Uncontrolled diabetes and health care utilisation: panel data evidence from Spain

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Abstract

Despite size and relevance of uncontrolled diabetes, robust evidence on its effects on health care utilisation is very limited, especially among European countries. We employed longitudinal administrative data from Spain (2004-2010) to explore the relationship between uncontrolled type 2 diabetes and health care utilisation. We used a biomarker (glycated haemoglobin, HbA1c) to detect the presence of uncontrolled diabetes and explore its effects on both primary and secondary health care. We estimated a range of panel count data models, including negative binomials with random effects, dynamic and hurdle specifications to account for unobserved heterogeneity, previous utilisation and selection. We found uncontrolled diabetes in between 27-30% of patients of both genders. Our estimates suggested that although women appeared to systematically consume more health care compared to men, their consumption levels did not seem to be influenced by uncontrolled diabetes. Conversely, among men uncontrolled diabetes increased the average number of GP visits per year by between 3-3.4%, specialist visits by 5.3-6.1%, depending on specifications, and also extended annual hospital length of stay by 15%. We also found some evidence of heterogeneity in utilisation based on the level of uncontrolled diabetes among male individuals. Overall, our results suggested the need for different diabetes management plans depending on gender and levels of glycaemic control.

Keywords: uncontrolled diabetes; biomarkers; health care utilisation; panel count data

JEL codes: C23; I1; I12

Acknowledgments: We are grateful to Bruce Hollingsworth, Paolo Li Donni, Ian Walker, Will Whittaker, Giuseppe Moscelli and participants to the 2015 UK Health Economists Study Group (HESG) Conference, XXXV Spanish Health Economics Association Conference, 11th World Congress of the International Health Economics Association (iHEA) and the 2016 EuHEA Conference for helpful comments. We also would like to thank two anonymous referees for their valuable comments. We gratefully acknowledge funds from the Catalan Government through grant 2014-SGR-1257. The usual disclaimer applies.

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1. Introduction

Diabetes mellitus (DM) is one of the most prevalent chronic conditions worldwide [1]. According to the WHO [2], we are currently experiencing a global diabetes epidemic with DM affecting 422 million adult individuals worldwide in 2014, compared to 108 million in 1980 and projected to be 7th leading cause of death by 2030. In the U.S. alone, the estimated total costs of diagnosed diabetes increased by 41% in a five year period, from $174 billion in 2007 to an estimated $245 billion in 2012 [3]. In the UK the cost of diabetes to the NHS is around 10% of the NHS budget for England and Wales [4]. Similarly, DM absorbs around 8% of total public health expenditures in Spain with an estimated €5.1 billion for direct costs and €1.5 billion for diabetes-related complications [5].

The medical literature consistently finds that uncontrolled diabetes or poor glycaemic control resulting in higher levels of blood sugar is a prevailing condition concerning around 50% of diabetic patients [6, 7]. Glycaemic control is a major step in managing DM and is often driven by the interaction of genetic endowment, risk factors (e.g. whether and to what extent patients follow recommended diet and exercise regimens); therapeutic inertia or resistance to intensify medication; and poor treatment adherence [8, 9]. Uncontrolled diabetes has potentially severe consequences on patients' health and well-being exposing individuals to higher risks of life-threatening comorbidities such as heart disease and stroke as well as vision problems, kidney and nerves damages [10].

From an economic perspective, a related problem may be the additional health care utilisation caused by uncontrolled diabetes. Individuals with uncontrolled diabetes may potentially use more health care resources resulting in *extra utilisation* and added costs for the health system as well as further loss in productivity due to work absence, work limitations, lower earnings and early mortality [11-13]. Furthermore, whereas uncontrolled diabetes is a widespread phenomenon, robust evidence of its effects on health care utilisation is very limited, especially among European countries.

The economic literature has traditionally focused on the effects of diabetes on the labour market [14-18] and quality of life [19], yet it has so far overlooked its impact on health care utilisation. Similarly, previous medical evidence on the relationship between poor glycaemic control and health care use is often based on selected samples, mostly from U.S. health insurance claims, and standard methods such as linear regression models. For

instance, Wagner et al. [20] employ U.S. insurance claims data of patients with diabetes from a large Health Maintenance Organization (HMO) in the state of Washington between 1992-1997 to analyse the association between improved glycaemic control, health care utilisation and costs. They employ linear and log-linear regression models and find that sustained reduction of HbA1c (glycated haemoglobin, a clinical measure of blood sugar) levels is correlated with lower utilisation and cost savings. Gilmer *et al*. [21] combine claims and survey data of diabetic patients in Minnesota with generalised linear models (GLM) and find that coronary heart disease (CHD), hypertension and depression are stronger predictors of health care costs than high baseline HbA1c levels. Oglesby *et al*. [22] use similar methods and data from the U.S. Health Core Managed Care Database between 1998-2003 and observe that direct medical costs driven by type 2 diabetes were between 16% to 20% lower for individuals with good glycaemic control (HbA1c $\leq$ 7%).[1] Recent evidence from Catalonia (Spain) based on primary care cross-sectional data focuses on costs and highlights that, among other findings, patients with poor glycaemic control had higher average costs (with increases of around 16%) compared with patients with good control [24]. [2]

