CESifo

AREA CONFERENCES 2019

Economics of Education

Munich, 30–31 August 2019

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August 21, 2019

PRELIMINARY AND INCOMPLETE

Abstract

This paper presents a life-cycle model with human capital investment during working life through on-the-job training. The model predicts a positive effect of an increase in working life on training. We estimate this effect using a regression discontinuity design that exploits a large and cohort-specific pension reform that increased working life. We find that the reform increased on-the-job training by about 20%. We discuss and test further predictions regarding the relation between initial schooling, training, and the reform effect. Our results speak to a large class of human capital models as well as policies extending or shortening working life.

Keywords: human capital, retirement policies, RDD.
JEL classification: J24; J26; H21.

*We thank Pio Baake, Rainald Borck, and participants at seminars at the Universities of Cologne, Vienna, and the Lund Workshop on the Economics of Education for comments. We gratefully acknowledge funding through the CRC/TRR190. All remaining errors are our own.

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1 Introduction

Human capital theory starting with Ben-Porath (1967) and Becker (1962) predicts that the value of human capital investment increases with the payout period of the investment. This important prediction is the basis to explain the joint increases in life expectancy and educational investments that have been witnessed in most countries over the past century, see e.g. Soares (2005); Cervellati and Sunde (2013). However, the literature providing a causal test of the theory is scarce, mostly because adult life expectancy varies smoothly over time.[1]

In this paper we propose a novel approach to test the key prediction of the human capital theory. We exploit an exogenous increase in the working life induced by a sizable pension reform which changes the payout period of the human capital investment. Our main finding based on theory and empirical analysis using a regression discontinuity design (RDD) is that an increase in the working life causally increases human capital investment.

We proceed in two steps. In the first step, we discuss the implications of an increase in the working life on human capital accumulation in a human capital model. The model is based of the standard life cycle theory of human capital by Ben-Porath (1967) but we allow for human capital accumulation during the working life through on-the-job training (in the following training). Moreover, changes in the payout period for human capital investment are not determined by variation in life expectancy, but by a change in the working life. We derive three propositions from the model. Specifically, Proposition I shows that investment in training increases with working life while according to Proposition II training is increasing with initial education. Moreover, Proposition III determine the conditions when investments in training induced by an increase in the working life increase with initial schooling.

In the second step, we provide empirical evidence for the propositions. The empirical analysis is based on the data from the German microcensus; the microcensus is a representative yearly household survey which covers 1% of all German households (about 370,000 households per year). This data includes detailed information about specific job-related training which we use to measure post-schooling human capital investment. In the analysis, we exploit a pension reform to provide causal evidence about the effect of working life on human capital investment. Specifically, the pension reform abolished an important early retirement program for women born after 1951. Women born in 1951 and before could enter retirement at the age of 60 through this pathway. In contrast, for women born in 1952 and later this pathway has been closed; these women can enter retirement only at the age of 63. The reform is well suited to estimate the effect of an increase in working life on training and to test the human capital theory. First, Geyer and Welteke (2019) document a sizable positive employment effect and an increase in working life induced by the pension reform.

[1] See discussion of literature below.

Second, the pension reform was implemented when women born in 1991 and 1952 were aged between 47 and 48. Thus, the affected women had a long remaining working life to benefit from human capital investment. Finally, there is little empirical evidence that pension reforms have meaningful effects on life expectancy.[2] As a result, we can exploit the variation at the cut-off between two adjacent cohorts to isolate the effect of increases in working life on human capital investment on the job.

In the empirical analysis we first use descriptive evidence from the microcensus to provide empirical support for Proposition I and II: In line with Proposition I, we show that training positively correlates with remaining working life. Moreover, training also positively correlates with initial educational levels (Proposition II). This finding is in line with the assumption of a complementarity between initial education and further training and with empirical evidence which documents that skills beget skills (Cunha and Heckmann, 2007, 2010; Jacobs, 2009) .

We then present causal support for Propositions I and III. We exploit the regression discontinuity induced by the 1999 pension reform to test for human capital effects of changes in the remaining working life: Our empirical results show that the increase in the retirement age has a sizable effect on human capital accumulation: training increases by about 3 percentage points which corresponds to an increase of 20% for these age groups. This finding is robust to changes in the bandwidth and for different specifications of the running variable in the RDD. Further, it is supported by placebo test for which we artificially alter the cut-off date. Moreover, we find clear evidence that the training effect is increasing with initial education. The pension reform increases training for women with a college degree or more by 11 percentage points, which corresponds to a relative increase of about 35%. The effect for women without college degree is not significant.

Our study is related to several strands of the literature. Most important, we contribute and extend empirical studies related to the human capital theory which estimate the effect of mortality on educational outcomes and economics growth. Studies using variation in mortality face at least two challenges. First, as discussed in Hazan (2009) and Cervellati and Sunde (2013), it is not the change in the length of life pre-se which matters for investment in human capital, but the survival rates during working life. Second, variation in life expectancy is rarely random or unexpected, complicating causal estimation. A large part of the empirical literature uses variation in mortality rates between countries or states, e.g. Acemoglu and Johnson (2007), Lorentzen, McMillan, and Wacziarg (2008) or Hansen and Strulik (2017)[3], with mixed findings. Several paper specifically address the methodological challenges in

[2] The literature shows mixed evidence about the effect of retirement on mortality, but in general the effects are relatively small, in particular for women. Kuhn, Wuellrich, and Zweimueller (2010) and Fitzpatrick and Moore (2018) document that retirement has a positive effect on mortality for men but no significant effect on female mortality. Similarly Hernaes, Markussen, Piggott, and Vestad (2013) find that the retirement age has no effect on mortality.

[3] For a detailed summary and discussion, see Bloom, Kuhn, and Prettner (2019).

the context of developing countries. For example, Jayachandran and Lleras-Muney (2009) use a strong decline in maternal death rates in Sri Lanka, Oster and Dorsey (2013) use variation in life expectancy driven by Huntington disease, and Baranov and Kohler (2018) exploit variation in adult mortality rates related to HIV medication in Malavi. These studies document a positive effect of an increase in life expectancy on different educational outcomes. Our study is complementary to these studies as it presents evidence in a developed country setting. Moreover, we use a regression discontinuity design and variation in working life induced by a pension reform, a common policy parameter across the developed world.

