Thesis submitted for the degree of Doctor of Philosophy (PhD)

The Economics of Diabetes in Middle-Income-Countries

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Abstract

This thesis focuses on the economic analysis of type 2 diabetes in middle-income countries (MICs). Given its rising prevalence, in-depth country specific analysis is key for understanding the economic consequences of T2D in MICs. I analyse the economic burden of type 2 diabetes in terms of labour market consequences, taking into account the heterogeneity of the diabetes population, for both Mexico and China. For China I further investigate the effects of a diabetes diagnosis on health behaviours.

The thesis consists of four studies with the unifying theme of improving our understanding of the causal relationship between diabetes and economic outcomes. Study (1) provides an updated overview, critically assesses and identifies gaps in the current literature on the economic costs of T2D using a systematic review approach; study (2) investigates the effects of self-reported diabetes on employment probabilities in Mexico, using cross-sectional data and making use of a commonly used instrumental variable (IV) approach; study (3) revisits and extends on these results via the use of panel data and fixed effects (FE), also considering a broader range of outcomes, including wages and working hours. Further, it makes use of cross-sectional biomarker data that allow for the investigation of measurement error in self-reported diabetes. Study (4) investigates the effect of a diabetes diagnosis on employment as well as health behaviours in China, using longitudinal data and applying two distinct identification strategies: FE and marginal structural model (MSM) estimation.

The findings of the first paper document a considerable increase in studies on the economic costs of diabetes in MICs. It also illustrates that most of the evidence is based on cost-of-illness studies and the literature on adverse labour market effects of diabetes in MICs is scarce. The thesis fills part of this void and shows that self-reported diabetes has a considerable impact on employment probabilities of people living in Mexico and China. The findings are robust to the application of different estimation strategies. No consistent evidence of an adverse effect of diabetes on wages or working hours is found. The findings for Mexico indicate that it is the poor and less protected as well as women that are most negatively affected by the disease. Taking into account those unaware of the disease, the adverse effect of diabetes is reduced because undiagnosed diabetes itself does not show an adverse association with any labour market outcome. This suggests that the undiagnosed population is distinctly different from the diagnosed population, likely due to differences in health information and health status. With regards to the effect of a diabetes diagnosis on health behaviours, the results from China suggest that a diagnosis leads to moderate reductions in body mass index (BMI), waist circumference, alcohol and caloric consumption. Perhaps surprisingly, especially men appear to be able to lose weight

and reduce their caloric consumption. Not accounting for unobserved heterogeneity leads to a change in the coefficient sign for the effect of a diagnosis on body mass index (BMI) and waist circumference, while the differences in estimates are less pronounced for other outcomes.

The thesis identifies a considerable economic burden of diabetes in MICs. Efforts to reduce this burden should consider inequities in the economic burden.

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Abbreviations

ATE average treatment effect

BMI body mass index

CHNS China Health and Nutrition Survey

CHARLS The China Health and Retirement Longitudinal Study

COI cost-of-illness

FE fixed effects

GDP gross-domestic-product

HbA1c glycated hemoglobin

HIC high-income country

ICD International Statistical Classification of Diseases and Related Health Problems

IDF International Diabetes Federation

IV instrumental variable

LATE local average treatment effect

LIC low-income country

LMIC low- and middle-income country

LPM linear probability model

MSM marginal structural model

MIC middle-income country

MxFLS Mexican Family Life Survey

NCD non-communicable disease

OLS ordinary least squares

OOP out-of-pocket

PPP purchasing-power-parity

PRISMA Preferred Reporting Items for Systematic Reviews and Meta-Analyses

UK United Kingdom

WHO World Health Organization

WTP willingness to pay

Publications and statement of authorship

Publications arising from this thesis

Seuring, T., Archangelidi, O., and Suhrcke, M. (2015). "The Economic Costs of Type 2 Diabetes: A Global Systematic Review." *PharmacoEconomics* 33 (8), 811–831.

This publication can be found at: `http://link.springer.com/article/10.1007%2Fs40273-015-0268-9`

Seuring, T., Goryakin, Y., and Suhrcke, M. (2015). "The impact of diabetes on employment in Mexico." *Economics & Human Biology* 18, 85–100.

This publication can be found at: `http://www.sciencedirect.com/science/article/pii/S1570677X15000349`

Statement of jointly authored publications

The research reported is my own original work which was carried out in collaboration with others as follows:

Chapter 1: Written by Till Seuring.

Chapter 2: Till Seuring was the lead author of a paper published as:

Seuring, T., Archangelidi, O., and Suhrcke, M. (2015). "The Economic Costs of Type 2 Diabetes: A Global Systematic Review." *PharmacoEconomics* 33 (8), 811–831.

Till Seuring, Marc Suhrcke and Olga Archangelidi designed the study. The search strategy was designed and executed by Till Seuring. Till Seuring and Olga Archangelidi screened the initial results and extracted the data from the primary studies. Till Seuring drafted the original manuscript which was critically reviewed by Olga Archangelidi and Marc Suhrcke.

Chapter 3: Till Seuring was the lead author of a paper published as:

Seuring, T., Goryakin, Y., and Suhrcke, M. (2015). "The impact of diabetes on employment in Mexico." *Economics & Human Biology* 18, 85–100.

Till Seuring, Yevgeniy Goryakin and Marc Suhrcke designed the study. Till Seuring analysed the data. Till Seuring drafted the original manuscript which was critically reviewed by Yevgeniy Goryakin and Marc Suhrcke.

Chapter 4: Till Seuring, Pieter Serneels and Marc Suhrcke designed the study. Till Seuring analysed the data. Till Seuring drafted the original manuscript which was critically reviewed by Pieter Serneels and Marc Suhrcke.