In earlier studies, selected samples limit the generalisability of the results while standard linear models do not account for potentially relevant issues such as unobserved heterogeneity and selection which may affect the estimates of the effects of uncontrolled DM. A more accurate assessment of the health care consequences of uncontrolled diabetes will help enhance the evidence base for physicians to better plan treatments and for policy-makers to develop cost-effective interventions to increase adherence rates and reduce excess utilisation leading to resource inefficiencies.

Accordingly, the main objective of this paper is to more accurately identify and quantify changes in healthcare utilisation driven by uncontrolled diabetes. To this aim, we made

[1] Similarly, Menzin *et al*. [23] focus on a subsample of managed-care diabetic patients from Massachusetts covering a 5-year period (2002-2006) and employ logit and GLM models. They notice that diabetes-related hospitalisations were significantly higher among patients with uncontrolled diabetes.

[2] For a broader overview on the relationship between diabetes and its related costs, see the United Kingdom Prospective Diabetes Study UKPDS Outcomes Model; the Economic and Health Outcomes Model of Type 2 Diabetes Mellitus (ECHO-T2DM); the Michigan Model for Diabetes (MMD); Cardiff Diabetes Model; the School of Public Health Research (SPHR) Diabetes Prevention Model and the Modelling Integrated Care for Diabetes based on Observational data (MICADO) model [25-30]. Although they do not specifically focus on uncontrolled diabetes, these are comprehensive models capable of simulating the progression of diabetes under different scenarios, including diabetes-related complications and estimating the cost-effectiveness of specific interventions.

use of rich longitudinal data from the province of Barcelona, Spain, and measured uncontrolled diabetes using a biomarker, glycated haemoglobin (HbA1c). We focused on the effects of uncontrolled diabetes on primary and secondary care and exploited the longitudinal nature of the data by estimating panel count data models. These models accounted for unobserved heterogeneity, selection, previous utilisation and hence provide new evidence on the relationship between uncontrolled diabetes and health care use.

2. Methods

2.1 Data

We employed individual-level longitudinal data drawn from administrative records of patients from Catalonia, Spain, followed over seven consecutive years (2004-2010). More specifically, these data were drawn from 6 primary care centres and 2 hospitals in the municipality of Badalona (north-east of Barcelona), serving a population of around 104,000 individuals. Since Spain has a national health care system which provides universal coverage, data from these health care centres are also representative of the way the health system operates in the whole country. Furthermore, within this system, provision of health services is organised at regional level and free of charge at the point of delivery with the exception of pharmaceuticals which require some form of co-payment.[3]

Our data included a rich set of information about patients' use of health care resources, including our three main outcomes of interest i.e. number of GP visits, specialist care and hospital length of stay.[4] Our data also encompassed information on clinical measurements of height and weight (used to build an individual's body mass index, BMI); patient's chronic and diagnosed health conditions (classified according to the International Classification of Primary Care codes, second edition, ICPC-2); dates of hospital admission and discharge; type of healthcare professional(s) contacted; and the main reason for their visit. Moreover, the dataset included individual level socio-demographic

[3] Only individuals in employment would face a 40% co-payment for prescribed medicines, whereas pensioners would be completely exempted. Patients with chronic conditions would have a reduced co-payment of 10% and civil servants would only pay 30% of the market price regardless of their employment status.

[4] We focused on utilisation as it constitutes the largest component of diabetes-related medical costs. Furthermore, Mata-Cases *et al*. [24] using data from Catalonia report that hospital care, medications and primary care appear to be the main drivers of costs for both patients with type 2 diabetes and non-diabetics.

characteristics such as age, gender, marital status, immigration (Spanish or EU national versus non-EU national) and employment status (active vs retired), place of birth and residence and health-behaviours (tobacco and alcohol use).

Given the purpose of this study, we focused on a sub-sample of individuals with diagnosed type 2 diabetes mellitus (DM), aged 16 years or over, who had at least one contact with the aforementioned hospitals and primary health care centres between 1 January 2004 and 31 December 2010.[5] Individuals transferred or moved to other health centres and patients from other areas were excluded from our analysis. Patients with diabetes were identified via the corresponding ICPC-2 code or alternatively through a mean HbA1 level $\geq$ 6.5% ($\geq$ 48 mmol/mol) [31] based on a glycated haemoglobin (HbA1c) test reported by physicians. This test is routinely used by clinicians to diagnose and monitor diabetes and should provide an accurate measure of glucose concentration up until the previous 8 weeks [31-33].

