

The Effect of Type 2 Diabetes Diagnosis in the Elderly

Abstract

In this paper, I use a novel approach based on biomarkers data to examine the effect of type 2 diabetes (T2D) diagnosis on both physical and mental health for a sample of individuals aged 50 and above. In order to retrieve reliable estimates, I exploit the fact that medical guidelines cause a discontinuity in the probability that General Practitioners (GP) diagnose their patients with T2D as a function of exact blood test cut-off in a regression discontinuity design (RDD) approach. Using data from the English Longitudinal Study of Ageing (ELSA), I find compelling evidence that health information, in the form of T2D diagnosis, influences the protection of health into old age. Specifically, after receiving T2D diagnosis, over time, individuals reported a 2.1 lower body mass index (BMI) as well as 5.5 centimetres lower waist circumference, relative to their counterparts. With respect to self-reported physical health, the results imply that those diagnosed with T2D reported a 0.19 and 0.70 higher score in increased activities of daily living (ADL) and body mobility indexes, respectively. Finally, while I find evidence that T2D-diagnosed patients reported a significant, 0.5 higher, score in the word listening test, I find no evidence that T2D diagnosis impacted self-reported depression levels. I provide a wide variety of evidence on the validity of the results.

Keywords: Biomarkers; Type 2 diabetes diagnosis; RDD.

1. Introduction and Motivation

Everywhere around the world, life expectancy has increased dramatically. It is the first time in the history of human kind that most people can expect to live beyond the age of 60. The World Health Organisation (WHO, 2015) reports 900 million people are aged 60 and over, and this number is forecasted to become 2 billion by 2050.¹ Since a natural component of the ageing process is the decline of both physical and mental health (Milanovic et al., 2013; Mazzonna and Peracchi, 2012), the rise in the elderly population is likely to create significant pressure on public finances, especially in terms of healthcare expenditure. Amongst the various chronic diseases affecting the ageing population, type 2 diabetes (T2D) is the most common. The British Geriatrics Society (2009) reports half of all people in the UK diagnosed with T2D are aged over 65 years, and also that, for them, the management of this condition is particularly challenging due to their frailty and tolerance to standard therapies.² Despite this, there is still little evidence of the effect that the diagnosis of T2D may have on this group of the population.³

Several studies show that individuals significantly change their lifestyle behaviours when diagnosed with T2D, in terms of diet, physical activity, smoking and drinking behaviours. For example, Slade (2012) explores the effect of T2D on lifestyle behaviours (weight, exercises, drinking and smoking) using a health and retirement survey with dynamic panel techniques. He finds that individuals initially responded to the T2D diagnosis by increasing exercise, losing weight, and curbing smoking and drinking behaviour, but that the effects diminish with time. Similar to this paper, Kim et al. (2019) use discontinuities for T2D, as well as for hyperlipidaemia (high cholesterol) and obesity diagnosis, to examine whether individuals

¹ <https://www.who.int/features/factfiles/ageing/en/>

² <https://www.bgs.org.uk/resources/diabetes>

³ Several studies report the positive effects of following healthy lifestyles on a variety of health outcomes (Kenkel, 1995; Contoyannis and Jones, 2004; Balia and Jones, 2008). Further, there is substantial literature that directly links health to labour market outcomes (Cawley, 2004; Han et al., 2008; Lindeboom et al., 2010; Morris, 2007).

change their lifestyle behaviours (weight and exercise) upon receiving the diagnosis. Employing a sample of the Korean population, they find evidence of weight loss around the threshold for T2D.^{4 5} Very little is known, however, concerning whether a change in lifestyle behaviours may lead to a subsequent improvement in overall health outcomes in the elderly. In this study, I attempt to fill this gap and estimate the effect of T2D diagnosis on both physical and mental health outcomes for a sample of older adults in the UK.

In a randomised evaluation, I would (randomly) diagnose some individuals with T2D, while leaving similar individuals undiagnosed, and estimate the difference in health outcomes in the two groups. In the absence of random assignment, however, retrieving such an estimate is very problematic because T2D diagnoses are assigned in a non-random manner, and generally targeted based on certain individual characteristics unobservable to the researcher. In this paper, I use a novel approach based on biomarkers data, collected through blood samples, to deal with the issue of non-random assignment. The key insight of the identification strategy is that General Practitioners (GP) diagnose their patients with T2D on the basis of an exact blood test, namely the fasting blood glucose (FBG) level, being above a pre-determined cut-off. Accordingly, I implement a regression discontinuity design (RDD) to estimate the impact of T2D diagnosis on both physical and mental health, by comparing individuals just below and just above the pre-determined cut-off level of the FBG.

The main source of data employed in the study is the English Longitudinal Study of Ageing (ELSA). This dataset is uniquely suited to answer the research question posed by this paper as it focusses on people aged 50 and above (and their partners), and as it contains detailed

⁴ A number of papers report comparable changes in lifestyle behaviour following hypertension and high cholesterol diagnosis (Zhao et al., 2013; Gaggero, 2019).

⁵ There is some evidence of the negative effect of T2D diagnosis on employment (Seuring et al., 2015) and other labour market outcomes (Seuring et al., 2019).

information on both physical and mental health, anthropometric measurements and various biomarkers data, collected through blood samples, which are at the core of this study.

The RDD estimates reveal that health information, in the form of T2D, significantly matters for the health of the elderly. Specifically, relative to their counterparts, individuals diagnosed with T2D exhibit: *(i)* a significant lower level of overall and central obesity; *(ii)* significantly higher levels of self-reported body mobility; and, *(iii)* significantly higher scores on memory. However, I find no evidence that lifestyle recommendations have an effect on self-reported depression levels. In terms of magnitude of the estimated coefficients, the results appear to be strongest for men and for individuals below the age of 65. Importantly, the estimates are robust across a variety of specifications, including the inclusion (or exclusion) of different control variables and different functional form choices of the running variable. Additionally, I demonstrate that the results are unlikely to be driven by discontinuities in individual pre-diagnosis characteristics, or endogenous sorting around the threshold.

The paper proceeds as follows. Section 2 presents the conceptual framework and outlines the quasi-experimental setting based on T2D diagnosis. Section 3 presents the data and reports summary statistics of the main variables of interest. In Section 4, the econometric methods employed in the analysis are explained. Section 5 presents the results, and Section 6 reports a series of robustness checks to confirm the validity and strength of the approach. The final Section provides a discussion of the results and concludes the paper.

2. The Setting

The key variable employed in the study is the person-specific fasting blood glucose (FBG) level, which is generally used as a measure of presence, or risk, of Type 2 Diabetes (henceforth, T2D). T2D is a metabolic disorder characterised by the body's inability to use insulin properly, due to a combination of insulin resistance and beta-cells failure. As a result, the body cannot

maintain normal blood glucose levels that, consequently, may become importantly elevated. For this reason, the measurement of fasting blood glucose has been the conventional method for screening for T2D. While elevated blood glucose does not cause any immediate physical or mental symptom, if left untreated it can lead to heart disease, stroke and kidney problems in the long run. However, via adequate management and treatment much, if not all, of these complications can be avoided (Lim et al., 2011).

According to the medical guidelines provided by the WHO (2006), the American Diabetes Association (ADA), as well as the European Association for the Study of Diabetes (EASD), if the FBG level is greater than or equal to 7 millimoles per litre (henceforth, mmol/L) then the individual is diagnosed with T2D.⁶ As suggested by the most recent National Institute for Health and Care Excellence (NICE) guidelines, the first line of treatment for T2D-diagnosed subjects is the provision of a set of lifestyle recommendations to help patients manage their condition, which include: *(i)* promotion of healthy eating patterns low in fats and carbohydrates; *(ii)* reduction of energy intake to achieve substantial weight loss; *(iii)* reduction of sedentary time, including at least 150 min per week of moderate-intensity aerobic physical activity as well as engagement in resistance training at least twice a week; *(iv)* smoking and drinking cessation.⁷ Moreover, depending on the specific characteristics of the patients, GPs may assign T2D medications (e.g., metformin) to help lower blood glucose levels and restore insulin sensitivity, and may even prescribe bariatric surgery in cases of very elevated levels of BMI.

⁶ Since 2011, the WHO suggested that T2D may also be diagnosed by means of the haemoglobin A1c, which measures glycaemic control over the previous 3 months. Although the sample of interest was not affected by this change, I include this variable in the analysis to increase the precision of the point estimates.

⁷ Recent studies show significant improvements in glycaemic control for patients with type 2 diabetes that change to healthier lifestyles (Huang et al., 2016; Chen et al., 2015). Moreover, in a comprehensive review, Glechner et al., (2018) show that lifestyle changes may be an effective tool not only to manage but also to prevent T2D.

3. Data

Overview

The study employs data from the English Longitudinal Study of Ageing (ELSA). The ELSA is a large-scale longitudinal panel study of people aged 50 and over, and their partners, living in private households in England. The original sample was drawn in 2002 from households that had previously responded to the Health Survey for England (HSE). Every two years, the sample has been interviewed to measure changes in their health status, economic conditions and social circumstances.