The paper is also related to the literature which analyzes the effect of pension reforms on employment, income or welfare. In general, these studies document positive employment effects and an increase in the working life of pension reforms that reduce the generosity of the pension system. These studies either exploit exogenous variation in the pension rules for the identification[4] or they are based on structural retirement models[5]. Crucially, these studies typically assume an exogenous process of human capital investment which implies that individuals cannot adjust their human capital investment through additional training in response of a pension reform. A notable exception is the structural analysis by Fan, Seshadri, and Taber (2017). Fan, Seshadri, and Taber (2017) document that the assumption of an exogenous human capital process can have important quantitative implications. They show that a reduction in the generosity of the pension system leads to an increase in human capital accumulation.

Finally, several papers show that a reduction in the generosity of the pension system leads to an increase in training, e.g. Montizaan, Coervers, and de Grip (2010), Brunello and Comi (2013) or Bauer and Eichenberger (2017). However, these papers do not link their findings to a theoretical model and are based on smaller reforms and/or specific settings such as workers in large public sector firms only.[6]

The paper is organized as follows. In Section 2 we develop a model of human capital accumulation during the working life. Section 3 describes the German public pension system and the 1999 pension reform, introduces the data and provides descriptive support for the predictions of the human capital model. In Section 4, we turn to the causal analysis. We describe the method and document causal evidence from graphical and regression analyses. Finally, Section 5 concludes.

[4]Examples include, Duggan, Singleton, and Song (2007),Mastrobuoni (2009), Staubli and Zweimueller (2013),Atalay and Barrett (2015),Manoli and Weber (2016),or,Geyer and Welteke (2019).

[5]See e.g.Gustman and Steinmeier (1986), Rust and Phelan (1997), French (2005), French and Jones (2011) or Haan and Prowse (2014)

[6]The paper is as well related to studies which focus on other dimensions of human capital investment and training. Several studies discuss the theory of human capital investment through training and empirical evidence about the effect on labor market outcomes in form of wages, job security or employment probability (see for example Pischke (1996), Zweimueller and Winter-Ebmer (2000), Barrett and O'Connell (2001), Leuven (2005) and Picchio and van Ours (2011)).

2 Theoretical model

In this section we derive a theoretical human capital model and show that individuals, ceteris paribus, have an incentive to increase training when working life increases.

The central mechanism for this human capital effect is that the returns to training increase with the remaining working life of an individual i, denoted by R_i.[7]. Further, we analyze how the human capital effect induced by increasing working life differs by initial schooling, S_i. To derive testable predictions by initial schooling, it is necessary to establish first how on-the-job training, ceteris paribus, varies with initial schooling endowment. This results depends on the assumption about the relation between schooling endowment and training. With the assumption that initial schooling and further human capital accumulation are dynamic complements, which is widely accepted in the literature of human capital accumulation, see e.g. (Cunha and Heckmann, 2007) and Jacobs (2009), we can show that training increases with initial education. Finally, we determine the conditions when investments in training induced by an increase in the working life increase with initial schooling.

The theoretical model presented below illustrates these mechanism in a simplified and intuitive setting trough a discrete time model consisting of three stylized periods. Note that Y_{ti} denotes an individual i's income in period t and C_{ti} denotes the level of consumption in period t.

1. Period

Each individual derives utility through consumption, $U(C_{1i})$, with the standard assumption of $U'(C_{1i}) > 0$, $U''(C_{1i}) < 0$.

Income in period one is given by:

$$Y_{1i} = w_1(S_i)(1 - I_i) \tag{1}$$

Each individual earns wage $w_1(S_i)$.[8] The wage in period one depends on the initial level of schooling which is determined exogenously prior to period one. The wage is increasing in education, specifically we assume $w_1'(S_i) > 0$, $w_1''(S_i) < 0$. In this period the individual decides on his or her time investment in human capital, I_i, through participation in on-the-job training measures. Time investment in on-the-job training implies opportunity costs which

[7]A similar mechanism can be generated in a model of firm's investment decision in the human capital of their workers, where an increase in the working life of the worker has a positive effect on the firm investment decision in the human capital of this worker. In the empirical application we can not observe if the training is initiated by the worker or the firm. For the empirical test of the model this information is not required as we are interested in realized training.

[8]We assume that individuals are either full time employed or unemployed. Wages of the unemployed are zero. Thus an increase in the wage can result from entering employment or increase in earnings in full time employment.

in the model are characterized by a fraction of foregone labour income, $w_1(S_i)I_i$. Hence, individuals with high education face higher opportunity costs.

2. Period

Income in period two is given by:

$$Y_{2i} = w_2(S_i, I_i)R_i \tag{2}$$

R_i is the duration of the remaining working life and $w_2(S_i, I_i)$ is the wage earned in period two. Individuals in period two collect the returns from their human capital investment made in period one through their wage, as the wage in period two is a function of training as well as initial schooling, i.e. $w_2(I_i, S_i)$. Note that by assumption $w_{2I} > 0$ and $w_{2II} < 0$. Further, in order to capture the dynamic complementarity between initial schooling, S_i and human capital investment, I_i, we assume $w_{2IS} > 0$.