Our main variable of interest was uncontrolled type 2 DM, which we defined using a binary variable. We assumed that patients with diabetes were not adequately controlling their condition when their within year mean HbA1c level was equal or above 7.5%. We chose this threshold as it was used by physicians in the area of Badalona during the period 2004-2010 to identify poor control among patients in our data. However, since there is no universal consensus within the medical literature about the HbA1c thresholds which identify uncontrolled diabetes, we also estimated our models using a slightly lower value of blood sugar concentration (7%) [33].[6] As in the majority of studies using administrative data, information on HbA1c levels was not available for the entire sample of patients with diabetes. In our data there might be patients with repeated measurements within a year; other patients diagnosed as diabetics via ICPC-2 codes without any actual HbA1c measurement or others missing HbA1c measurements just for selected years. Given our definition of uncontrolled DM, we restricted our sample to individuals with at least one within year mean HbA1c value. Following this criteria, we obtained a sample of 29,363 patients with type 2 DM.[7]

[5] The sample may include patients with diabetes with zero utilisation (no GP visits or hospital admissions) in some of these years. These might be patients who had some positive use only in selected years. Note that we dropped all individuals with type 1 diabetes.

[6] Results obtained using a lower threshold appeared to be very similar and are available upon request.

[7] It might be argued that excluding patients without positive within year HbA1c means could potentially bias our estimates since in our data these patients tend to present lower frequency of visits. Yet, these

2.2 Empirical approach

We focused on the effects of uncontrolled diabetes on three main outcomes: the number of GP and specialist visits and hospital length of stay. Given that these are non-negative integer outcomes and to exploit the panel element of our data, we estimated *panel* count data models that account for individual-level unobserved heterogeneity.

More specifically, we present estimates on the effects of uncontrolled diabetes on the number of GP visits obtained using negative binomial (NB) models with random effects (RE).[8] This is a flexible specification which is often used to model health care utilisation in the economics literature as it goes beyond standard Poisson models allowing for overdispersion together with unobservables [35, 36].[9]

We modelled the number of specialist visits and hospital length of stay using hurdle (two-part) models. The previous literature points out that the decision to contact a physician and the one concerning the amount of visits may be the result of two distinctive decision-making processes [37-39]. Further, these decisions might depend on both the individual and the physician, or more generally the heath care provider, and the complexity of this process may be exacerbated by repeated decisions in the presence of longitudinal data.[10] This might also have been the case in our data when we analysed specialist visits (i.e. the decision to see a specialist vs. the number of visits) and hospital length of stay (i.e. the decision to walk into a hospital vs. length of stay) for patients with type 2 diabetes. Accordingly, we employed two-part or hurdle specifications to account for these two separate decisions. In our case, the first part of the hurdle was a probit model that distinguishes between users and non-users while the second part estimated the intensity of use (conditional on positive use) through a NB2 model with RE. This approach was also motivated by the relatively high frequency of zeros (non-use) for these two outcomes. All these models exploited variations in utilisation between the years 2004-2010 and accounted for a number of individual observable characteristics, individual-level

individuals also appeared to be overall healthier than the remaining patients with diabetes with full HbA1c information and ultimately this may contribute to their lower levels of health care consumption.

[8] More specifically, we estimated the so-called negative binomial 2 (NB2), a model where the conditional variance function is quadratic in the mean [34].

[9] We have also estimated Poisson specifications. Results were similar to the ones presented here and are available upon request.

[10] In the Spanish National Health Service, GPs exert a gatekeeper role and refer patients to specialist doctors and other health professionals.

unobserved heterogeneity, years and geographical area (local health authorities) fixed effects. Our basic specification was:

$$y_{ijt} = UD_{ijt-1}\,\tau + X_{ijt}\theta + D_t + G_j + \mu_i + \varepsilon_{ijt} \quad (i=1,\ldots,N;t=1,\ldots,T;j=1,\ldots,J) \qquad (1)$$

