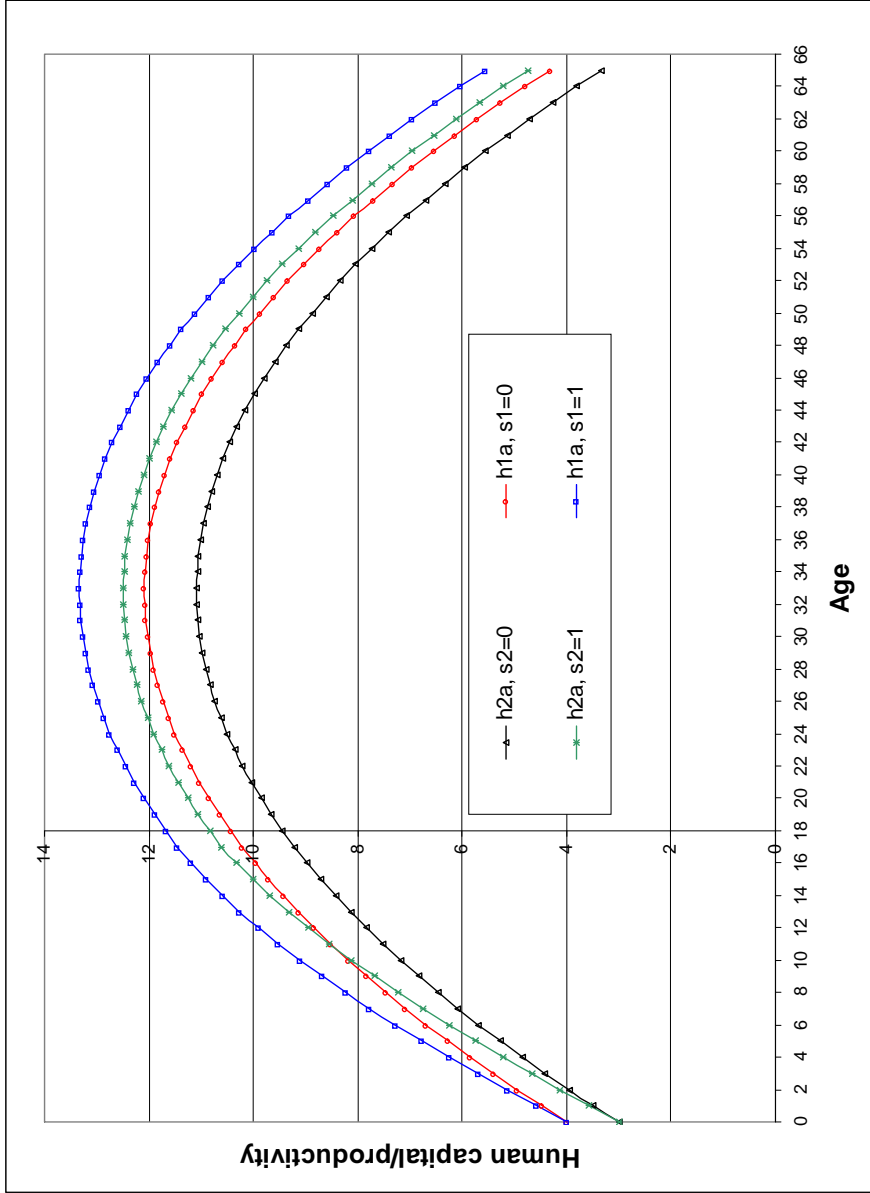


Figure 4: Human capital stock and productivity over the life-cycle. Figure generated using the specification of section 4.2, for individuals with endowed human capital  $h_{10} = 4$  and  $h_{20} = 3$ .