The ELSA is employed not only because it contains detailed information of both physical and mental health but, most importantly, because at alternative waves a nurse visit is carried out in addition to the main interview.⁸ The nurse visit includes the collection of anthropometric measurements and various biological samples, collected through blood samples, which are the core of this study.⁹ Within three months of the nurse visit, study participants receive a letter with the result of each of the analyses conducted on the blood. If any result are out of the normal range participants are asked to contact their GP in the near future. Moreover, blood pressure, lung function and blood test results are sent directly to the participants' GP.¹⁰ Accordingly, to fully exploit the biomarkers in the data, this paper focuses on the waves in which the nurse visit was carried out, that is, waves 2, 4, and 6, collected in the years 2004, 2008, and 2012.

⁸ All core sample members have been offered a nurse visit at waves 2, 4 and 6.

⁹ All sample members who gave consent were eligible for a blood sample to be taken. Respondents were not asked to fast if they had diabetes and were on treatment or if they were considered to be malnourished or otherwise unfit to fast (this information was obtained from the interviewer). Respondents who were asked to fast were given guidelines about when and what they could eat based on their appointment time.

¹⁰ http://www.elsa-project.ac.uk/uploads/elsa/docs_w2/nurse_leaflet.pdf

Key variables

The ELSA provides a rich source of variables for the analysis. The first set of outcome variables measuring physical health include anthropometric measurements for both total as well as central obesity. I focus on obesity because it is associated with a striking increase in the risk of all-causes mortality, including heart disease, kidney disease and cancer (Jahangir et al., 2014; Kovesdy et al., 2017; Bhaskaran et al., 2014). Total obesity is captured by the widely used body mass index (BMI), which is a measure of a person's weight relative to his/her height. One potential limitation of this index, however, is that it cannot differentiate between lean mass and fat mass and, consequently, may assign high values to individuals who are not overweight, but who are very muscular. To this end, in this study I also look at central obesity, as measured by waist circumference, which is a proxy for visceral fat in the body, and generally the underlying cause of increased risk of morbidity (Kuk et al., 2006).

Self-assessed measurements for physical health are also considered. First, I consider the six-item activities of daily living (ADL) index developed by Katz et al. (1963). The ADL index measures the difficulties in performing tasks required for personal self-care and independent living in every-day life. The functional assessment is based on individuals' responses (yes/no) at each wave to the six item questions asking them for (1) difficulties in dressing, (2) walking across a room, (3) bathing or showering, (4) eating, (5) getting out of bed, and (6) using the toilet. The overall score for each individual is calculated by summing across the item-specific responses (Zaninotto and Falaschetti, 2011) and, therefore, ranges from zero, the most difficulties and worst physical health, to six, the least difficulties and best physical health.

Additionally, participants in the ELSA were asked whether they had difficulty doing any of 10 activities that involved body mobility, such as (1) walking 100 yards, (2) sitting for two hours, (3) getting up from a chair after sitting long periods, (4) climbing several flights of stairs without resting, (5) climbing one flight of stairs without resting, (6) stooping, kneeling or

crouching, (7) reaching or extending arms above shoulder level, (8) pushing or pulling large objects, (9) lifting or carrying weights over 10 pounds, and (10) picking up a 5p coin from a table. Similar to the above, for each item I generate a dummy variable which equals unity if the individual reports to have difficulty in a certain activity, and I create a body mobility index that ranges from zero to ten, where zero implies most difficulties, and ten implies least difficulties in mobility.

Finally, I consider the set of outcome variables relating to mental health. In this study, mental health is measured in terms of learning and memory by means of the word-list learning test. In this test, participants are presented with ten common words and are asked to remember them. ELSA uses the word lists developed for health and retired studies (HRS), which comprise four different versions, so that different lists can be given to different members of the same household. The first member of the household to be tested is assigned a list at random by the computer, and where there is more than one member of the household in the ELSA sample, the remaining lists are also selected at random.¹¹

Lastly, I measure mental health in terms of depression, using the eight-item version of the CES-D scale developed by Radloff (1977). The CES-D is a depression screening test in which individuals were asked whether over the past week they had symptoms associated with depression, including: (1) if they felt depressed much of the time, (2) they felt everything they did was an effort, (3) their sleep was restless, (4) they were unhappy, (5) they felt lonely, (6) they enjoyed life, (7) they felt sad, and (8) if they could not get going. Similar to the above, responses were summed (Demakakos et al., 2010) for each individual to compute a total CES-

¹¹ To ensure standardisation, the lists are presented by the computer, using a taped voice.

D scale, ranging from zero, high depression and worst mental health status, to eight, no depression and best mental health.¹²

[TABLE 1 HERE]

Descriptive Analysis

Table 1 shows summary statistics of the main variables of interest. In columns (1) and (2), I compare statistics of men and women, respectively, and in column (3) I report the p -value of a two-sided test that compares the means of the two groups. The table shows that the average age of the sample is 68, and that men in the survey are significantly more likely to be married and to have a higher degree classification. Women, on the other hand, are significantly more likely than men to smoke.

The table shows that although there is no significant difference in BMI between men and women, men in the sample have a larger waist circumference than women. Following, men report significantly better scores in the self-assessed measurements of physical health than women, considering both the ADL and the body mobility indexes. Finally, women have a higher score in the word-listening test, but are more likely than men to have symptoms associated with depression, as measured by the CES-D scale.

Next, I report statistics of the key results obtained from the blood tests during the nurse visits. The table reports that men, on average, have slightly higher levels of fasting blood glucose (FBG) and of Haemoglobin A1c (HBA1c) than women. Further, the table reports that men are significantly more likely to be diagnosed with and taking medication for T2D. Finally, women are reported to have significantly higher levels of low-density lipoprotein (LDL) cholesterol (generally referred as *bad* cholesterol), but men have higher levels of both systolic and diastolic blood pressure.

¹² The CES-D scale has been validated in older populations and displays strong psychometric properties (Zivin et al., 2010, Lyness et al., 1997).

4. Econometric Methods

In this study, I use a sharp Regression Discontinuity Design (RDD) to estimate the effect of T2D diagnosis on physical and mental health. This type of design was first introduced by Thistlewaite and Campbell (1960) and then formalised by Hahn et al. (2001), who derived the necessary conditions for the identification of causal effects. Despite being underutilised in health economics and epidemiology (Moscoe et al., 2015), RDD is becoming increasingly popular in empirical studies given the assumptions needed for the identification of causal effects are quite weak. The defining feature of this class of models is that the probability of receiving the treatment changes discontinuously as a function of an assignment variable, denoted as $Z_{i,t}$, being above or below a certain cut-off point, denoted as z_0 .¹³ The underlying idea of an RDD is that, as in a randomised experiment, for individuals just above and below the pre-identified cut-off point, assignment to treatment is as good as random and, therefore, omitted variable bias disappears.

Formally, let $Z_{i,t}$ be the running variable which identifies the fasting blood glucose level for individual i at time t , and let the cut-off point of interest be $z_0 = 7$. Further, let us denote the indicator function $D_{i,t} = 1(Z_{i,t} \geq z_0)$, which takes the value of unity for subjects with fasting blood glucose levels above the pre-determined cut-off and, consequently, diagnosed with T2D, such that:

$$\Pr \{D_{i,t} = 1\} = \begin{cases} f_1(Z_{i,t}), & \text{if } Z_{i,t} < z_0; \\ f_0(Z_{i,t}), & \text{if } Z_{i,t} \geq z_0 \end{cases} \quad (1)$$

¹³ There are two types of RDD: the sharp and fuzzy design. In the sharp design, treatment status depends deterministically on the running variable being above or below the cut-off level. In contrast, in the fuzzy design the probability of receiving the treatment is known to be discontinuous in the cut-off point, but not in a deterministic manner. While the sharp design is the preferred model, I also employ a fuzzy design to check the robustness of the results.

where, due to the discontinuity at the cut-off point, $f_1(Z_{i,t}) \neq f_0(Z_{i,t})$. In the spirit of Hahn *et al.* (2001), I estimate a version of Equation (2) on a number of physical and mental health outcomes as follows:

$$Y_{i,t+s} = \alpha + \beta D_{i,t} + \delta Z_{i,t} + \mathbf{X}'_{i,t}\boldsymbol{\gamma} + \varepsilon_{i,t}, \quad t = 2004, 2008. \quad (2)$$

$Y_{i,t+s}$ denotes the outcome of interest for individual i at time $t + s$ (where $s = 4$); $D_{i,t}$ and $Z_{i,t}$ are respectively the T2D diagnosis binary variable and the running variable as described above. β is the main term of interest, as it measures the effect of T2D diagnosis on the outcomes of interest. $\mathbf{X}'_{i,t}$ includes a set of baseline respondents' attributes, including age, gender, education, family size, marital status, household income, and smoking behaviour, as well as a set of baseline biomarkers, including Haemoglobin A1c, LDL cholesterol, systolic and diastolic blood pressure, which are also key markers considered by the GP when diagnosing T2D. To take into account the medical history of the subjects, I also include a set of dummy variables that identify subjects' pre-existing medical conditions. Finally, $\varepsilon_{i,t}$ is a random error term. Standard errors are clustered at the individual level because individuals appear in the regressions in multiple waves, but results are insensitive to different specifications.¹⁴

¹⁴ To test the robustness of the results, I employ a fuzzy RDD as an alternative approach. Drawing from the above notation, let $SRD_{i,t+s}$ take the value of unity for patients with self-reported T2D. Then, I estimate the following model:

$$Y_{i,t+s} = \mu_0 + \mu_1 SRD_{i,t+s} + \mu_2 Z_{i,t} + \mathbf{X}'_{i,t}\boldsymbol{\mu}_3 + e_{i,t};$$

Where $SRD_{i,t+s}$ is instrumented by the indicator $D_{i,t}$. The results of this alternative method are reported in Table A.6 in the Appendix and are in line with the overall findings of the paper.