where y_{ijt} was health care utilisation, that is alternatively the number of GP visits, specialist visits or hospital length of stay of individual *i*, in (health authority) area *j* at time *t*. UD_{ijt-1} was our main variable of interest as it defined uncontrolled diabetes via the biomarker HbA1c. Following the medical literature in our basic specification we defined uncontrolled diabetes in the presence of within year average values of HbA1c ≥7.5%. This variable was lagged one period to address endogeneity and exploit the timing of uncontrolled DM to more precisely identify the effects of uncontrolled diabetes on our measures of utilisation.[11] We also estimated alternative specifications of uncontrolled diabetes using increasing levels of HbA1c, i.e. 7.5%≤HbA1c<8.5%; 8.5%≤HbA1c<9.5; and HbA1c≥9.5%. We did this to explore the potential presence of a gradient in health care utilisation driven by the severity of an individual's condition. X_{ijt} was a vector that included socio-demographic individual-level observable variables as well as clinically assessed health conditions. These included age (a third order polynomial for age, i.e. age, age squared and cubic age, to capture non-linear age effects); labour market status (being active in the labour market contrasted against being inactive); immigration status (being a non-EU immigrant versus a Spanish or EU citizen as a baseline); marital status (living alone versus married/with a partner); health-behaviours (alcohol consumption, smoking status and objectively measured BMI); a series of diabetes-unrelated chronic health conditions (i.e. asthma; chronic obstructive pulmonary disease, COPD; dementia; psychosis; clinical depression; and cancer); as well as diabetes-related health conditions (i.e. cardiovascular disease, cerebrovascular disease, neuropathy and heart failure). All models also included time dummies D_t which accounted for time trends while G_j identified primary health authority areas (defined at geographical level) fixed effects. μ_i

[11] We also explored the presence of simultaneity in our data between uncontrolled diabetes and health care utilisation as well as the use of the lagged value of our biomarker as an instrument via a two stage least squares (2SLS) estimation strategy [40]. Tests performed by following Reed [40] suggested, as expected, the presence of statistically significant (yet quantitatively small) simultaneity as well as statistically significant serial correlation between contemporaneous and lagged measures of uncontrolled DM. 2SLS estimates performed using pooled and panel linear models as well as specifications accounting for binary endogenous regressors appeared to suggest larger effects of uncontrolled diabetes compared to non-instrumented models. Since none of these 2SLS specifications closely reflected our preferred panel count data models and implausibly larger effects, we preferred to report findings from NB2 RE specifications, which simply employed lagged values of uncontrolled diabetes among their regressors.

represented individual-level time-invariant unobserved heterogeneity and ε_{it} was the idiosyncratic error term.

Importantly, we also examined whether and to what extent the effects of poor glycaemic control on utilisation were mediated by the number of patients' *diabetes-related* health conditions. To purge our estimates from such influences, we run our models on a sample of "healthy users", i.e. patients with diabetes without the aforementioned diabetes-related conditions. This identified both the relative contribution of diabetes complications and the "pure" or net effect of UD on health care utilisation.

Conditionally correlated random effects

To allow for correlation between observables and individual unobserved heterogeneity, we parameterised the individual effect μ_i as a function of the within individual means of the exogenous regressors [41-43].[12] This simply translated into including among our regressors the within mean of the time-varying exogenous (continuous) variables, i.e. $\overline{X_i}$. In our case, this included the average over the sample period of the variables defining age, BMI and the annual average value of the biomarker.

Robustness checks

In order to separately account for individual-level unobserved heterogeneity and the effects of previous period (*t*-1) health care utilisation on current consumption, we also estimated dynamic NB2 models with RE. This approach extended the previous conditionally correlated random effects model already augmented by a Mundlak correction by including among our regressors values of the dependent variables lagged one period, Y_{ijt-1}, as well as initial conditions in the parameterisation of the individual effect [44]. That is, we also included among our regressors initial (wave 1) values of our dependent variable, i.e. $Y_{i,j,0}$. Note that these estimates were performed on a balanced panel sample where patients observed during seven consecutive years (2004-2010) to

[12] For a more recent discussion on the use of the conditionally correlated (CCR) random effects models applied to count data models, including negative binomial models, see [43]. Note that since the random effect in negative binomial models applies to the distribution of the dispersion parameter, in this case, this Mundlak-type correction would only concern the variance of the model.

allow accounting for initial conditions and values of the lagged dependent variables. As such, these dynamic models were estimated on a smaller sample of individuals.

Finally, since the medical literature often finds higher percentages of poor control and non-adherence among males and this may have an impact on subsequent health care utilisation, we estimated separate models by gender.

3. Results

Descriptive statistics

The prevalence of DM in the full dataset of 104,000 patients (including individuals with and without diabetes) increased from 6.4% in 2004 to 9.3% in 2010. As expected, the prevalence was substantially higher for those aged 65 years or over (21.1% in 2004 versus 25.3% in 2010). Our sample of patients diagnosed with type 2 diabetes, defined using both physicians' disease classification codes and blood tests with at least one HbA1c measurement, reduced to 29,363 observations over the period 2004-2010.