3. Period

Period three is the period of retirement. The duration of period three is $T_i - R_i$, where T_i is the individual life expectancy. We assume that retirement is a discrete decision to exit the labor market completely. Income in the retirement period is covered by the state pension which is a fraction α, with $\alpha < 1$, of labour income in period two.

$$Y_3 = \alpha w_2(S_i, I_i)(T_i - R_i) \tag{3}$$

Utility over all three periods is given by:

$$U_G = U(C_{1i}) + \beta U(C_{2i})R_i + \beta^2 U(C_{3i})(T_i - R_i)$$

where β is the discount factors, with $\beta < 1$. The intertemporal budget constraint is:

$$y_{1i} + \beta y_{2i} + \beta^2 y_{3i} \geq C_{1i} + \beta C_{2i}R_i + \beta^2 C_{3i}(T_i - R_i)$$

The maximization problem can hence be depicted by the Lagrangian:

$$L = U_G + \lambda \left[y_{1i} + \beta y_{2i} + \beta^2 y_{3i} - \left(C_{1i} + \beta C_{2i}R_i + \beta^2 C_{3i}(T_i - R_i)\right)\right] \tag{4}$$

The details of the solutions and the set of First Order Conditions are presented in Appendix A.

Using comparative statics we derive three main propositions from the human capital model. Firstly, in Equation 5 we show how the effect of an exogenous increase in the remaining working life duration (R_i), affects the investment in training (I_i).

$$\frac{\partial I_i}{\partial R_i} = \frac{[\alpha\beta - 1]\, w_{2I}\,(S_i, I_i)}{[R_i + (T_i - R_i)\alpha\beta]\, w_{2II}(S_i, I_i)} \tag{5}$$

By assumption $w_{2I} > 0$ and $w_{2II} < 0$. Further, $\alpha\beta - 1$ is negative [9]. Therefore the expression above is positive and we can derive the following proposition.

Proposition I (Working life effect)
The effect of an increase in the working life on training is positive.

Further, we discuss how initial schooling affects the amount of time allocated towards on-the-job training. The relation between initial schooling and training is captured by Equation 6.[10]

$$\frac{\partial I_i}{\partial S_i} \gtreqless 0 \Longleftrightarrow w_{2IS}(S_i, I_i)\frac{S_i}{w_{2I}(S_i, I_i)} \gtreqless w_{1S}\frac{S_i}{w_1(S_i)} \tag{6}$$

The above shows that as long as the relative return to human capital investment collected in period two, $w_{2IS}(S_i, I_i)$, proportionally out-weighs the opportunity costs, i.e. the return of schooling received in period one, w_{1S}, human capital investment will increase in schooling, i.e. $\frac{\partial I_i}{\partial S_i} > 0$.

Proposition II (Initial education effect)
The level of time investment in training rises with initial schooling as long as the additional returns to human capital investment related to the initial level of schooling are larger than the opportunity cost of the investment

For Proposition II to hold it is necessary that $w_{2IS}(S_i, I_i)$ is positive. As mentioned above the assumption of complementary between schooling and productivity of (vocational) training investment has frequently been made in the schooling and human capital literature (Cunha and Heckmann, 2007, 2010; Jacobs, 2009). Cunha and Heckmann (2010), for example, show that there indeed is evidence for a positive complementarity between educational investment and cognitive skills acquired during early child hood. In our empirical part, by testing the propositions of the model, we can implicitly analyze whether such positive complementarity also holds between schooling and on-the-job training.

Finally, in Equation 7 we discuss how the effect of the increase in the working life on training varies by the initial level of schooling. This effect can be decomposed in two effects.

$$\frac{\partial}{\partial S_i}\left[\frac{\partial I_i}{\partial R_i}\right] = \frac{\partial I_i^2}{\partial R_i \partial S_i} + \frac{\partial I_i^2}{\partial R_i \partial I_i}\frac{\partial I_i}{\partial S_i} \tag{7}$$

[9] This follows from $\alpha < 1$ and $\beta < 1$.
[10] For a detailed derivation of Equation 6 see Appendix

The first effect captures the direct effect of how the working life effect, $\frac{\partial I_i}{\partial R_i}$ (Proposition I), changes with initial schooling and the second effect captures the indirect effect of how the working life effect is influenced by the existing level of training given the initial schooling effect $\frac{\partial I_i}{\partial S_i}$ (Proposition II). Under the assumption of complementarity between schooling and training the direct effect is positive. Individuals with a higher initial level of schooling have higher returns to training. Hence, they have a stronger incentive to invest in training as a response to an increase in the working life. The indirect effect, however, is negative as the returns to training are positive but decreasing. Given an increase in the working life, individuals with higher levels of training, therefore, have a lower incentive to further increase their training investment. The overall effect ultimately depends on the two opposing sub-effects, as summarized in Proposition III. In the Appendix we present a detailed formal derivation of the two opposing effects and their respective signs.

Proposition III (Working life effect by education)
The reform effect rises with the initial level of schooling, as long as the positive direct effect outweighs the negative indirect effect.

The remainder of the paper will empirically assess the predictions derived from the theoretical model depicted above. First we will present descriptive evidence to provide empirical support for Propositions I and II. Then, we exploit the variation in the working life induced by the pension reform to causally test Propositions I and III.

3 Institutional Setting and Data

3.1 Pension reform

Before we turn to the empirical analysis we summarize the relevant aspects about the German pension system and the 1999 pension reform which induces exogenous variation in the working life.

The statutory public pension system is the central part of the pension system in Germany. It covers more than 80% of the workforce with the exceptions of groups that are not subject to compulsory pension insurance, most important civil servants, and self-employed. It includes old-age pensions, disability pensions, and survivors benefits. The system is financed by a pay-as-you-go (PAYG) scheme and has a strong contributory link: pension benefits depend on the entire working history. The pension system provides several pathways into early retirement, i.e. claiming retirement benefits before reaching the normal retirement age. In this analysis we focus on the *pension for women* which allows drawing benefits starting from age 60.[11]

The 1999 reform abolished the *pension for women* for cohorts born after 1951. Effectively, the reform raised the ERA for most women from age 60 to age 63 and therefore increased the working life.[12] Women born before 1952 could claim the *pension for women* if they fulfilled certain qualifying conditions. The eligibility criteria were: (i) at least 15 years of pension insurance contributions; and (ii) at least 10 years of pension insurance contributions. According to Geyer and Welteke (2019), about 60% of all women born in 1951 were eligible for the old-age pension for women. In our empirical analysis we focus only on employed women, about 75% of these women full fill the criteria and are therefore eligibility for this pathway (See Table 6 below). The pension reform was implemented when affected women born in 1952 were aged 47. Thus, these women had still a long horizon to benefit from human capital investments.