5. Results

[FIGURE 1 HERE]

In Figure 1, I begin to investigate the effect of T2D diagnosis on physical and mental health, graphically, by plotting a series of (unconditional) local polynomial smoothing (LPS) regressions of the main outcomes of interest at time $t + s$ as a function of the baseline fasting blood glucose (FBG) at time t .¹⁵ Figure 1 shows that, after receiving T2D diagnosis, individuals with FBG just above the threshold report a jump in the levels of overall and central obesity, and also a jump with respect to both ADL and body mobility indexes. Finally, the figure does not report a discontinuity in word listening and self-reported depression test. In what follows, I test the significance of these findings in a regression framework, as specified in Equation (2), when controlling for a number of other possible confounding factors.

[TABLE 2 HERE]

Table 2 reports RDD estimates of the effect of T2D diagnosis on health outcomes for the sample of interest. Columns (1) and (2) imply that four years after receiving T2D diagnosis individuals report a statistically significant lower score in their BMI level (over 2 points), and around 5.5 cm less in their waist circumference than their counterparts. In columns (3) and (4), the table reports that individuals diagnosed with T2D exhibited statistically significant better scores in the ADL and in the body mobility indexes, implying they reported encountering fewer difficulties in performing activities of daily living, as well as performing physical movements.

¹⁵ Due to the small sample size on the right-hand side of the cut-off, the unconditional LPS regressions report very big standard errors. We address this in a regression framework by including a full set of covariates, as explained in Section 4, and by clustering the standard errors at the individual level.

Specifically, the estimated coefficients imply that four years after receiving the diagnosis, relative to their counterpart, individuals reported a 0.19 and 0.70 increase in the scores of ADL and body mobility indexes, respectively. Finally, columns (5) and (6) display that individuals diagnosed with T2D exhibit a 0.5 higher memory and learning score than their counterparts, as measured by the word-listening test, but insignificant effects were found in the reported depression level.¹⁶

Overall, the table shows there are other variables that significantly affect the outcomes of interest. As expected, variables such as education and household income have a strong and significant explanatory power for all outcomes. Subjects who completed higher education and subjects that belong to richer households, report lower obesity levels and better scores in terms of self-assessed physical and mental health. Smoking behaviour also has a strong effect on the outcomes. Interestingly, individuals who were reported to smoke have lower BMI and waist-circumference levels, but report statistically significant worse scores in the remaining outcomes that identify healthy ageing.

To conclude, Table 3 reports heterogeneous effects of T2D diagnosis by disaggregating the sample in different categories. The results show that, relatively to women, men report greater improvements and that, while T2D diagnosis has positive effects at all ages, in terms of the

¹⁶ Additionally, in table A.7 I explore in a descriptive manner whether improvements in subjects' self-assessed physical and mental health outcomes are driven by the observed reduction in obesity levels. To do so, I use an instrumental variable (IV) approach that investigates the relationship between reduced BMI and physical and mental health. Specifically, first, I estimate the following equation:

$$Y_{i,t+s} = \pi_0 + \pi_1 BMI_{i,t+s} + \pi_2 Z_{i,t} + X'_{i,t} \pi_3 + e_{i,t};$$

In which the term $BMI_{i,t+s}$ is the predicted reduced BMI of individual i at time $t + s$, as predicted by the following first-stage equation:

$$BMI_{i,t+s} = \omega_0 + \omega_1 D_{i,t} + \omega_2 Z_{i,t} + X'_{i,t} \omega_2 + u_{i,t}.$$

It is worth mentioning that the estimated coefficient π_1 cannot be interpreted as causal because the implied exclusion restriction by this approach would not be satisfied.

magnitude of the estimated coefficients those below the age of 65 are those that benefitted. To sum up, the findings provide strong evidence that health information, in the form of T2D diagnosis, may have important effects on the health of the elderly. In the section that follows, I present a series of tests and checks to confirm the validity of these findings.¹⁷

[TABLE 3 HERE]

6. Robustness Checks

The main assumption that needs to be satisfied for the above identification strategy to produce unbiased estimates is continuity. Borrowing from the jargon of the program evaluation literature, let $\{Y_i^1, Y_i^0\}$ be the potential outcome for individual i in case of either receiving or not receiving T2D diagnosis, respectively. Then, the continuity assumption that needs to be satisfied for the validity of a (sharp) RDD can be formally written as follows:

$$E[Y_i^0 | Z_i = z_0^+] - E[Y_i^0 | Z_i = z_0^-] = 0, \quad (3)$$

where z_0^+ and z_0^- represent, respectively, people just above and below the cut-off point, z_0 . In this case, the continuity assumption entails that the people just above and just below the pre-identified cut-off level of fasting blood glucose are identical in every aspect, both in terms of observable and unobservable characteristics, but only differ in the probability of being assigned

¹⁷ In Table A.1 in Appendix, I also report estimated effects of T2D diagnosis on a number of respondents' biomarkers. The results show that individuals diagnosed with T2D report lower levels of blood pressure (systolic), higher levels of the high-density lipoprotein (HDL) cholesterol (often referred as *good* cholesterol), and lower levels of triglycerides (a measure of fat in the blood often associated with the risk of heart disease). Further, in tables A.2, A.3, and A.4, I report the effect of T2D diagnosis on the self-assessed outcomes (ADL index, body mobility index, and CES-depression scale) by splitting the indexes into their individual components.

lifestyle recommendations. A direct way to assess this assumption is to examine if baseline variables change discontinuously around the cut-off point. Accordingly, in Figure 2, I plot a set of local polynomial smoothing (LPS) regressions of baseline variables including: (a) log-equivalised household income, (b) education level; (c) bodyweight; (d) body height; (e) haemoglobin A1c; (f) LDL cholesterol; (g) systolic; and, (h) diastolic blood pressure. The figure does not show any statistically significant discontinuity at the cut-off point for any of these variables.¹⁸

[FIGURE 2 HERE]

A potential threat for the validity of the identification could arise in case of manipulation of the forcing variable. As McCrary (2008) argues, if individuals can manipulate the score of $Z_{i,t}$, in order to receive or not receive the treatment, then the continuity assumptions will not be satisfied. In my case, this may have occurred if study participants changed their behaviour in anticipation of the nurse visit. Although visual inspection (Figure A.1) reveals no suspect discontinuity in the distribution of the running variable,¹⁹ one way to account for the potential endogenous sorting around the running variable is the so called “donut hole” approach, suggested by Barreca et al. (2016). The main idea behind this approach is that units closest to the cut-off are those most likely to have engaged in manipulation. Consequently, excluding such units from the analysis would eliminate this potential concern. Accordingly, Table 4 reports RDD estimates of T2D diagnosis on physical and mental health outcomes, excluding

¹⁸ Analogous plots for other covariates show very similar patterns.

¹⁹ The McCrary density test confirms that I cannot reject the hypothesis that there is no shift in the discontinuity. The estimated log difference in the height of the density is 0.90 with a standard error of 0.49.

subjects with FBG values within 0.50 mmol/L around the pre-identified cut-off. As the table shows, the results remain virtually unchanged.²⁰

[TABLE 4 HERE]

Notably, the findings are robust across a variety of specifications. These estimates are robust to the inclusion/exclusion of various control variables and different functional form choices. Moreover, Table 5 shows the robustness of the results by performing a non-parametric RDD, that is, an approach in which Equation (2) is estimated only for a sample of subjects in arbitrarily small neighbourhoods around the cut-off point. I report estimated coefficients when using a window of $[-2, +2]$ mmol/L around the cut-off, but results are robust when using different windows. Additionally, Table 6 presents RDD estimates of the diagnosis with different function forms of the running variable. Although the results remain consistent across the different specification, when including third and fourth degree polynomials of the running variable, the estimated coefficient of interest loses its statistical significance for the ADL index.²¹

[TABLE 5 & 6 HERE]

²⁰ Additionally, the findings are robust when implementing the treatment effect derivative (TED) of the estimated RDD, constructed by Dong and Lewbel (2015), which tests for the stability of the RDD estimates (Cerulli et al., 2017).