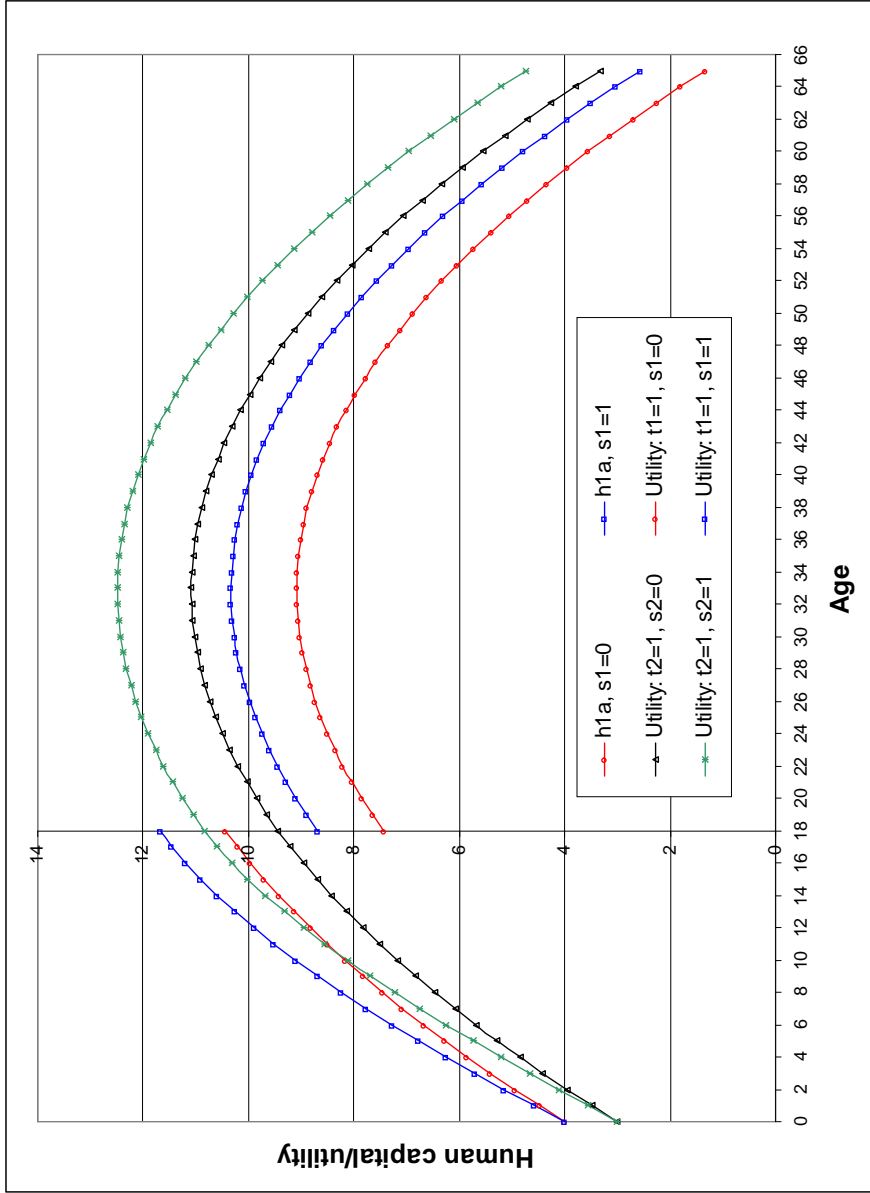


Figure 5: Human capital stock and utility over the life-cycle. Figure generated using the specification of section 4.2, for individuals with endowed human capital  $h_{10} = 4$  and  $h_{20} = 3$ , with social barrier  $B_1 = 3$ .