Geyer and Welteke (2019) and Geyer, Haan, Hammerschmid, and Peters (2018) have evaluated the labor market effects of the pension reform based on administrative data of the public pension insurance accounts and the Microcensus, respectively. Several findings of these studies are relevant for the following empirical analysis. First, the increase in the ERA from 60 to 63 has sizable labor market effects for women older than 60 years: employment rates for eligible women aged between 60 and 62 increase by about 15 percentage points, the combined effect on inactivity and unemployment has with about 12 percentage points a similar size. Second, the pension reform has no significant effect on employment, unemployment, disability or inactivity before the age of 60. This implies, estimation results on the effect on human capital accumulation for employed women before the age of 60 are not affected by selection effects into employment induced by the pension reform. Third, there exists important effect heterogeneity by initial education. Specifically, employment effects are larger for high educated women.

3.2 The German Microcensus

For the analysis we use the German Microcensus. The Microcensus is an annual, household based survey with representative information about the population and the labour market in Germany. Participation in the survey is mandatory. It has a sampling fraction of one percent of the German population (about 370 000 households) and constitutes the largest

[11] In addition early retirement is possible via : (1) the *invalidity pension*; (2) the *pension after unemployment or after old-age part-time work*; (3) the *pension for the long-term insured*, for more details see Geyer, Haan, Hammerschmid, and Peters (2018). For a more general description on the German pension system, see Boersch-Supan and Wilke (2004).

[12] The *pension after unemployment or after old-age part-time work* was abolished at the same time as the *pension for women*. However, this does not affect our analysis, as the ERA for this pension type was already 63.

annual household survey in Europe (RDC of the Federal Statistical Office and Statistical Offices of the Laender, 2015).

In the main analysis we concentrate on employed[13] women younger than 60 years born in 1951 and 1952 which we observe during the period 2005 to 2012. For these years the data include information about the month of birth and consistent information about the participation of on-the-job training.[14] We observe around 1,250 individuals for each birth month in our sample. Thus, overall, the sample includes information of about 30,000 women born in the two cohorts of interest. The Microcensus includes important socio-demographic variables, such as age, education,[15] marital status, occupation or firm size which we use as control variables.

3.3 On the job training: descriptive evidence

The Microcensus provides information if an employed person has participated in training during the last twelve months. The training information includes specifically courses that are related to career development e.g. to improve management, computer or rhetoric skills.

Figure 1 shows the age pattern of training for all employed women born between 1940 and 1997. As expected we find a hump shaped age profile. Training rates are low at very young ages however they rapidly increase in the first years of the working career of individuals. Towards the end of the working life, after the age of 50, training strongly rates decline. Specifically, Figure 1 suggests that training rates decline between age 53 and 58 by about 10 percentage points. Hence, the period after the age of 50, which we study in the causal analysis, seems particularly sensitive to changes in the incentives for training . In summary, the pattern of Figure 1 provides first support for Proposition I. Training is reduced when the working horizon, i.e. the payout period, decreases.

In Table 1 we turn to the training pattern by initial education. In line with Proposition II we find that training increases with the level of education. Specifically, employed women born in 1951 with no college degree training rates of 11.7 percent. In contrast women with the (some) college have training rates of 31.7 percent. As discussed above the positive correlation between initial education and training is consistent with a complementary between schooling and training (proposition II). Moreover, a similar complementary between early and later human capital investments features in models of cumulative skills accumulation, e.g. Cunha and Heckmann (2007, 2010).

[13]Women working in "mini-jobs" are not counted as employed.

[14]Before the year 2005 the Microcensus only provides information about the birth year and the definition of training changes at several points in time. Therefore, the extension of the sample before 2005 would require additional assumptions.

[15]Education is measured with ISCED 2011 levels: based on this information with define women without college degree or with college degree or more [more detail].

4 Causal Analysis: RDD

4.1 Empirical method

In the empirical analysis we exploit the 1999 pension reform to estimate the effect of an increase in working life on human capital investment and to provide a causal test of Propositions I and III using a RDD. The reform leads to an arbitrary and distinct cutoff for women born before and after December 31, 1951, which determines the assignment into the treatment and the control group.

More formally, in the empirical analysis the woman's month of birth is the running variable M, which determines treatment D as one if she was born after December 31, 1951 an zero otherwise:

$$D_i = \begin{cases} 1, & if\ M_i \geq c \\ 0, & if\ M_i < c \end{cases} \tag{8}$$

The identification is based on the following assumptions. Fist, no manipulation of the month of birth for women born in 1951 and 1952, i.e. the running variable, and no selection into or out-of treatment is possible. As a result, the treatment and control groups should be otherwise comparable around the cut-off. We provide supporting evidence based on comparisons of important pre-policy covariates of the 1951 and 1952 birth cohorts, and by moving the cutoff to hypothetical "placebo" dates. Finally, as discussed e.g. in Geyer and Welteke (2019) no other relevant policy reform differently affected women born in 1951 and 1952.

In the main specification we implement the RDD in the following regression model:

$$y_i = \alpha + \beta D_i + \gamma_0 f(M_i - c) + \gamma_1 D_i f(M_i - c) + X_i \delta + \varepsilon_{it} \tag{9}$$

D_i is a dummy specifying treatment, that is equal to 1 if a woman is born 1.1.1952 or later and 0 otherwise. A woman's month of birth is described by M_i and c is the cut-off date for the increase in early retirement age, ERA (January 1, 1952). Therefore, f is a function of the difference between a woman's birth date and the beginning of the ERA increase $M_i - c$, i.e. the running variable. This function is interacted with the treatment variable D_i to allow for different slopes before and after the cutoff. In addition we account for further explanatory variables (X), including age, education, marital status, firm size and regional information. We implement this specifications using either global polynomials for f up to the third degree, as well as local polynomials, also up to the third degree.[16]

The outcome variable Y in our analysis is on-the-job training which is dichotomous i.e. taking on the value 1 if a women has participated in training in the last twelve months and

[16] The latter are estimated using the Stata package "rdrobust" (Calonico, Cattaneo, Farrell, and Titiunik, 2018).