²¹ In Table A.5 of the Appendix, I report a series of falsification tests in which I present RDD estimates for a number different cut-offs just before the pre-determined value, that is, with z_0 ranging from 6 to 6.9 mmol/L. The table shows that, with the only exception of the 6.9 cut-off value, virtually none of the estimated coefficients is statistically significant at the different cut-offs value.

7. Conclusion

Current medical guidelines cause a discontinuity in the probability individuals receive type 2 diabetes diagnosis (T2D) as a function of exact blood test results. This feature is exploited in a regression discontinuity design (RDD) framework to identify the causal effects of T2D diagnosis on physical and mental health for a sample of individuals aged 50 and above. Employing the English Longitudinal Study of Ageing, I find compelling evidence that health information, in the form of T2D diagnosis, significantly matters for the health of the elderly. In particular, upon receiving T2D diagnosis individuals reported considerably lower levels of overall and central obesity, less difficulties in body mobility, and performed better in the learning memory test. Importantly, these findings are robust to a battery of tests that confirm the strength and validity of the approach.

One potential shortcoming of the current approach is that, as explained in Section 2, upon receiving T2D diagnosis, individuals may simultaneously be assigned to a number of lifestyle recommendations (e.g., diet, exercise, smoking and drinking behaviour) as well as specific medications and/or treatments to help improve glycaemic control. Regrettably, the current data does not permit to estimate the specific effect of the different components.

This paper may have important policy implications. Firstly, to the extent that people respond to health information, as in the case of T2D diagnosis, the results of this paper suggests that health information and health screening programs may be an effective tool policymakers might use as a pre-emptive measure to promote healthy behaviours. Further, to the extent to which jobs and occupations require the performance of both physical and mental activities, this study suggests that health information and screening programs could also have important benefits in the productivity of the elderly and, potentially, prolong their participation in the labour force beyond retirement age.

As this is one of the first studies to evaluate the effect of a T2D diagnosis exploiting biomarkers data in an RDD framework, more research is needed to verify whether the findings can be observed in other contexts. In particular, as highlighted from Slade (2012), it is possible that the estimated effects may gradually disappear with time. Accordingly, future work should investigate the long term effects of the diagnosis. Moreover, further studies should examine whether, and the extent to which, the observed benefits on physical and mental health outcomes can spill over to other family members and in the labour market.

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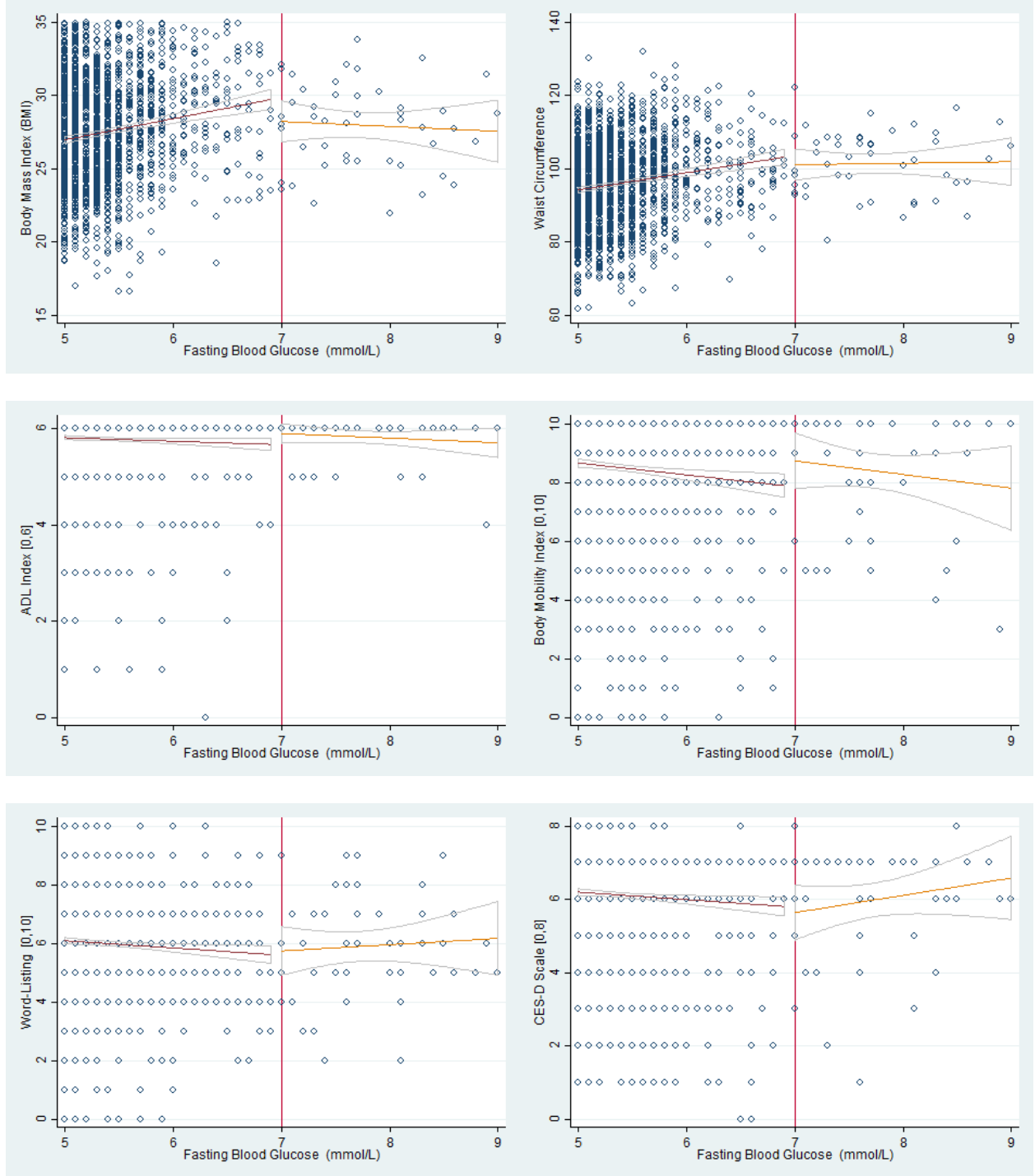
Table 1: SUMMARY STATISTICS

	(1) Men	(2) Women	(3) <i>p</i> -value
Attributes:			
Years of Age	68.51 (8.192)	68.53 (8.435)	0.905
Married [0,1]	0.77 (0.419)	0.60 (0.491)	0.000
Family Size	2.05 (0.762)	1.85 (0.749)	0.000
Higher Education [0,1]	0.45 (0.498)	0.28 (0.448)	0.000
Log-equivalised HH Income	5.66 (0.661)	5.56 (0.680)	0.000
Smoking [0,1]	0.07 (0.248)	0.09 (0.281)	0.001
Outcome Variables:			
Body Mass Index (Kg/m ²)	27.95 (4.333)	28.04 (5.485)	0.426
Waist Circumference (cm)	101.62 (11.513)	91.57 (12.830)	0.000
ADL Index [0,6]	5.77 (0.699)	5.73 (0.759)	0.030
Body Mobility Index [0,10]	8.72 (2.046)	7.99 (2.397)	0.000
Word-Listing [0,10]	5.76 (1.667)	6.17 (1.677)	0.000
CES-D Scale [0,8]	6.26 (1.256)	5.80 (1.554)	0.000
Biomarkers:			
FBG (mmol/L)	4.99 (0.874)	4.88 (0.693)	0.000
Haemoglobin A1c (%)	5.73 (0.730)	5.70 (0.596)	0.088
T2D Diagnosis [0,1]	0.10 (0.298)	0.07 (0.251)	0.000
T2D Treatment [0,1]	0.05 (0.219)	0.03 (0.178)	0.000
LDL Cholesterol (mmol/L)	3.28 (0.998)	3.60 (1.027)	0.000
Systolic Pressure (mm Hg)	134.41 (16.346)	132.00 (18.164)	0.000
Diastolic Pressure (mm Hg)	75.81 (10.525)	74.62 (10.255)	0.000
Observations	3293	4099	7392

Source: English Longitudinal Study of Ageing (ELSA).

Note: The table reports summary statistics of the variables of interest, comparing men and women. Standard deviations in parentheses.

Figure 1: OUTCOMES OF INTEREST AT THE CUT-OFF



Note: The figure shows local polynomial estimates of the discontinuity on the outcomes of interest at time $t + s$, as a function of the fasting blood glucose (FBG) at time t .