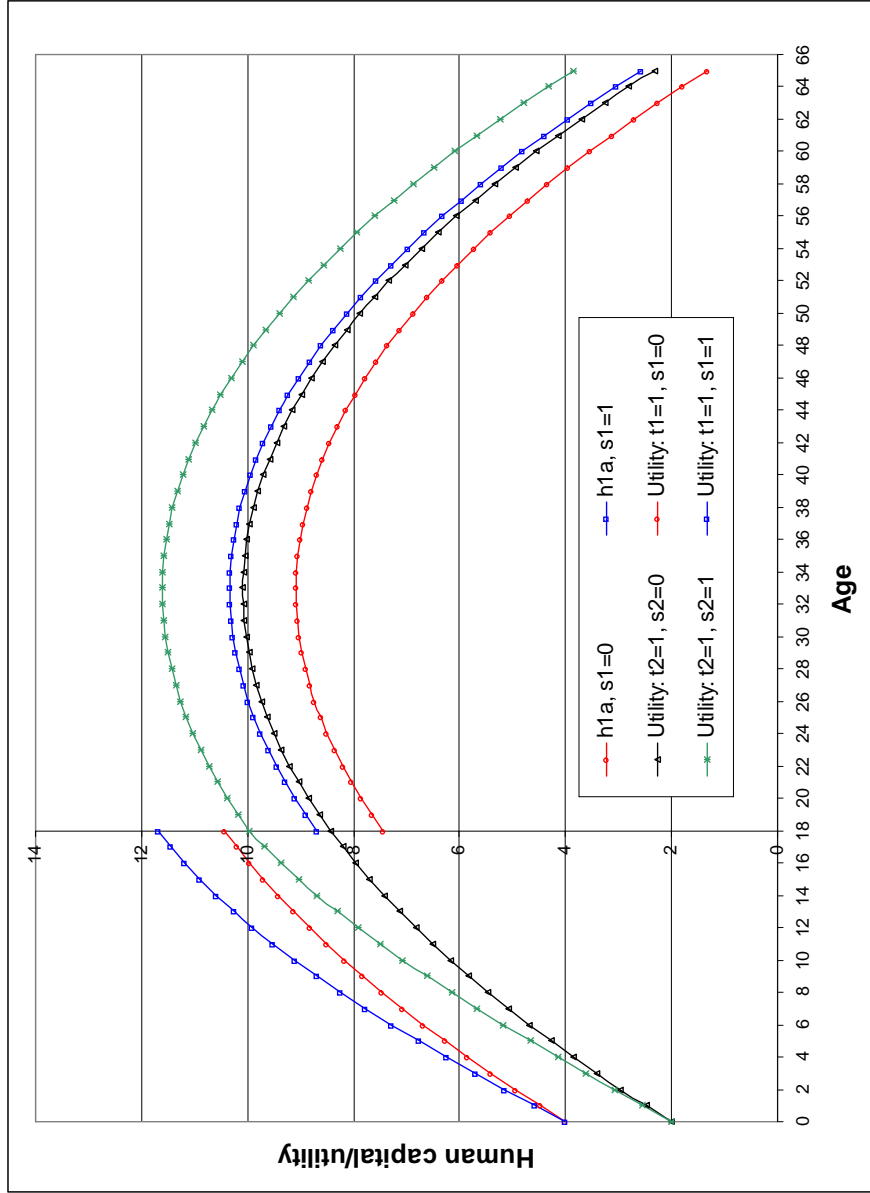


Figure 6: Human capital stock and utility over the life-cycle. Figure generated using the specification of section 4.2, for individuals with endowed human capital  $h_{10} = 4$  and  $h_{20} = 2$ , with social barrier  $B_1 = 3$ .