0 if she has not. In the main specification we implement the RDD in a linear probability model.[17]

Finally, we cluster the residual at the monthly level to allow for arbitrary correlations of the error term within each month.

4.2 Graphical analysis

Before turning to the estimation result we provide graphical evidence how an increase in the working life affects training. In Figure 2 we present the pattern of training for the relevant cohorts, 1951 and 1952, for the ages which we can observe in the data. The Figure clearly shows that women with a longer working horizon (cohort 1952) have higher training rates than women born in 1951. As expected, the difference gets smaller close to age 60, i.e. when both groups have only a short working horizon.

Figure 3 shows participation rates in training by month of birth 12 months before and after the cut-off birth date, 1.1.1952. The share of employed women participating in training is clearly higher after the cut-off. The average rate of participation in the 12 month before the cut-off date is approximately 15.4 percent. After the cut-off date, the graphs shows a jump in the average rate of training participation for employed women under 60 to more than 16.5 percent. The fitted line is a local polynomial of degree two. In the next section, we examine the robustness and significance of the the graphical evidence using various choices in the RDD framework (degree of polynomial, global and local polynomial, bandwidth).

4.3 Regression results - overall effects

To test the implications of the theoretical model (Section 2) and to quantify the effect of an increase in the working life on the investment into human capital we use the RDD described in Section 4.1. In the analysis, we focus on all employed women in their later working life, i.e. when they are aged between 53 and 60.

In Table 2 we present the estimation results for different specifications with observations 12 months before and after the cut-off date. We consider regressions with global and local polynomials, with linear, quadratic and cubic specifications. Moreover, the table includes these regressions without and with additional control variables.

The results of these different specifications, including the same specifications using a sample of only six months before and after the cut-off date (Appendix Table A.1) all point in the same direction despite some expected differences in the magnitude of the point estimates: the increase in the early retirement age has a positive and significant effect on the investment in training. Most point estimates show that the participation in training increases between

[17]Estimation results based of a Probit model show very similar results.

3-5 percentage points, which translates into a relative increase of about 20-30% given the pre-reform share in training of 15.5%.

Only the global linear specification in the top panel (without covariates) in column 1 is not statistically significant, albeit positive. However, this is the least flexible version of conditioning on the running variable and therefore -a priori- not the preferred specification. In contrast, the local linear regressions in columns 4 to 6 of Table 2 consistently show positive and significant estimates in similar magnitude across all specifications. In the last specification in column 6, which allows for a cubic polynomial within the local bandwidth, the estimated effect is with 2.3 percentage points a little smaller.[18]

To provide further empirical support for the proposed identification strategy we present balancing tests of other variables and results of placebo tests. For both tests, we use the same RDD specification as described in Equation 9, and the specification with a global polynomial of degree two (column 2 of Table 2) as the baseline. The choice of this baseline does not alter any of the conclusions that we reach.

The balancing test presented in Table 3 shows that all control variables, except the share of women with high income, are insignificant. The income variable is significant at the 10% level of statistical significance, however as documented in Table 2 adding the control variables in the RDD does hardly affect the results. This finding lends support to the assumption that no other factors jump discontinuously around the cut-off.

In addition, we conduct two placebo analyses presented in Table 4. In the first placebo analysis we artificially shift the cut-off date by one year to 1.1.1950 and in the second placebo analysis to 1.1.1952. Importantly, the pension rules are identical before and after the chosen placebo cut-offs. The results of the placebo test which are again implemented with a band with of 24 month and global quadratic specification are presented in Table 4. We find clear support for our identification strategy: the treatment effect is very close to zero and not significant in both specifications, with and without additional explanatory variables. Moreover, these effects are precisely estimated and we can clearly reject the hypothesis that these are identical to our main findings in Table 2.

In summary, these results provide strong empirical support of Proposition I derived in the human capital model. Specifically, we show that an increase in the early retirement age which shifts the working horizon and therefore the payout period on an human capital investment, has a causal positive and sizable effect on the investment in human capital.

[18]These specifications use a local bandwidth of 3 month, which is the chosen bandwidth of the endogenous bandwidth selection routine "rdbwselect", and a triangular kernel (Calonico, Cattaneo, and Titiunik, 2014).

4.4 Effects by initial education

We now extend the empirical analysis and focus on effect heterogeneity along prior educational levels. We have already shown descriptively that training participation positively correlates with prior educational levels in Section 3.3 (Proposition II). We now move on to test if the reform effect also varies by prior educational level (Proposition III). Since we only focus on women close to the cut-off, we aggregate the ISCED educaitonal levels into two education groups of women with "college" and "non-college".

We find very strong differences by education in Table 5. Women with college education or more increase training by nearly 12 percentage points which corresponds to a relative increase of about 35%. The effect for women without college education is estimated to be close to zero and not significant at conventional levels. We therefore conclude that the direct training effects outweighs the negative indirect effect (Proposition III) which explains why the human capital induced by an increase in working life increase with education.

4.5 Quantification of effects

As discussed in Section 3.1, the 1999 pension reform only affected the working life of women which fulfill the eligibility criteria for the so-called pension *for women.*. The Microcensus, which we base our analysis on, is a cross sectional data set without information about the employment history. Therefore, we can not directly determine the eligibility within this data. As a result, our estimates should be interpreted as "intentent-to-treat" (ITT) effects, giving a lower bound of the true effect.

To gauge information about actual eligibility, we use information from the longitudinal data of the Socio-economics panel (SOEP), the largest household panel data set available in Germany. In the representative SOEP data, about 76% of women employed before entering retirement were indeed eligible for this pathway into retirement. Further, the SOEP data show that about 72% of employment women without a college degree and 85% of women with a college degree fulfill the eligibility criteria..