Table 2: RD ESTIMATES OF PHYSICAL AND MENTAL HEALTH

	Physical Health Anthropometrics		Physical Health Self-Assessed		Mental Health	
	(1) Body Mass Index	(2) Waist Circumference	(3) ADL Index	(4) Body Mobility Index	(5) Word Listening Test	(6) CES - D Scale
T2D Diagnosis [0,1]	-2.149*** (0.568)	-5.521*** (1.307)	0.193** (0.090)	0.702*** (0.271)	0.427* (0.236)	0.245 (0.213)
Running Variable:						
FBG (mmol/L)	0.361*** (0.098)	0.970*** (0.264)	-0.030 (0.020)	-0.038 (0.059)	-0.049 (0.038)	0.001 (0.036)
Attributes:						
Female [0,1]	0.308* (0.157)	-9.710*** (0.383)	-0.017 (0.021)	-0.617*** (0.067)	0.536*** (0.047)	-0.379*** (0.043)
Years of Age	0.341** (0.153)	0.614 (0.380)	0.047* (0.027)	0.158** (0.074)	0.166*** (0.057)	0.069 (0.054)
Years of Age ²	-0.003** (0.001)	-0.005* (0.003)	-0.000** (0.000)	-0.002*** (0.001)	-0.002*** (0.000)	-0.001 (0.000)
Higher Education [0,1]	-0.808*** (0.164)	-2.122*** (0.400)	0.056*** (0.021)	0.374*** (0.067)	0.460*** (0.050)	0.127*** (0.044)
Family Size	0.237* (0.124)	0.204 (0.261)	-0.067** (0.028)	-0.113* (0.059)	0.010 (0.035)	-0.036 (0.038)
Married [0,1]	-0.001 (0.187)	-0.076 (0.442)	0.139*** (0.036)	0.291*** (0.091)	-0.016 (0.059)	0.391*** (0.059)
Log-equivalised HH Income	-0.143** (0.066)	-0.427** (0.199)	0.051*** (0.012)	0.225*** (0.041)	0.188*** (0.032)	0.140*** (0.031)
Smoking [0,1]	-0.930*** (0.272)	-0.898 (0.680)	-0.093** (0.045)	-0.539*** (0.133)	-0.212** (0.083)	-0.225** (0.091)
Biomarkers:						
Haemoglobin A1c (%)	0.866*** (0.162)	2.253*** (0.401)	-0.019 (0.026)	-0.186** (0.081)	-0.068 (0.055)	-0.095* (0.053)
LDL Cholesterol (mmol/L)	-0.170** (0.068)	-0.395* (0.166)	0.007 (0.011)	0.047 (0.032)	0.047** (0.024)	-0.010 (0.022)
Systolic Pressure (mm Hg)	0.010** (0.005)	0.035*** (0.012)	-0.000 (0.001)	-0.001 (0.002)	-0.004** (0.002)	0.000 (0.002)
Diastolic Pressure (mm Hg)	0.039*** (0.008)	0.069*** (0.020)	0.001 (0.001)	0.002 (0.004)	0.006** (0.003)	-0.002 (0.003)
Taking Medications for:						
T2D Treatment [0,1]	2.397*** (0.841)	6.530*** (1.544)	-0.120 (0.096)	-0.836*** (0.308)	-0.023 (0.185)	-0.410* (0.221)
High Cholesterol [0,1]	0.273* (0.157)	0.692 (0.437)	-0.039 (0.037)	-0.193* (0.099)	-0.163** (0.078)	-0.213*** (0.071)
Hypertension [0,1]	0.807*** (0.141)	2.237*** (0.364)	-0.090*** (0.028)	-0.272*** (0.081)	-0.017 (0.058)	-0.114** (0.055)
Time dummy	0.212** (0.095)	1.253*** (0.239)	-0.031 (0.020)	-0.114** (0.052)	-0.247*** (0.044)	-0.109*** (0.041)
Constant	8.029 (5.153)	56.991*** (13.221)	4.311*** (0.949)	4.904* (2.552)	1.508 (1.948)	3.794** (1.860)
Observations	4970	4970	4970	4970	4970	4970

Source: English Longitudinal Study of Ageing (ELSA).

Note: The table presents regression discontinuity (RD) estimates of the effect of type 2 diabetes diagnosis on the outcomes of interest. Robust standard errors in parentheses are clustered at the individual level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

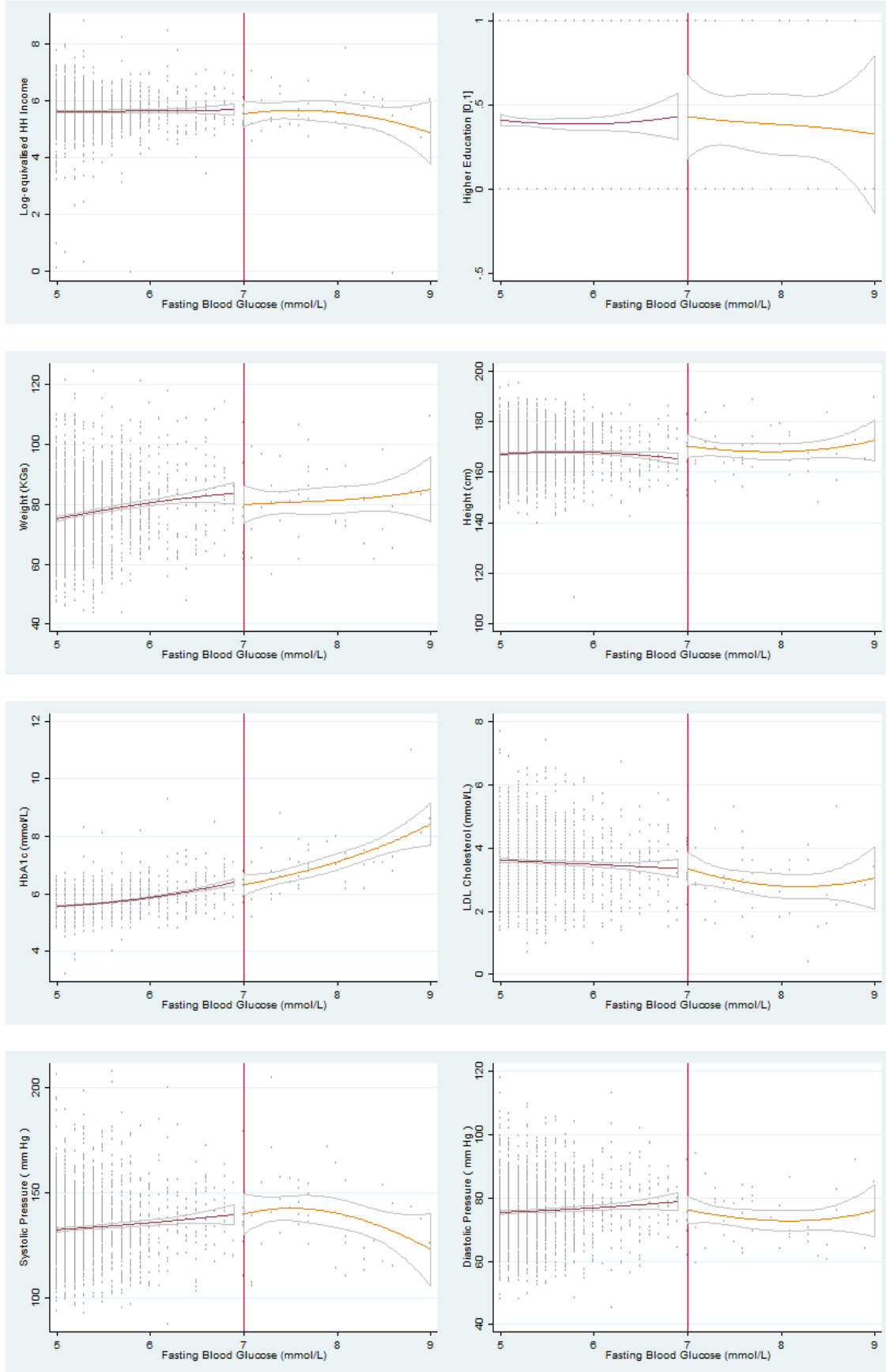
Table 3: RD ESTIMATES OF PHYSICAL AND MENTAL HEALTH, HETEROGENEOUS EFFECTS

	Physical Health Anthropometrics		Physical Health Self-Assessed		Mental Health	
	(1) Body Mass Index	(2) Waist Circumference	(3) ADL Index	(4) Body Mobility Index	(5) Word Listening Test	(6) CES - D Scale
Men:						
T2D Diagnosis [0,1]	-2.403*** (0.626)	-5.038*** (1.640)	0.187 (0.115)	0.620* (0.332)	0.714** (0.338)	0.085 (0.235)
Observations	2213	2213	2213	2213	2213	2213
Women:						
T2D Diagnosis [0,1]	-1.434 (0.895)	-4.764** (1.960)	0.144 (0.143)	0.504 (0.441)	0.130 (0.320)	0.295 (0.380)
Observations	2757	2757	2757	2757	2757	2757
Age $\geq$ 65:						
T2D Diagnosis [0,1]	-1.706** (0.719)	-4.108*** (1.544)	0.159 (0.098)	0.448 (0.323)	0.706** (0.282)	0.173 (0.254)
Observations	2996	2996	2996	2996	2996	2996
Age < 65:						
T2D Diagnosis [0,1]	-5.138*** (1.458)	-13.187*** (2.658)	0.465** (0.207)	1.717*** (0.534)	-0.270 (0.418)	0.788** (0.376)
Observations	1974	1974	1974	1974	1974	1974

Source: English Longitudinal Study of Ageing (ELSA).