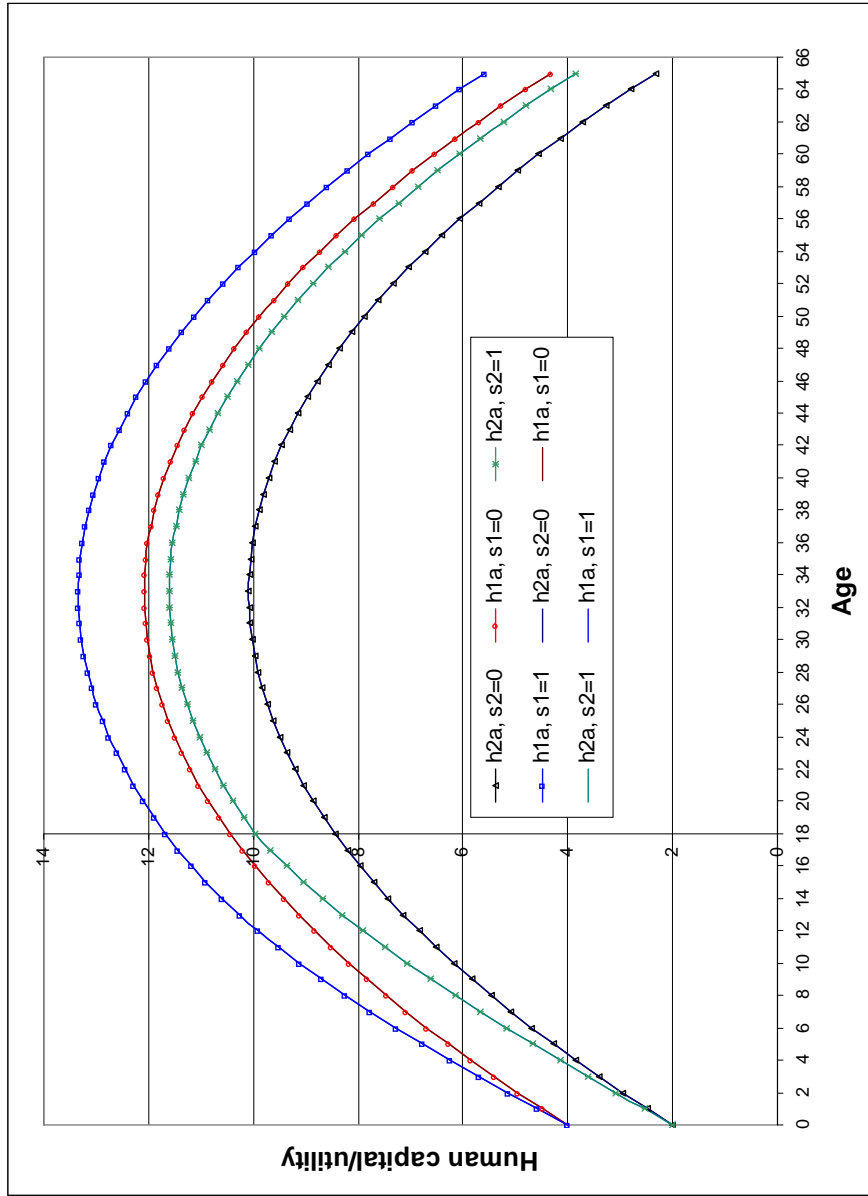


Figure 7: Human capital stock and utility over the life-cycle. Figure generated using the specification of section 4.2, for individuals with endowed human capital  $h_{10} = 4$  and  $h_{20} = 2$ , with social barrier  $B_1 = 0$ .