With this information and the estimated effects (ITT) presented in Tables 2 and 5, we can derive the average treatment effect on the treated (ATT). These are presented in Table 6. Overall, the pattern of the ATT effects is similar to the ITT effects, but the effects are slightly larger. Importantly, the ATT effects provide as well empirical support for Propositions I and III derived from the human capital model. The point estimates suggest that overall women training increases by 4.6 percentage points (column 1), for women with college the increase is over 13 percentage points (column 2) and the effect for women without college is close to zero (column 3). The point estimates imply a relative increase in training of 30% of all women and 40% of women with college degree.

The magnitude of these estimates are consistent with the strongly declining pattern of training after the age of 50, presented in Figure 1. As discussed above, training participation is particularly sensitive to changes in ages close to retirement which determine the remaining working life. Therefore, it is not surprising that an increase in the working life induced by the increase in retirement age from 60 to 63 can have sizable effects on training.

5 Conclusion

In this paper we provide causal evidence for the theory of human capital accumulation. In the empirical analysis we use an exogenous change in the working life which increases the payout period for the human capital investment. Specifically we exploit a sizable pension reform which increased the early retirement age for women between two adjacent cohorts from 60 to 63 years. The analysis is based on the German Microcensus and exploits in a RDD the cohort specific variation of the pension reform.

The empirical analysis offers support for three key propositions of the human capital model which are derived in the first part of the paper. First we provide descriptive evidence that training positively correlates with remaining working life and with initial educational levels. We then present causal evidence that an increase in working life induced by the pension reform has a positive effect on human capital investment and that this human capital effect increases with initial schooling. In more detail, our empirical results show that the increase in the retirement age has a sizable effect on human capital accumulation of employed women aged 63-60: depending on the specification training increases by about 3-5 percentage points which corresponds to an increase of 20-30% for these age groups. This finding is robust to changes in the bandwidth and for different specifications of the running variable in the RDD and is supported by placebo test. Moreover, we show that the pension reform increases training for women with a college degree or more by 11 percentage points, which corresponds to a relative increase of about 35%. The effect for women without college degree is not significant.

Besides testing a key prediction of human capital theory, our results have important implications for the policy debate about pension reforms. This debate usually abstracts from the dynamic human capital investment that we document.

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Figures and Tables

Figure 1: Average on-the-job training participation for all employed women, Cohorts: 1940-1997

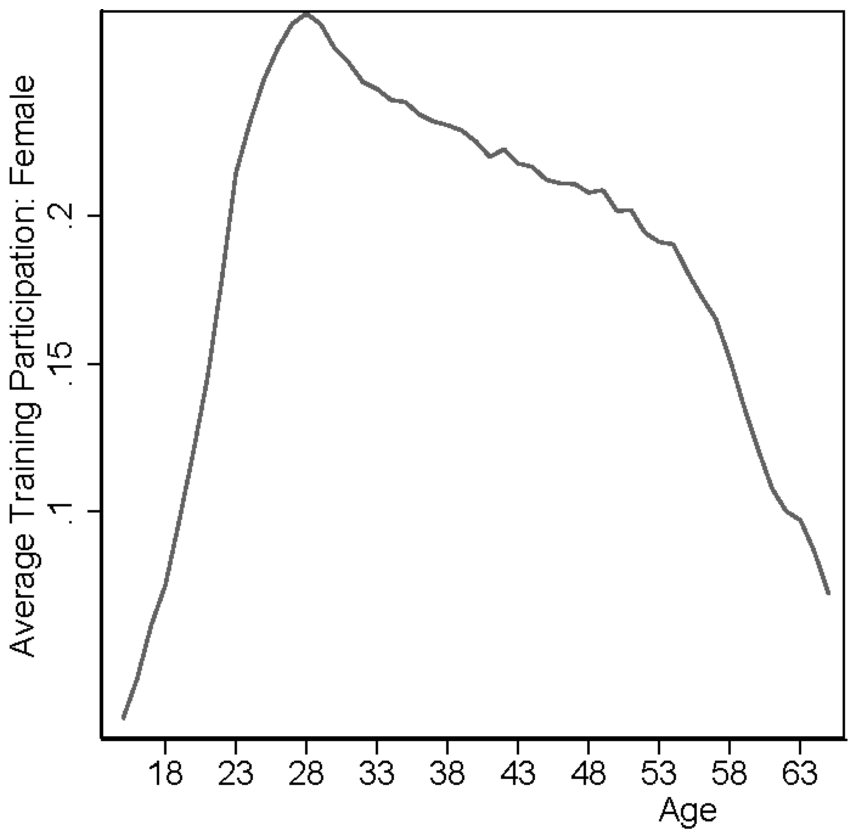

Figure 2: Average on-the-job training participation for sample group

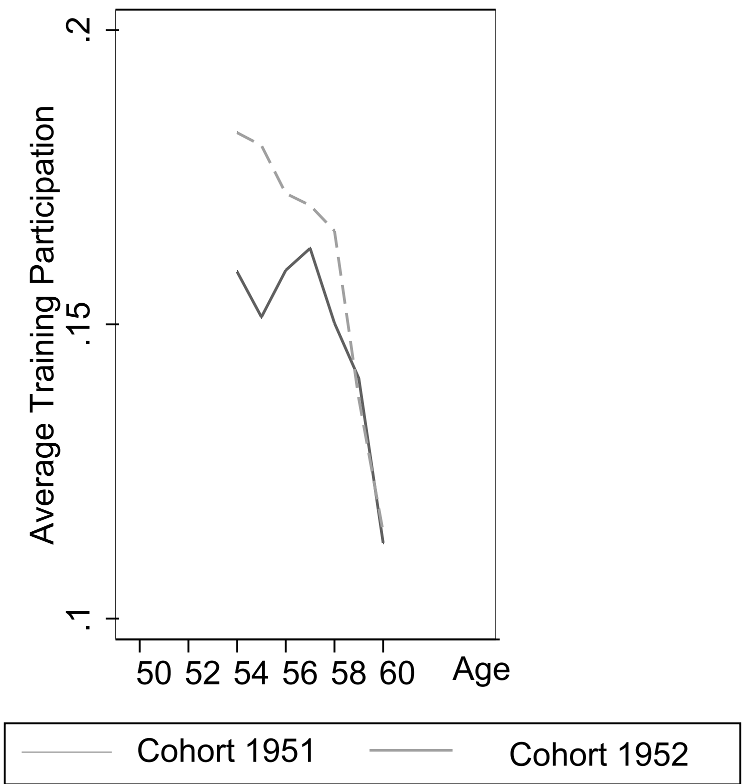

Figure 3: On the job training around the cut-off date

Notes: The fitted lines are local linear regressions using a first degree polynomial, a triangular kernel, and local bandwidth of three month. In total, information for 13,658 individuals below the threshold and 14,873 individuals above the threshold are used.