(Table 1 around here)

Table 1 reports descriptive statistics for both the sample of all patients with diabetes and the one that only included individuals with uncontrolled diabetes (HbA1c>=7.5%). Both samples were broken down by gender. Within our sample of individuals with diabetes, the mean number of GP visits per year were 15.46 (men) and 18.70 (women), while these reduced to 4.51 (men) and 4.83 (women) in the case of specialist visits and 0.58 (men) and 0.72 (women) for hospital length of stay. We also noted that this sample included mainly older individuals with a mean age of 66.9 years and their mean HbA1c value was 7%. Importantly, our dataset showed that a significant number of individuals are not controlling adequately their condition despite the well-known potentially life-threatening health consequences caused by the diabetes-related complications: uncontrolled diabetes (HbA1c levels $\geq$ 7.5%) is 30.53% for men and 27.59% for women. For patients with uncontrolled diabetes health care consumption was higher, especially their primary care use: GP visits increased to 16.32 (men) and 20.18 (women), specialist visits to 4.68 (men) and 5.15 (women), while hospital length of stay grew only marginally to 0.63 (men) and 0.77 (women). Overall, women with and without uncontrolled diabetes appeared to

systematically consume more health care compared to men. Patients of both genders with uncontrolled diabetes presented average HbA1c levels of 8.7%.[13]

Our three main outcome variables appeared to present a highly right-skewed distribution with a long tail indicating a very large consumption of resources by a small fraction of patients with diabetes.[14] Another relevant feature of the dataset was the existence of zero visits during the years 2004-2010. This was negligible for GP visits (1.15%) but increased to 20% for specialist visits and 89% for hospital length of stay.[15] Hence, the existence of a zero mass problem in the data appeared to be of concern only in case of specialist visits and hospital length of stay. This ultimately justified our decision to examine such outcomes through a hurdle approach.

Main results

We present separate estimates by gender on an unbalanced panel. All tables report average marginal effects.

(Table 2 around here)

The first two columns of Table 2 show the estimates of our variable of interest, the lagged value of the biomarker detecting UD, on the number of GP visits for men and women.[16] We found that for men, the effect of UD was positive and statistically significant with a quantitative effect of 0.48 GP visits, i.e. UD increased the average number of GP visits by around half a visit per year. This translated into an increase of almost 3% of the annual GP visits of men driven by poor glycaemic control. Although the effect of UD on GP visits for women also appeared to be positive, it was not statistically significant.

[13] Men with poor glycaemic control were slightly younger and more likely to be immigrants; in the labour market; to consume alcohol and tobacco smoke; and had a higher BMI than men who better control their condition. Men with uncontrolled diabetes presented higher percentages of depression, heart and cerebrovascular diseases. Women who did not control adequately their blood sugar levels appeared to be also somewhat younger; more likely to be in the labour market; and also showed increased percentages of alcohol and tobacco consumption and a higher BMI. This category of women also presented a higher incidence of depression, heart and cerebrovascular diseases. See Table A in the Appendix for further descriptive statistics broken down by time periods (2004, 2007, and 2010) for the main variables of interest.

[14] For instance, the variance of GP visits was 9 times greater than its mean. The same applies to specialist visits (6.5 times) and hospital stays (18 times).

[15] Once we conditioned on positive counts, the average number of specialist visits was 5.87 per year and the average length of stay was 5.19 days per year.

[16] Note that we lost some observations (i.e. those of the initial year, 2004) when using the one-period lagged uncontrolled DM regressor.

In columns (3) and (4) we report the effects of UD on specialist visits using a hurdle RE NB2 model. Again, estimates differed by gender as the quantitative effects were positive but only statistically significant for men. More specifically, we found that among male individuals with diabetes, the effect of having HbA1c≥7.5% in the previous period led to an increase of specialist visits of 0.25 (at 5% significance level) conditional to positive visits. This corresponded to a percentage increase of 5.3 in the number of annual specialist visits. Finally, the last two columns of Table 2 present the effects of UD on hospital length of stay using the same hurdle approach. These models presented a reduced number of observations as a consequence of the larger number of zeros in the data for these outcomes. Interestingly, we found again marked gender-related differences since UD was solely associated with an increase in the number of days in hospital among male patients. Specifically, the results indicate that one-year lagged uncontrolled DM led to a statistically significant increase of 0.78 additional days in hospital, conditional to positive stays (i.e. admission into an hospital). This corresponded to an increase of 15.1% in the annual length of stay.[17]

(Table 3 around here)

Table 3 presents estimates from RE NB2 as well as hurdle RE NB2 for a sub-sample of healthy-users. Interestingly, these estimates appeared to substantially confirm the ones presented in Table 2. Among men, we found statistically significant effects of UD on both GP and specialist visits. These effects were quantitatively larger if compared to the results obtained from the more general sample of individuals with diabetes in Table 2 with increases of 0.56 (3.4%) and 0.28 (6.1%) of annual GP and specialist visits, respectively. This implied that for men, increases in health care consumption may be mainly driven by UD and not necessarily its related complications. We also found a weakly significant effect of UD on hospital length of stay, conditional on admission. As for the previous models in Table 2, we did not identify any effects for women that were statistically different from zero.