Note: The table presents regression discontinuity (RD) estimates of the effect of type 2 diabetes diagnosis on the outcomes of interest. Each coefficient in the table is from a separate regression. Results are conditional on a vector of covariates, as reported in table 2. Robust standard errors in parentheses are clustered at the individual level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Figure 2: RDD CONTINUITY TEST



Source: English Longitudinal Study of Ageing (ELSA).

Note: The figure shows local polynomial estimates of a number of control variables, as a function of the fasting blood glucose (FBG).

Table 4: RD ESTIMATES, DONUT-HOLE APPROACH

	Physical Health Anthropometrics		Physical Health Self-Assessed		Mental Health	
	(1) Body Mass Index	(2) Waist Circumference	(3) ADL Index	(4) Body Mobility Index	(5) Word Listening Test	(6) CES - D Scale
T2D Diagnosis [0,1]	-3.060*** (0.803)	-7.566*** (1.897)	0.249* (0.128)	0.676* (0.378)	0.545* (0.298)	0.427 (0.261)
Running Variable:						
FBG (mmol/L)	0.378*** (0.101)	1.004*** (0.270)	-0.035 (0.022)	-0.027 (0.062)	-0.050 (0.039)	-0.001 (0.038)
Attributes:						
Female [0,1]	0.270* (0.158)	-9.759*** (0.385)	-0.017 (0.021)	-0.606*** (0.068)	0.528*** (0.047)	-0.371*** (0.043)
Years of Age	0.340** (0.154)	0.603 (0.383)	0.047* (0.027)	0.147* (0.075)	0.170*** (0.057)	0.072 (0.054)
Years of Age ²	-0.003** (0.001)	-0.005* (0.003)	-0.000* (0.000)	-0.001*** (0.001)	-0.002*** (0.000)	-0.001 (0.000)
Higher Education [0,1]	-0.813*** (0.164)	-2.152*** (0.402)	0.053** (0.021)	0.358*** (0.067)	0.455*** (0.050)	0.127*** (0.044)
Family Size	0.250** (0.125)	0.227 (0.262)	-0.066** (0.028)	-0.118** (0.060)	0.007 (0.035)	-0.044 (0.039)
Married [0,1]	-0.050 (0.186)	-0.122 (0.444)	0.136*** (0.036)	0.284*** (0.091)	-0.021 (0.059)	0.382*** (0.059)
Log-equivalised HH Income	-0.139** (0.066)	-0.420** (0.200)	0.050*** (0.012)	0.225*** (0.041)	0.190*** (0.032)	0.138*** (0.031)
Smoking [0,1]	-0.985*** (0.271)	-1.085 (0.665)	-0.088** (0.045)	-0.505*** (0.132)	-0.216** (0.084)	-0.223** (0.092)
Biomarkers:						
Haemoglobin A1c (%)	0.893*** (0.168)	2.352*** (0.424)	-0.030 (0.028)	-0.181** (0.085)	-0.079 (0.058)	-0.101* (0.055)
LDL Cholesterol (mmol/L)	-0.173** (0.068)	-0.385** (0.167)	0.006 (0.011)	0.038 (0.033)	0.046* (0.024)	-0.012 (0.023)
Systolic Pressure (mm Hg)	0.011** (0.005)	0.039*** (0.012)	-0.000 (0.001)	-0.001 (0.003)	-0.004** (0.002)	0.001 (0.002)
Diastolic Pressure (mm Hg)	0.039*** (0.008)	0.067*** (0.020)	0.001 (0.002)	0.002 (0.004)	0.006** (0.003)	-0.002 (0.003)
Taking Medications for:						
T2D Treatment [0,1]	2.591*** (0.957)	7.114*** (1.757)	-0.135 (0.102)	-0.906** (0.352)	-0.055 (0.200)	-0.465* (0.242)
High Cholesterol [0,1]	0.253 (0.159)	0.733* (0.441)	-0.042 (0.038)	-0.215** (0.100)	-0.184** (0.079)	-0.220*** (0.072)
Hypertension [0,1]	0.769*** (0.143)	2.193*** (0.368)	-0.088*** (0.028)	-0.263*** (0.082)	-0.011 (0.059)	-0.107* (0.056)
Time dummy	0.218** (0.095)	1.289*** (0.242)	-0.036* (0.020)	-0.111** (0.053)	-0.245*** (0.044)	-0.099** (0.041)
Constant	10.300** (5.163)	63.266*** (13.387)	4.162*** (0.963)	5.064* (2.623)	1.091 (1.975)	3.742** (1.886)
Observations	4899	4899	4899	4899	4899	4899

Source: English Longitudinal Study of Ageing (ELSA).

Note: The table presents regression discontinuity (RD) estimates of the effect of type 2 diabetes diagnosis on the outcomes of interest, employing the donut-hole approach with excluded 0.5 mmol/L around the cut-off. Robust standard errors in parentheses are clustered at the individual level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 5: NON-PARAMETRIC RD ESTIMATES

	Physical Health Anthropometrics		Physical Health Self-Assessed		Mental Health	
	(1) Body Mass Index	(2) Waist Circumference	(3) ADL Index	(4) Body Mobility Index	(5) Word Listening Test	(6) CES - D Scale
T2D Diagnosis [0,1]	-2.124*** (0.792)	-3.921** (1.656)	0.196* (0.111)	0.973*** (0.327)	0.516* (0.296)	0.387 (0.272)
Running Variable:						
FBG (mmol/L)	0.861*** (0.249)	1.799*** (0.615)	-0.070 (0.045)	-0.237* (0.124)	-0.026 (0.091)	-0.145 (0.089)
Attributes:						
Female [0,1]	0.800*** (0.249)	-8.392*** (0.595)	-0.014 (0.036)	-0.758*** (0.108)	0.556*** (0.073)	-0.492*** (0.069)
Years of Age	0.380 (0.275)	0.782 (0.629)	0.060 (0.044)	0.220* (0.118)	0.091 (0.092)	0.170** (0.086)
Years of Age ²	-0.003* (0.002)	-0.006 (0.005)	-0.000 (0.000)	-0.002** (0.001)	-0.001* (0.001)	-0.001** (0.001)
Higher Education [0,1]	-1.016*** (0.252)	-2.682*** (0.609)	0.063* (0.036)	0.375*** (0.107)	0.393*** (0.076)	0.171** (0.068)
Family Size	0.133 (0.199)	-0.184 (0.474)	-0.105** (0.052)	-0.086 (0.105)	0.067 (0.054)	0.019 (0.067)
Married [0,1]	0.387 (0.305)	0.793 (0.718)	0.171*** (0.059)	0.302** (0.149)	-0.128 (0.089)	0.392*** (0.096)
Log-equivalised HH Income	-0.169 (0.128)	-0.496 (0.319)	0.057*** (0.021)	0.329*** (0.066)	0.238*** (0.046)	0.135*** (0.047)
Smoking [0,1]	-0.863** (0.405)	-0.388 (1.136)	-0.048 (0.062)	-0.489** (0.238)	-0.125 (0.137)	-0.183 (0.165)
Biomarkers:						
Haemoglobin A1c (%)	0.881*** (0.282)	2.034*** (0.638)	0.032 (0.044)	-0.078 (0.123)	-0.132 (0.082)	-0.059 (0.079)
LDL Cholesterol (mmol/L)	-0.499*** (0.119)	-1.079*** (0.260)	0.019 (0.018)	0.176*** (0.049)	0.029 (0.037)	0.026 (0.034)
Systolic Pressure (mm Hg)	0.012 (0.009)	0.020 (0.019)	0.001 (0.002)	-0.001 (0.004)	-0.001 (0.003)	0.002 (0.003)
Diastolic Pressure (mm Hg)	0.051*** (0.015)	0.120*** (0.032)	0.002 (0.003)	0.010 (0.007)	0.007 (0.005)	-0.003 (0.005)
Taking Medications for:						
T2D Treatment [0,1]	1.517** (0.757)	4.430*** (1.515)	-0.100 (0.132)	-0.855** (0.358)	-0.090 (0.231)	-0.304 (0.266)
High Cholesterol [0,1]	0.125 (0.266)	-0.413 (0.661)	-0.003 (0.059)	-0.079 (0.161)	-0.067 (0.111)	-0.080 (0.108)
Hypertension [0,1]	0.656*** (0.230)	2.015*** (0.523)	-0.088** (0.041)	-0.361*** (0.122)	-0.034 (0.091)	-0.107 (0.086)
Time dummy	0.217 (0.189)	1.085** (0.435)	-0.012 (0.034)	-0.137 (0.087)	-0.282*** (0.073)	-0.128* (0.068)
Constant	4.964 (9.479)	51.207** (22.219)	3.544** (1.568)	1.095 (4.189)	3.754 (3.239)	0.674 (3.044)
Observations	1927	1927	1927	1927	1927	1927

Source: English Longitudinal Study of Ageing (ELSA).