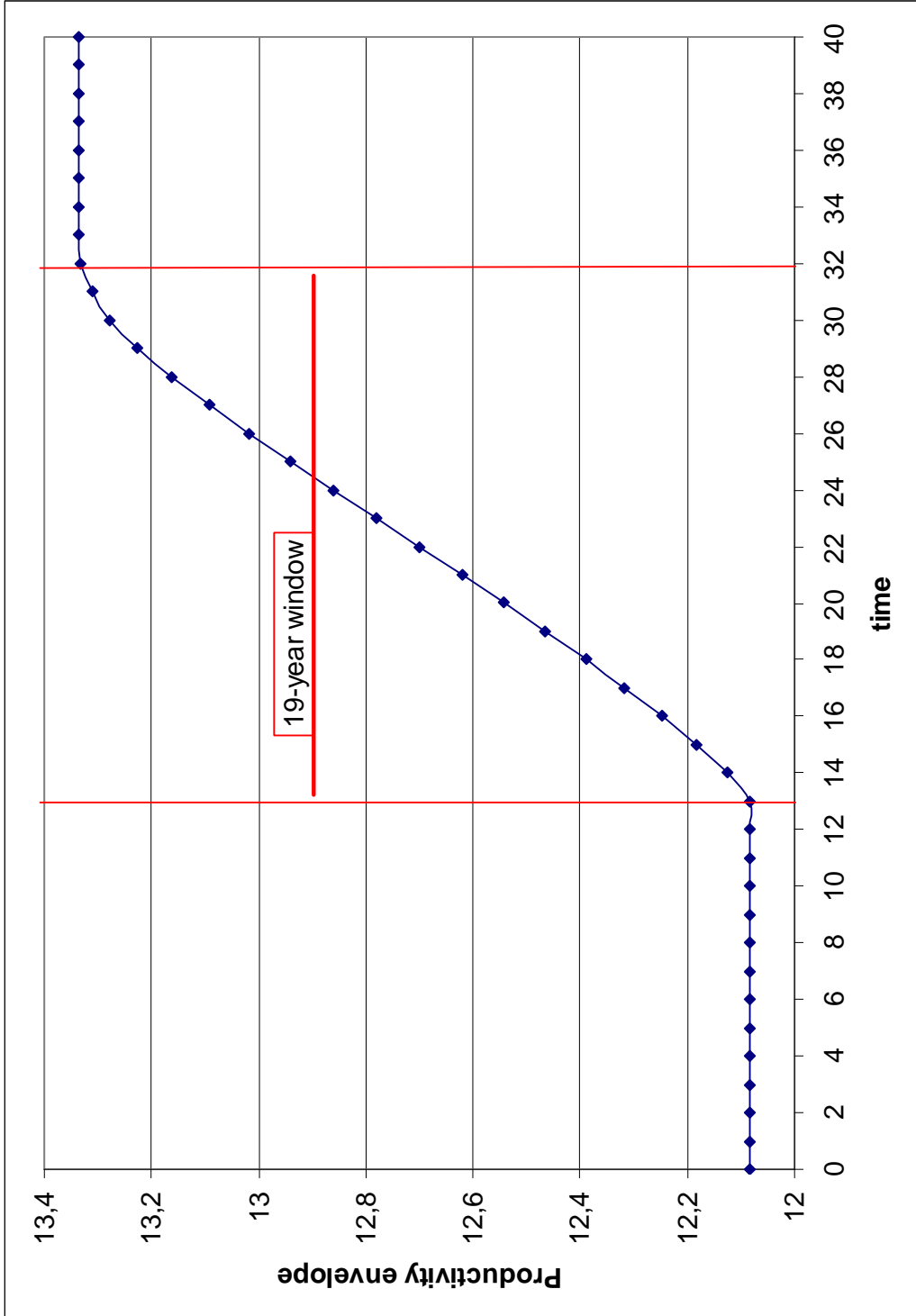


Figure 8: Evolution of the most productive worker with endowed type 1 stock of human capital  $h_{10} = 4$  after that social barrier drops from  $B_1 = 3$  to 0 at  $T = 0$ .