Table 1: Training Participation by Education

Training Participation	*Overall*	*Non-College*	*College*
1952	0.169	0.125	0.340
Observations	16,753	13,413	3,364
1951	0.154	0.117	0.317
Observations	13,658	11,073	2,576

Notes: Source: Microcensus 2005-2012, own calculations

Temporary note: we can break this down further by ISCED education levels using all cohorts available to us (7 categories), but the resulting figure is not cleared from the secure server at this point - key finding that training increases with educaion is confirmed.

Table 2: Regression Discontinuity: Main Results

	Global Polynomial			Local Polynomial		
	(1)	(2)	(3)	(4)	(5)	(6)
Without Covariates						
Treatment Variable	0.0157	0.0352***	0.0502***	0.0413**	0.0412***	0.0236**
	(0.0147)	(0.0142)	(0.0105)	(0.0208)	(0.0143)	(0.095)
With Covariates						
Treatment Variable	0.0150*	0.0358***	0.0439***	0.03426*	0.0387***	0.0233**
	(0.0082)	(0.0104)	(0.0110)	(0.0204)	(0.0140)	(0.0093)
Running Variable	Linear	Quadratic	Cubic	Linear	Quadratic	Cubic

Notes: Standard Errors in parentheses; clustered at birth month level. Sample includes twelve month before and after reform cutoff. Significance levels: $*$ p 0.10, $**$ p 0.05, $***$ p 0.01; Pre-Policy Mean: 15.41 percent. Source: Microcensus 2005-2012, own calculations.

Table 3: Balancing Test

	Employment	High Education	Medium/Low Education	High HH Income	West	Large Company	Single
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Treatment Variable	-0.0084	0.0088	-0.0080	-0.0295*	0.0057	-0.0130	-0.0084
	(0.0065)	(0.0301)	(0.0303)	(0.0169)	(0.0298)	(0.0122)	(0.0065)
Running Variable	Quadratic	Quadratic	Quadratic	Quadratic	Quadratic	Quadratic	Quadratic
R-squared	0.0003	0.0003	0.0003	0.0004	0.0006	0.0001	0.0003
Cohorts	1951,1952	1951,1952	1951,1952	1951,1952	1951,1952	1951,1952	1951,1952

Notes: Standard Errors in parentheses, clustered at birth month. Sample includes twelve month pre and post reform. Specification is equivalent to column 2 of Table 2. Significance levels: ∗ p 0.10, ∗∗ p 0.05, ∗ ∗ ∗ p 0.01
Source: Microcensus 2005-2012, own calculations.

Table 4: Regressions with Monthly Running Variable - Placebo

	Placebo 1952/53		Placebo 1950/51	
	(1)	(2)	(3)	(4)
Treatment Variable	0.0008	-0.0029	-0.0033	-0.0046
	(0.0119)	(0.0097)	(0.0270)	(0.0286)
R-squared	0.0003	0.0609	0.0003	0.0559
Covariates	No	Yes	No	Yes

Notes: Standard Errors in parentheses, clustered at month level. Sample includes twelve month pre and post placeo year of reform. Specification is equivalent to column 2 of Table 2. Significance levels: $*$ p 0.10, $**$ p 0.05, $***$ p 0.01
Source: Microcensus 2005-2012, own calculations.

Table 5: Heterogeneity by educational level

	College (1)	Non-College (2)
Treatment Variable	0.1181***	0.0084
	(0.0354)	(0.0165)
Running Variable	Quadratic	Quadratic
Observations	5,469	22,694
Cohorts	1951,1952	1951,1952
Covariates	Yes	Yes

Notes: Standard Errors in parentheses, clustered at birth month. Significance levels: $*$ p 0.10, $**$ p 0.05, $***$ p 0.01. For the estimates we choose a specification with a bandwidth of 24 month, with a global quadratic running variable and with control variables. For women with college degree participation rates in train before the reform are 0.317, for women without college degree 0.117.
Source: Microcensus 2005-2012, own calculations.

Table 6: Average Treatment effect on the treated (ATT)

	All (1)	College (2)	Non-College (3)
ATT	0.046	0.1342	0.0112
Relative Size ATT (in%)	30.06	42.32	9.24
Observations	28,531	5,469	22,694
Eligibility (in%)	76	84	72

Notes: The ATT is derived by weighting the ITT effects presented in Tables 2 and 5 with the share of employed women eligible for the pension or women. The eligibility rates are calculate from the SOEP data. For the ITT estimates we choose the specification equivalent to column 2 in Table 2, with a global quadratic running variable and with control variables. The sample includes twelve month pre and post reform. Participation rates in training before the reform are 0.154, 0.317, 0.117 for all employed women, employed women with college and employed women without college, respectively.

Appendix Tables

Table A.1: Regression Discontinuity: Main Results, smaller sample

	Global Polynomial			Local Polynomial		
	(1)	(2)	(3)	(4)	(5)	(6)
Without Covariates						
Treatment Variable	0.0329**	0.0273	0.0945***	0.1409**	0.0559***	0.0307***
	(0.0131)	(0.0190)	(0.0204)	(0.0524)	(0.0237)	(0.0135)
With Covariates						
Treatment Variable	0.0325***	0.0241	0.0713***	0.09512*	0.0436***	0.0286**
	(0.0103)	(0.0142)	(0.0146)	(0.0524)	(0.0237)	(0.0133)
Running Variable	Linear	Quadratic	Cubic	Linear	Quadratic	Cubic

Notes: Standard Errors in parentheses; clustered at birth month level. Sample includes six month before and after reform cutoff. Significance levels: $*$ p 0.10, $**$ p 0.05, $***$ p 0.01; Pre-Policy Mean: 15.41 percent. Source: Microcensus 2005-2012, own calculations.