Note: The table presents non-parametric regression discontinuity (RD) estimates of the effect of type 2 diabetes diagnosis on the outcomes of interest, at a window [+2,-2] mmol/L around the cut-off Robust standard errors in parentheses are clustered at the individual level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 6: RD ESTIMATES, WITH HIGHER ORDER POLYNOMIALS OF THE RUNNING VARIABLE

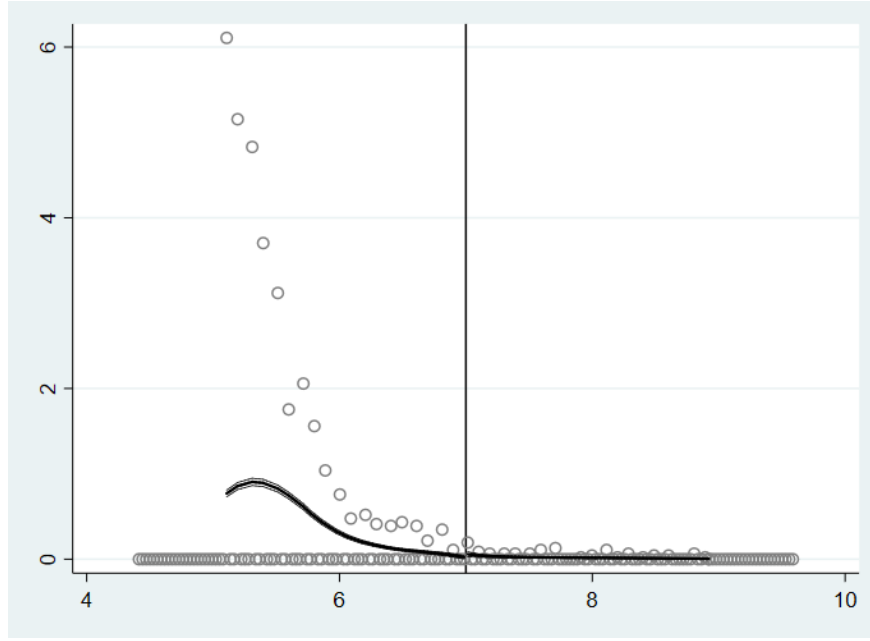
	Physical Health Anthropometrics		Physical Health Self-Assessed		Mental Health	
	(1) Body Mass Index	(2) Waist Circumference	(3) ADL Index	(4) Body Mobility Index	(5) Word Listening Test	(6) CES - D Scale
Quadratic:						
T2D Diagnosis [0,1]	-1.571** (0.667)	-3.701*** (1.379)	0.179** (0.091)	0.692** (0.311)	0.457* (0.243)	0.162 (0.219)
Observations	4970	4970	4970	4970	4970	4970
Cubic:						
T2D Diagnosis [0,1]	-1.351* (0.729)	-3.616** (1.597)	0.125 (0.118)	0.902** (0.356)	0.517* (0.300)	0.266 (0.283)
Observations	4970	4970	4970	4970	4970	4970
Quartic:						
T2D Diagnosis [0,1]	-1.288* (0.713)	-3.547** (1.568)	0.127 (0.119)	0.932*** (0.349)	0.526* (0.300)	0.283 (0.285)
Observations	4970	4970	4970	4970	4970	4970

Source: English Longitudinal Study of Ageing (ELSA).

Note: The table presents regression discontinuity (RD) estimates of the effect of type 2 diabetes diagnosis on the outcomes of interest, with higher order polynomials of the running variable. Each coefficient in the table is from a separate regression. Results are conditional on a vector of covariates, as reported in table 2. Robust standard errors in parentheses are clustered at the individual level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Appendix

Figure A.1: MANIPULATION OF RUNNING VARIABLE



Source: English Longitudinal Study of Ageing (ELSA).

Note: The figure reports evidence of no manipulation around the cut-off.

Table A.1: RD ESTIMATES OF OTHER BIOMARKERS

	Glycemic Control:		Blood Pressure:		Blood Lipids:				Inflammation:
	(1) Fasting Glucose	(2) Hemoglobin A1c	(3) Systolic Pressure	(4) Diastolic Pressure	(5) Total Cholesterol	(6) LDL Cholesterol	(7) HDL Cholesterol	(8) Tryglicerides Level	(9) C-Reactive Protein
T2D Diagnosis [0,1]	-0.514 (0.540)	-0.213 (0.146)	-5.761** (2.393)	-1.165 (1.375)	-0.086 (0.158)	-0.106 (0.140)	0.157** (0.075)	-0.260** (0.125)	-0.485 (1.362)
Observations	2778	4204	4737	4737	4260	4227	4260	4260	4260

Source: English Longitudinal Study of Ageing (ELSA).

Note: The table presents regression discontinuity (RD) estimates of the effect of type 2 diabetes diagnosis on different biomarkers. Each coefficient in the table is from a separate regression. Results are conditional on a vector of covariates, as reported in table 2. Robust standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table A.2: RD ESTIMATES OF ACTIVITIES OF DAILY LIVING

	(1) Dressing	(2) Walking Across a Room	(3) Bathing or Showering	(4) Cutting up Food	(5) Using the Toilet	(6) Getting In and Out of Bed
T2D Diagnosis [0,1]	0.084* (0.044)	0.022** (0.010)	0.025 (0.040)	0.022** (0.011)	0.002 (0.022)	0.053** (0.025)
Observations	4970	4970	4970	4970	4970	4970

Source: English Longitudinal Study of Ageing (ELSA).

Note: The table presents regression discontinuity (RD) estimates of the effect of type 2 diabetes diagnosis on the ADL. Each coefficient in the table is from a separate regression. Results are conditional on a vector of covariates, as reported in table 2. Robust standard errors are clustered at the individual level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table A.3: RD ESTIMATES OF BODY MOBILITY

	(1) Walk 100 Yards	(2) Sit 2 Hours	(3) Get up from a Chair	(4) Climb Several Stairs	(5) Climb One Stair	(6) Kneel or Crouch	(7) Extend Arms	(8) Push or Pull Objects	(9) Lift Weights	(10) Pick up 5p Coin
T2D Diagnosis [0,1]	0.058 (0.047)	0.097** (0.042)	0.108* (0.062)	0.041 (0.063)	0.139*** (0.049)	0.137** (0.065)	0.030 (0.043)	0.079 (0.051)	0.038 (0.058)	0.027 (0.026)
Observations	4970	4970	4970	4970	4970	4970	4970	4970	4970	4970

Source: English Longitudinal Study of Ageing (ELSA).

Note: The table presents regression discontinuity (RD) estimates of the effect of type 2 diabetes diagnosis on body mobility. Each coefficient in the table is from a separate regression. Results are conditional on a vector of covariates, as reported in table 2. Robust standard errors in parentheses are clustered at the individual level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table A.4: RD ESTIMATES OF CES- DEPRESSION SCALE

	(1) Depressed Much of the Time	(2) Everything was Effort	(3) Sleep is Restless	(4) Unhappy	(5) Lonely	(6) Enjoyed Life	(7) Sad	(8) Could not Get going
T2D Diagnosis [0,1]	-0.047 (0.051)	-0.039 (0.054)	-0.088 (0.064)	-0.027 (0.045)	0.013 (0.041)	0.002 (0.042)	-0.034 (0.056)	-0.033 (0.058)
Observations	4970	4970	4970	4970	4970	4970	4970	4970

Source: English Longitudinal Study of Ageing (ELSA).