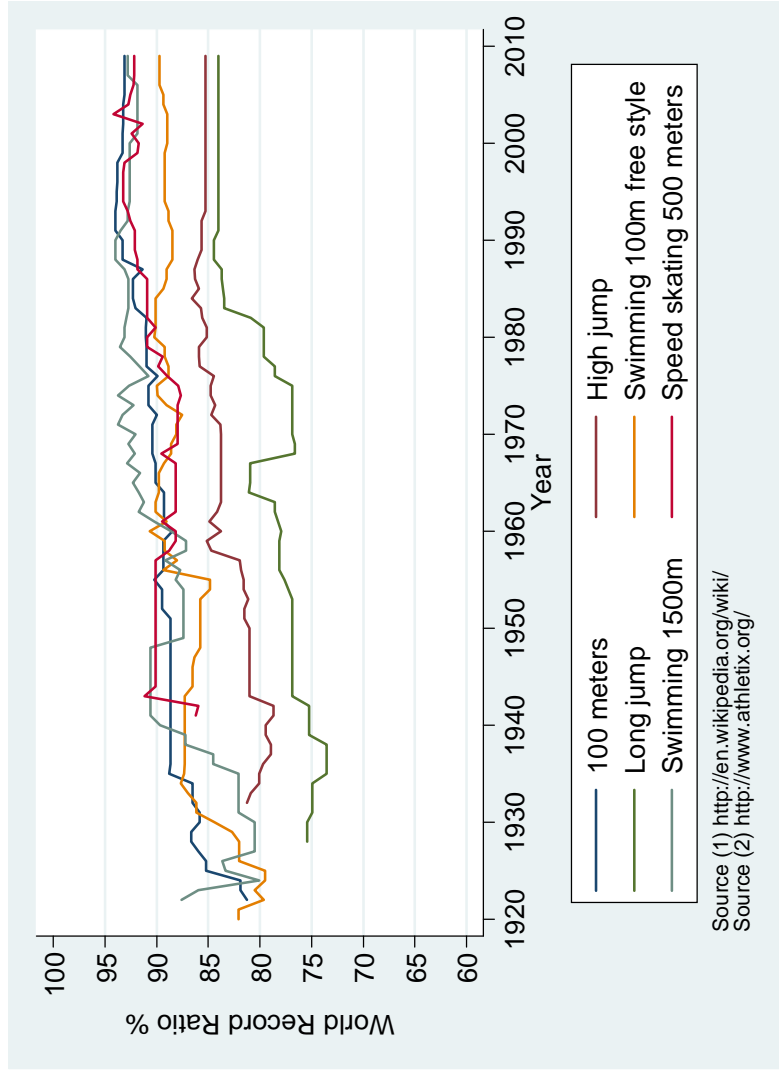


Figure 9: Evolution of the World Record ratio of women relative to men across disciplines and sports.