(Table 4 around here)

[17] We have also estimated the same models on a pooled sample of men and women and found slightly lower quantitative effects for men. This is not surprising as this should be a direct result of the sample pooling and the differences in the effects between genders. These findings are available upon request.

Conversely, since reduced glycaemic control increases the risk of diabetes-related complications and this may in turn influence health care use, Table 4 examines potential non-linearities in the effects of UD by defining increasing levels of this condition: low (7.5%≤HbA1c<8.5%); moderate (8.5%≤HbA1c<9.5) and high (HbA1c>=9.5%) UD. Our estimates showed that the raise in GP visits among men with diabetes were mainly concentrated among those with low and moderate levels of UD with increases of 0.4 and nearly 0.7 GP visits respectively. Among men, we also found statistically significant effects of low and high UD on specialist visits with the largest effect observed for individuals with the poorest control (high UD). Our estimates showed that having low and high levels of UD in the previous year led to annual increases of 0.26 and 0.46 specialist visits respectively, conditional on having a specialist visit. These corresponded to average increases of around 4.4% and 7.8%. Men also presented a positive, large and highly statistically significant effect of low UD and only a weakly significant effect (although also large) of high UD on hospital length of stay. The effect of low UD on utilisation implied an additional 1.1 days in hospital, representing a mean annual increase in the length of stay, conditional on having a hospital admission, of 21%. It should be noted that for women, none of the effects related to UD were statistically significant.

(Table 5 around here)

Table 5 provides results from *dynamic* RE NB2 and hurdle models on a balanced sample. Statistically significant persistence of health care consumption appeared to be present for both genders and for both GP and specialist visits. However, this did not appear to play a major role among the determinants of hospital length of stay for men and also presented a negative effect on consumption for women.[18]

[18] This is expected and might be related to the different nature and frequency of health care consumption identified by the three outcomes considered: hospital admission is a much rarer event if compared to GP and specialist visits. Interestingly, in this case we found statistically significant effects of UD on GP visits among women and only on specialist visits amongst men, although only significant at 10%. In any case, we should be cautious in the interpretation of the effects of past heath care consumption on current use because these might be also partly driven by previous (further back in time) levels of UD. Also, given the substantial drop in the number of observations when using a balanced sample, we should be careful in comparing these estimates with our main results. Furthermore, we also run the same dynamic specifications on an unbalanced sample and found similar effects to those reported in Table 2. These findings are available upon request.

4. Discussion and Conclusion

Evidence on the effects of uncontrolled diabetes on health care utilisation is sparse, particularly among European countries. Results from previous US medical studies are mixed, often based on limited data and standard linear models as well as self-reported information that may be plagued by reporting bias. We employed detailed longitudinal data on a large population of adult individuals with diabetes, and used a clinically assessed biomarker together with panel count data models to estimate the effects of uncontrolled diabetes on GP and specialist visits as well as hospital length of stay.

Our administrative data drawn from the municipality of Badalona presented estimated mean HbA1c value of 7% close to the figure for the whole region of Catalonia [45] and diabetes prevalence rates similar to those at national level in Spain for the same years [8, 46]. Consistent with evidence found in other developed countries, our analysis confirmed that a large fraction of patients with diabetes (between 27 to 30%) appeared to poorly control their condition. This led to an excess use of GP (3%), specialist visits (5.3%) and increases in the annual hospital length of stay (15%) for men. The latter figure may imply that, although hospitalisation is a relatively rare event for patients with diabetes, uncontrolled diabetes increases the length of hospital stay, therefore imposing additional costs on the health system. Importantly, models for male "healthy-users" (which exclude diabetes-related complications) presented quantitatively larger effects of uncontrolled diabetes on health care utilisation in both primary and secondary care. This confirmed that among men in our sample, variations in utilisation were primarily influenced by uncontrolled diabetes.

Our data indicated that although women with diagnosed type 2 DM appeared to consistently consume more health care compared to men, as confirmed by the previous medical literature [47, 48], we found that their higher consumption did not seem to be influenced by uncontrolled diabetes. As such, our findings suggested the presence of gender-related heterogeneity in health care consumption for similar levels of uncontrolled DM. However, further research and data with a wider set of socioeconomic variables might be needed to more precisely establish the reasons behind this difference.