Note: The table presents regression discontinuity (RD) estimates of the effect of type 2 diabetes diagnosis on the CES - depression scale. Each coefficient in the table is from a separate regression. Results are conditional on a vector of covariates, as reported in table 2. Robust standard errors in parentheses are clustered at the individual level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table A.5: RD ESTIMATES OF PHYSICAL AND MENTAL HEALTH, AT DIFFERENT CUT-OFFS

	Physical Health Anthropometrics		Physical Health Self-Assessed		Mental Health	
	(1) Body Mass Index	(2) Waist Circumference	(3) ADL Index	(4) Body Mobility Index	(5) Word Listening Test	(6) CES - D Scale
Using 6.0 cut-off	1.164** (0.592)	1.092 (0.775)	-0.025 (0.070)	-0.225 (0.176)	-0.093 (0.127)	-0.295** (0.124)
Using 6.1 cut-off	0.123 (0.310)	-0.141 (0.868)	-0.023 (0.081)	-0.212 (0.184)	0.012 (0.139)	-0.259* (0.141)
Using 6.2 cut-off	0.128 (0.345)	-0.053 (0.944)	-0.006 (0.093)	-0.277 (0.203)	-0.005 (0.152)	-0.176 (0.152)
Using 6.3 cut-off	0.128 (0.345)	-0.053 (0.944)	-0.006 (0.093)	-0.277 (0.203)	-0.005 (0.152)	-0.176 (0.152)
Using 6.4 cut-off	-0.230 (0.371)	-1.033 (1.026)	0.110 (0.082)	-0.035 (0.194)	0.003 (0.162)	-0.066 (0.159)
Using 6.5 cut-off	-0.316 (0.363)	-1.035 (1.070)	0.160* (0.082)	0.155 (0.209)	0.065 (0.165)	0.011 (0.166)
Using 6.6 cut-off	-0.575 (0.460)	-1.855 (1.282)	0.160* (0.085)	0.304 (0.232)	0.233 (0.199)	0.064 (0.177)
Using 6.7 cut-off	-0.793 (0.557)	-1.899 (1.414)	0.094 (0.083)	0.246 (0.245)	0.215 (0.207)	0.115 (0.182)
Using 6.8 cut-off	-0.793 (0.557)	-1.899 (1.414)	0.094 (0.083)	0.246 (0.245)	0.215 (0.207)	0.115 (0.182)
Using 6.9 cut-off	-1.492*** (0.562)	-3.797*** (1.278)	0.152* (0.089)	0.540*** (0.250)	0.309 (0.231)	0.180 (0.206)

Source: English Longitudinal Study of Ageing (ELSA).

Note: The table presents regression discontinuity (RD) estimates of the effect of lifestyle recommendations on the outcomes of interest. Each coefficient in the table is from a separate regression. Results are conditional on a vector of covariates, as reported in table 2. Robust standard errors in parentheses are clustered at the individual level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table A.6: FUZZY RD ESTIMATES OF PHYSICAL AND MENTAL HEALTH

	Physical Health Anthropometrics		Physical Health Self-Assessed		Mental Health	
	(1) Body Mass Index	(2) Waist Circumference	(3) ADL Index	(4) Body Mobility Index	(5) Word Listening Test	(6) CES - D Scale
Self-Reported T2D [0,1]	-6.556*** (1.761)	-17.271*** (4.402)	0.533** (0.241)	1.538** (0.746)	1.061** (0.532)	0.506 (0.485)
Running Variable:						
FBG (mmol/L)	0.756*** (0.142)	1.639*** (0.321)	-0.040** (0.019)	-0.109* (0.060)	-0.061 (0.043)	-0.017 (0.039)
Attributes:						
Female [0,1]	0.380** (0.149)	-9.607*** (0.370)	-0.014 (0.020)	-0.611*** (0.063)	0.544*** (0.045)	-0.388*** (0.041)
Years of Age	0.222 (0.187)	0.705 (0.429)	0.046* (0.026)	0.127 (0.079)	0.155*** (0.057)	0.067 (0.052)
Years of Age ²	-0.002 (0.001)	-0.005* (0.003)	-0.000** (0.000)	-0.001** (0.001)	-0.002*** (0.000)	-0.001 (0.000)
Higher Education [0,1]	-0.769*** (0.154)	-2.206*** (0.384)	0.056*** (0.021)	0.365*** (0.065)	0.462*** (0.047)	0.122*** (0.043)
Family Size	0.455*** (0.115)	0.389 (0.271)	-0.060*** (0.016)	-0.106** (0.049)	0.020 (0.035)	-0.040 (0.032)
Married [0,1]	0.040 (0.186)	0.034 (0.452)	0.126*** (0.026)	0.254*** (0.079)	-0.033 (0.056)	0.369*** (0.051)
Log-equivalised HH Income	-0.264** (0.105)	-0.539** (0.242)	0.055*** (0.014)	0.309*** (0.045)	0.204*** (0.032)	0.177*** (0.029)
Smoking [0,1]	-1.028*** (0.267)	-1.330** (0.641)	-0.109*** (0.037)	-0.566*** (0.113)	-0.216*** (0.081)	-0.260*** (0.074)
Biomarkers:						
Haemoglobin A1c (%)	2.139*** (0.293)	5.633*** (0.743)	-0.103** (0.040)	-0.454*** (0.124)	-0.221** (0.089)	-0.188** (0.081)
LDL Cholesterol (mmol/L)	-0.352*** (0.076)	-0.847*** (0.177)	0.028*** (0.010)	0.122*** (0.032)	0.068*** (0.023)	0.038* (0.021)
Systolic Pressure (mm Hg)	0.023*** (0.006)	0.054*** (0.014)	-0.001 (0.001)	-0.003 (0.002)	-0.005*** (0.002)	-0.001 (0.002)
Diastolic Pressure (mm Hg)	0.071*** (0.010)	0.132*** (0.022)	0.002 (0.001)	0.005 (0.004)	0.008*** (0.003)	-0.001 (0.003)
Time dummy	0.441*** (0.167)	1.822*** (0.353)	-0.045* (0.023)	-0.130* (0.071)	-0.262*** (0.050)	-0.108** (0.046)
Constant	0.037 (6.561)	27.217* (15.156)	4.790*** (0.900)	6.957** (2.780)	2.542 (1.982)	4.161** (1.809)
Observations	4970	4970	4970	4970	4970	4970

Source: English Longitudinal Study of Ageing (ELSA).

Note: The table presents fuzzy regression discontinuity (RD) estimates of the effect of self reported type 2 diabetes on physical and mental health. Robust standard errors in parentheses are clustered at the individual level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table A.7: INSTRUMENTAL VARIABLE ESTIMATES OF PHYSICAL AND MENTAL HEALTH

	Physical Health:		Mental Health:	
	(1) ADL Index	(2) Body Mobility Index	(3) Word Listening Test	(4) CES - D Scale
Reduced BMI	0.076** (0.033)	0.250** (0.104)	0.146 (0.093)	0.091 (0.075)
Running Variable:				
FBG (mmol/L)	0.017 (0.018)	0.078 (0.063)	0.044 (0.053)	0.049 (0.041)
Female [0,1]	0.014 (0.027)	-0.513*** (0.083)	0.598*** (0.064)	-0.351*** (0.054)
Years of Age	0.062** (0.031)	0.190** (0.090)	0.186*** (0.067)	0.094 (0.059)
Years of Age ²	-0.001** (0.000)	-0.002*** (0.001)	-0.002*** (0.001)	-0.001* (0.000)
Higher Education [0,1]	-0.002 (0.032)	0.169* (0.097)	0.354*** (0.083)	0.049 (0.068)
Family Size	-0.026 (0.032)	0.007 (0.086)	0.084 (0.062)	-0.001 (0.053)
Married [0,1]	0.130*** (0.036)	0.265*** (0.097)	-0.026 (0.067)	0.374*** (0.061)
Log-equivalised HH Income	0.035** (0.015)	0.242*** (0.051)	0.166*** (0.042)	0.153*** (0.036)
Smoking [0,1]	-0.187*** (0.057)	-0.822*** (0.176)	-0.364*** (0.131)	-0.352*** (0.126)
Biomarkers:				
Haemoglobin A1c (%)	0.058 (0.042)	0.101 (0.136)	0.081 (0.112)	0.022 (0.090)
LDL Cholesterol (mmol/L)	0.002 (0.013)	0.013 (0.038)	0.022 (0.029)	-0.013 (0.025)
Systolic Pressure (mm Hg)	0.001 (0.001)	0.003 (0.003)	-0.002 (0.003)	0.002 (0.002)
Diastolic Pressure (mm Hg)	0.007** (0.003)	0.022** (0.009)	0.018** (0.008)	0.005 (0.006)
Taking Medication for:				
T2D [0,1]	0.088 (0.120)	-0.241 (0.389)	0.336 (0.300)	-0.188 (0.305)
High Cholesterol [0,1]	-0.018 (0.047)	-0.185 (0.133)	-0.095 (0.102)	-0.187** (0.085)
Hypertension [0,1]	0.028 (0.054)	-0.046 (0.164)	0.177 (0.139)	-0.009 (0.116)
Time dummy	-0.010 (0.026)	-0.044 (0.075)	-0.193*** (0.062)	-0.089* (0.052)
Constant	4.825*** (1.058)	6.656** (3.089)	2.720 (2.249)	3.908* (2.010)
Observations	4970	4970	4970	4970

Source: English Longitudinal Study of Ageing (ELSA).

Note: The table presents instrumental variable estimates of the effect of type 2 diabetes diagnosis on physical and mental health, through a reduction in the body mass index. Robust standard errors in parentheses are clustered at the individual level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.