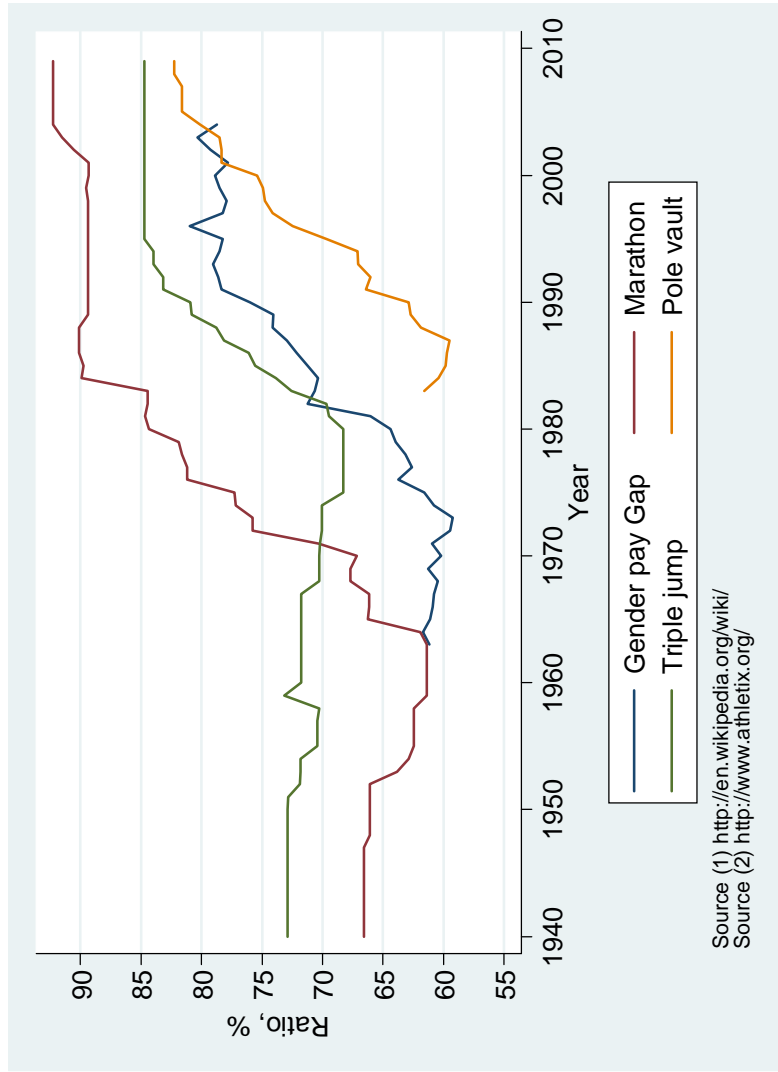


Figure 10: Similarity of the evolution of Gender Pay ratio and Gender World Record Ratios as female participation increases.

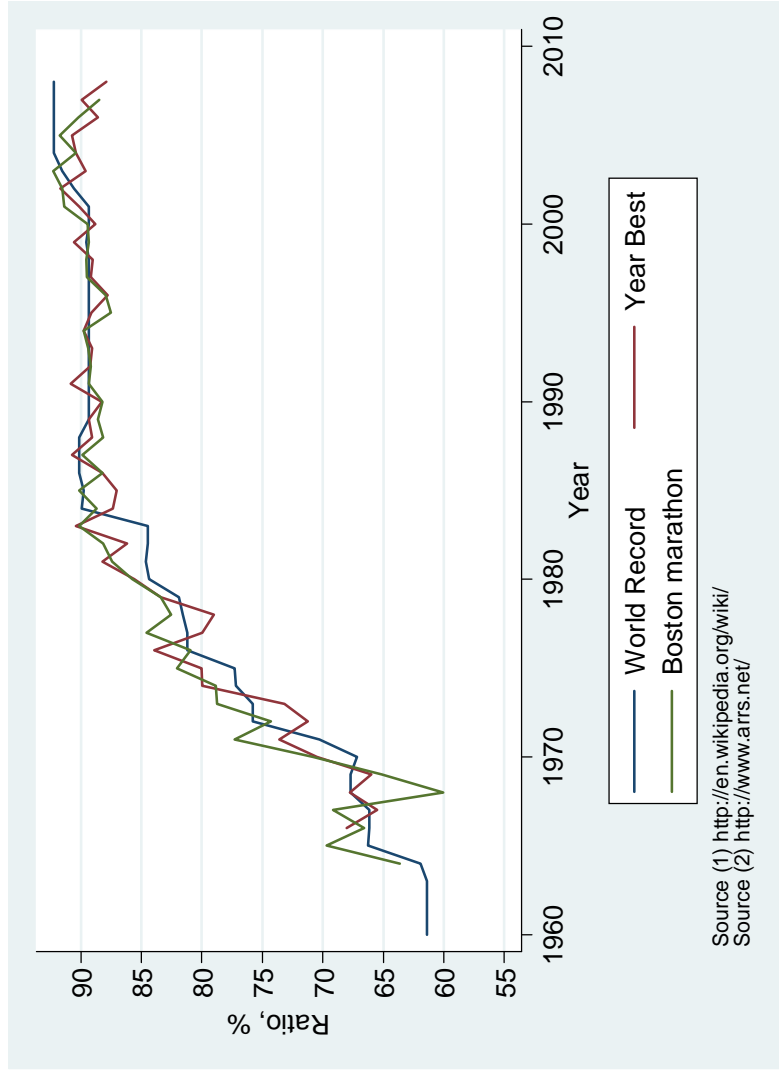


Figure 11: Evolution of the gender marathon performance ratio: World record, year best and Boston winning time.