Furthermore, although we did not identify clear-cut gradients in the effects of different levels of uncontrolled diabetes on utilisation, we found heterogeneous effects for men. For instance, we found that the increase in GP visits among men was concentrated among

those with low and moderate levels of uncontrolled diabetes. This could suggest that individuals with high levels of uncontrolled DM might be less aware of their condition or its consequences and this may in turn influence their decision not to follow up with appropriate health treatments and visits. In addition, we found an increase in the hospital length of stay among male patients with low levels of uncontrolled diabetes. Yet, the annual increase in specialist visits, conditional to a positive number of visits, concerned patients having both low and high levels of inadequate control. Given the need to a GP referral to access specialist care, this finding should be interpreted somehow differently and, in any case, does not solely depend on a patient's behaviour.

As usual, this study may have some limitations. First, our data did not include some potentially relevant supply side factors such as physicians' density that might affect the frequency of visits [36]. However, it can be argued that some of these (time-invariant) factors might be absorbed and proxied by our local health area fixed effects. Secondly, we were not able to include information on the duration of diabetes. This is mainly because dates of first diagnosis were not systematically available for all individuals in our data. In addition, we excluded from our analysis individuals transferred or moved to other health care centres. Yet, since movements across centres are relatively rare events, this exclusion is unlikely to have a major impact on our main results. Finally, it should be kept in mind that whereas our econometric methods were capable of estimating the statistical association between uncontrolled diabetes and health care utilisation over time, they did not identify causal effects. They improved on previous analyses by accounting for important issues in modelling the uncontrolled DM-health care use relationship such as selection, unobserved heterogeneity and dynamics.

Overall, our results suggested the presence of marked gender-related differences as well as potential heterogeneous behaviours in health care consumption depending on different levels of uncontrolled diabetes among men. These findings may have important implications for physicians and policy makers potentially suggesting the need for different diabetes management plans depending on gender and levels of glycaemic control. Since diabetes is the most widespread chronic condition worldwide, improving blood sugar control would not just be beneficial to patients' wellbeing but would also substantially reduce excess health care utilisation and free up resources that could be employed elsewhere.

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Table 1: Descriptive statistics: Years 2004-2010

	Diabetics				Diabetics with HbA1c ≥ 7.5%			
	Men	N	Women	N	Men	N	Women	N
GP Visits	15.46	14515	18.70	14848	16.32	4432	20.18	4096
Specialist visits	4.51	14515	4.83	14848	4.68	4432	5.15	4096
Hospital stays	0.58	14515	0.72	14848	0.63	4432	0.77	4096
HbA1c level	7.08	14515	7.00	14848	8.69	4432	8.68	4096
Uncontrolled DM *	30.53	14515	27.59	14848	-	4432	-	4096
Age	65.28	14515	68.54	14848	63.54	4432	67.66	4096
Immigrant	1.41	14515	1.68	14848	2.73	4432	2.37	4096
Active	28.46	14493	17.17	14802	34.46	4422	18.45	4075
Living alone	90.83	14515	83.99	14848	90.55	4432	83.76	4096
Alcohol	5.28	14515	0.63	14848	5.80	4432	0.71	4096
Tobacco	29.82	14515	6.97	14848	33.73	4432	8.64	4096
BMI	29.26	14319	31.23	14619	29.31	4352	31.73	4017
Asthma	1.80	14515	7.00	14848	1.65	4432	6.81	4096
CPOD	9.71	14515	2.23	14848	9.05	4432	2.54	4096
Dementia	1.30	14515	2.69	14848	1.65	4432	2.91	4096
Psychosis	1.03	14515	1.04	14848	1.08	4432	0.66	4096
Depression	9.39	14515	25.74	14848	10.24	4432	28.32	4096
Malignant neoplasm	7.22	14515	6.81	14848	5.75	4432	6.91	4096
Hypertension	55.53	14515	70.35	14848	49.99	4432	68.04	4096
Dyslipidemia	53.75	14515	57.89	14848	50.10	4432	57.84	4096
Heart Diseases	16.18	14515	8.53	14848	17.89	4432	9.38	4096
Cerebrovasc. D.	5.95	14515	1.85	14848	6.34	4432	3.03	4096
Heart failure	12.18	14515	12.72	14848	11.17	4432	12.06	4096
Neuropathy	0.87	14515	1.27	14848	0.81	4432	1.20	4096

* Uncontrolled DM is defined for HbA1c values ≥ 7.5%.