Appendix: Theoretical Model

Based on the the theoretical model outlined in section 2 we obtain the following maximization problem:

$$U_G = U(C_{1i}) + \beta U(C_{2i})R_i + \beta^2 U(C_{3i})(T_i - R_i)$$

max U_g subject to the intertemporal budget constraint:

$$y_{1i} + \beta y_{2i}R_i + \beta^2 y_{3i}(T_i - R_i) \geq \mathrm{C}_{1i} + \beta C_{2i}R_i + \beta^2 C_{3i}(T_i - R_i)$$

The Lagrangian is given by:

$$L = U_G + \lambda \left[y_{1i} + \beta y_{2i}R_i + \beta^2 y_{3i}(T_i - R_i) - (C_{1i} + \beta C_{2i}R_i + \beta^2 C_{3i}(T_i - R_i)) \right]$$

The set of First Order Conditions i :

$$\frac{\partial L}{\partial C_{1i}} = 0 \Rightarrow U'(C_{1i}) - \lambda = 0 \tag{A.1}$$

$$\frac{\partial L}{\partial C_{2i}} = 0 \Rightarrow \beta R(U_i'(C_{2i}) - \lambda) = 0 \tag{A.2}$$

$$\frac{\partial L}{\partial C_{3i}} = 0 \Rightarrow \beta(T - R)\beta^2[\lambda - U(C_{3i})] = 0 \tag{A.3}$$

$$\frac{\partial L}{\partial I_i} = 0 \Rightarrow \lambda[-w_1(S_i) + (R_i\beta + (R_i - T_i)\alpha\beta^2)w_{2I}(S_i, I_i)] = 0 \tag{A.4}$$

Based on the set of First Order Conditions we derive our results. Firstly, comparative statics yield Equation 5 in the main paper, i.e.

$$\frac{\partial I_i}{\partial R_i} = -\frac{[\alpha\beta - 1]\, w_{2I}\,(S_i, I_i)}{[R_i + (T_i - R_i)\alpha\beta]\, w_{2II}(S_i, I_i)}$$

The reform effect is positive as long as $w_{2I} > 0$ and $w_{2II} < 0$. $\alpha\beta - 1$ is negative since $\beta < 1$ and $\alpha < 1$.

Secondly, Equation 6 in the main paper can be derived as illustrated below. Solving Equation A.4, i.e. L_I; for β, gives

$$\beta = \frac{1}{R}\left(\frac{w_1(S_i)}{w_{2I}(S_i, I_i)} + \alpha\beta^2(R - T)\right)$$

Taking L_{IS} and substituting in L_{IS}:

$$sign\ L_{IS} = sign\left[\frac{w_{2SI}(S_i, I_i)}{w_{2I}(S_i, I_i)} - \frac{w_{1I}(S_i)}{w_1(S_i)}\right]$$

The above can then be simplified, written in elasticity form and solved for $\dfrac{\partial I_i}{\partial S_i}$. This then ultimately results in Equation 6 in the main paper :

$$\frac{\partial I_i}{\partial S_i} \gtreqless 0 \Longleftrightarrow w_{2IS}(S_i, I_i)\frac{S_i}{w_{2I}(S_i, I_i)} =: \eta_{w_{2S},S} \gtreqless \eta_{w_1,S} := w_{1S}\frac{S_i}{w_1(S_i)}$$

Lastly, we apply the multivariate chain rule, given that the reform effect is a function of R_i, S_i and I_i, which in itself is a function of s_i and R_i. Consequently, the size of the reform effect with respect to schooling can be derived by splitting up the effect into two components:

$$\frac{\partial}{\partial S_i}\left[\frac{\partial I_i}{\partial R_i}\right] = \frac{\partial I^2}{\partial R_i \partial S_i} + \frac{\partial I^2}{\partial R_i \partial I_i}\frac{\partial I}{\partial S_i}$$

Using comparative statics, it is possible to firstly derive:

$$\frac{\partial I^2}{\partial R_i \partial S_i} = \frac{\partial I_i}{\partial R_i}\left[\frac{w_{2SI}(S_i, I_i)}{w_{2I}(S_i, I_i)} - \frac{w_{2SII}(S_i, I_i)}{w_{2II}(S_i, I_i)}\right]$$

The above expression is positive as long as $w_{2SII}(S_i, I_i)$ is positive, meaning that the larger S, the slower is the decline in $w_{2I}(S_i, I_i)$ with I.

Secondly, it is possible to derive:

$$\frac{\partial I^2}{\partial R_i \partial I_i} = \frac{\partial I_i}{\partial R_i}\left[\frac{w_{2II}(S_i, I_i)}{w_{2I}(S_i, I_i)} - \frac{w_{2III}(S_i, I_i)}{w_{2II}(S_i, I_i)}\right]$$

With $w_{2III}(S_i, I_i) \leq 0$ or sufficiently small the above expression will be negative. Considering, the expression derived for $\frac{\partial I_i}{\partial S_i}$, we can write:

$$\frac{\partial I^2}{\partial R_i \partial I_i}\frac{\partial I_i}{\partial S_i} \gtreqless 0 \Longleftrightarrow \left[\frac{w_{1_{I(S_i)}}}{w_1(S_i)} - \frac{w_{2SI}(S_i, I_i)}{w_{2I(}S_i, I_i)}\right]$$

Thus assuming that $\frac{\partial I_i}{\partial S_i}$ is positive, the reform effect consists of a positive direct and negative indirect effect and the overall effect depends on the relative size of the respective effects, as formulated in Proposition III in the main paper.