Table 2: The effects of uncontrolled diabetes on health care utilisation

			Hurdle Models			
	(1) Men GP visits	(2) Women GP visits	(3) Men Specialist	(4) Women Specialist	(5) Men Hosp. Stays	(6) Women Hosp. Stays
UD (t-1)	0.483**	0.241	0.249**	0.155	0.777**	0.111
	(0.192)	(0.230)	(0.119)	(0.127)	(0.316)	(0.369)
N	11763	12147	9235	9924	1394	1574

UD (t-1) stands for uncontrolled type 2 diabetes as measured by HbA1c>=7.5% lagged one period. Table displays average marginal effects (AME) for static RE NB2 model augmented by a Mundlak specification (unbalanced sample). All models control for the full set of covariates. Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 3: The effects of uncontrolled diabetes on health care utilisation – healthy users

			Hurdle Models			
	(1) Men GP visits	(2) Women GP visits	(3) Men Specialist	(4) Women Specialist	(5) Men Hosp. Stays	(6) Women Hosp. Stays
UD (t-1)	0.560**	0.097	0.286**	0.216	0.718*	0.066
	(0.219)	(0.248)	(0.139)	(0.141)	(0.368)	(0.423)
N	8179	9466	6180	7633	832	1125

UD (t-1) stands for uncontrolled type 2 diabetes as measured by HbA1c>=7.5% lagged one period. Table displays average marginal effects (AME) for static RE NB2 model augmented by a Mundlak specification (unbalanced sample). All models control for the full set of covariates. Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 4: The effects of uncontrolled diabetes on health care utilisation - HbA1c levels

			Hurdle Models			
	(1) Men GP visits	(2) Women GP visits	(3) Men Specialist	(4) Women Specialist	(5) Men Hosp. Stays	(6) Women Hosp. Stays
UD1 [7.5, <8.5%] (t-1)	0.412**	0.310	0.261**	0.122	1.099***	0.058
	(0.210)	(0.248)	(0.130)	(0.137)	(0.353)	(0.401)
UD2 [8.5, <9.5%] (t-1)	0.669**	0.343	0.125	0.245	-0.014	0.393
	(0.303)	(0.360)	(0.187)	(0.195)	(0.468)	(0.524)
UD3 [>=9.5%] (t-1)	0.582	-0.504	0.459**	0.206	1.027*	-0.335
	(0.384)	(0.449)	(0.232)	(0.244)	(0.553)	(0.680)
N	11763	12147	9235	9924	1394	1574

UD1,2,3 (t-1) stands for the uncontrolled type 2 diabetes defined within the corresponding HbA1c interval lagged one period. All models present average marginal effects (AME) for static RE NB2 models augmented by a Mundlak specification (unbalanced panel). All models control for the full set of covariates. Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 5: The effects of uncontrolled diabetes on health care utilisation – dynamic models

			Hurdle Models			
	(1) Men GP visits	(2) Women GP visits	(3) Men Specialist	(4) Women Specialist	(5) Men Hosp. Stays	(6) Women Hosp. Stays
UD (t-1)	0.431	0.871***	0.380*	0.001	-0.131	-0.523
	(0.292)	(0.310)	(0.198)	(0.183)	(0.478)	(0.495)
GP visits (t-1)	0.186***	0.106***	-	-	-	-
	(0.0137)	(0.0106)				
Spec. visits (t-1)	-	-	0.118***	0.131***	-	-
			(0.013)	(0.012)		
Hosp. stays (t-1)	-	-	-	-	0.056*	-0.069**
					(0.031)	(0.032)
N	3738	4704	3122	4094	468	602

UD (t-1) stands for uncontrolled type 2 diabetes as measured by HbA1c>=7.5% lagged one period; GP visits (t-1) stands for the number of GP visits lagged one period; Spec. visits (t-1) for number of specialist visits lagged one period; Hosp. Stays (t-1) for the length of hospital stays lagged one period. Table displays average marginal effects (AME) for dynamic RE NB2 model augmented by initial conditions and a Mundlak specification (balanced sample). All models control for the full set of covariates. Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Appendix

Table A: Descriptive statistics for selected years

A) Individuals with diabetes

	Men			Women		
	2004	2007	2010	2004	2007	2010
GP Visits	14.92	15.53	15.72	17.87	18.80	19.02
Specialist visits	3.35	4.27	5.09	3.74	4.77	5.31
Hospital stays	0.48	0.60	0.68	0.61	0.83	0.79
HbA1c level	7.14	6.91	7.34	7.15	6.78	7.29
Uncontrolled DM *	33.00	26.93	35.79	30.74	23.26	32.30

* Uncontrolled DM is defined for HbA1c values ≥ 7.5%.

B) Individuals with uncontrolled diabetes (HbA1c ≥ 7.5%)

	Men			Women		
	2004	2007	2010	2004	2007	2010
GP Visits	15.96	16.07	16.65	18.36	21.05	20.41
Specialist visits	3.95	4.14	5.20	4.10	5.23	5.44
Hospital stays	0.68	0.38	0.79	0.58	1.25	0.83
HbA1c level	8.61	8.76	8.64	8.70	8.65	8.68