Chapter 5: Till Seuring and Max Bachmann designed the study. Till Seuring analysed the data. Till Seuring drafted the original manuscript which was critically reviewed by Max Bachmann.

Chapter 6: Written by Till Seuring.

1 General Introduction

1.1 Background to the thesis

Diabetes, and especially type 2 diabetes, has seen an unprecedented rise in prevalence globally and especially in low- and middle-income countries (LMICs), where rates reached and often surpassed those of high-income countries (HICs) such as the USA, UK or Germany (Hu, 2011; NCD Risk Factor Collaboration, 2016). Today, of the over 400 million people with diabetes, over two-thirds live in LMICs (International Diabetes Federation, 2014) and in particular in China, India, Brazil, Indonesia, Pakistan, Russia, Egypt and Mexico (NCD Risk Factor Collaboration, 2016). In 2015 diabetes has been responsible for over 5 million death and people with diabetes are estimated to die 6 years earlier due to the disease and increasingly before the age of 60 (International Diabetes Federation, 2015; Seshasai et al., 2011). This increase is due to a shift in age structure towards older populations and is further spurred by rapid changes in levels of physical activity, in nutrition and other lifestyle related factors (Hu, 2011; NCD Risk Factor Collaboration, 2016).

In LMICs the rise of non-communicable diseases (NCDs) has in many cases led to a double disease burden, where health systems have to deal with high rates of infectious as well as non-communicable diseases (Jamison et al., 2013). Given the scarce resources in these countries (Mills, 2014), the increasing numbers of diabetes cases and people at risk of the disease are putting an additional burden on these systems (Chan and Luk, 2016; Wareham and Herman, 2016). However, despite the epidemic proportions diabetes has reached in LMICs, research on its economic consequences has remained sparse for these countries and mostly limited to HICs. More research is needed to identify how diabetes is affecting individuals in LMICs and what are the groups most adversely affected. This will not only help to raise awareness of policy makers but also of the potential inequities in disease burden, and help to design strategies to reduce these.

1.1.1 Types of diabetes

Diabetes is a term used to describe various conditions characterised by elevated blood glucose levels. These either occur because the pancreas is not able to produce sufficient insulin or due to insulin resistance, where the body is not able to use the produced insulin effectively (World Health Organization, 2016). The different conditions themselves have distinct origins, especially the two most common types called type 1 diabetes and type 2 diabetes.

- **Type 1 diabetes** is an autoimmune disease with an important genetic component and whose triggers still remain largely elusive. It emerges when the insulin producing

cells on the pancreas are attacked and destroyed by the immune system and insulin has to be provided exogenously. About 10% of all global diabetes cases are type 1 diabetes and it is particularly prevalent in Northern European countries such as Finland, though generally exhibits much geographic variation. Its onset is mainly during the first 30 years of life. Symptoms tend to appear rather quickly and can be quite severe leading to a relatively rapid diagnosis or death, if insulin is not given or available. People with type 1 diabetes will need to inject insulin to control their blood glucose levels for their entire life following diagnosis (Tuomilehto, 2013).

- **Type 2 diabetes** results from the body's ineffective use of insulin and accounts for about 90% of all diabetes cases (World Health Organization, 2016). Albeit there is a considerable genetic component to the development of type 2 diabetes, there are many known risk factors that favour the development of type 2 diabetes, such as overweight and obesity, unhealthy diet, physical inactivity and smoking, among others (American Diabetes Association, 2014; World Health Organization, 2016). Interestingly, the risk to develop type 2 diabetes varies also by ethnicity, with South-East Asian populations developing diabetes at lower body mass index (BMI) levels than populations of European decent (Ramachandran, Wan Ma, et al., 2010). Type 2 diabetes often remains undetected for several years due to its more gradual development compared with type 1 diabetes (American Diabetes Association, 2014). Therefore, even in HICs and especially in LMICs, a proportion of at least 1/4 of the type 2 diabetes population is unaware of the condition (Beagley et al., 2014).

The onset of type 2 diabetes also appears to be increasingly earlier in life. This has been observed mainly in ethnic minorities in HIC, such as Mexicans and Asians, while data is limited for LMIC (Fazeli Farsani et al., 2013). Also the increasing numbers of obesity in child- and early adulthood are leading to the earlier onset of type 2 diabetes (Chen et al., 2012). Hence, type 2 diabetes increasingly affects people in the middle of their productive lifespan, extending the time they have to live with the disease and the probability of developing debilitating complications.

1.1.2 Diabetes complications

The most common complication for all types of diabetes, and often already present at diagnosis, is retinopathy (35% at diagnosis), being responsible for 2.6% of blindness globally. Further, up to 50% of cases of end stage renal disease are a direct result of diabetes, especially in countries where access to dialysis is restricted. People with diabetes also have a 2–3 times higher risk to experience cardiovascular disease compared to people without

diabetes. A further complication is amputation of lower limps due to impaired wound healing, being 10–20 higher for people with diabetes (World Health Organization, 2016). There is also a growing literature suggesting a—potentially bidirectional—relationship between diabetes and depression (Dooren et al., 2013; Nouwen, Winkley, et al., 2010; Roy and Lloyd, 2012). In addition, there seems to be a link between diabetes and the development of certain types of cancer, (Nead et al., 2015; Tsilidis et al., 2015), as well as an array of other of other infectious diseases, intentional self-harm and degenerative disorders diseases (Seshasai et al., 2011).

1.1.3 Diabetes prevention

Diabetes complications are a result of consistently elevated blood glucose levels. Hence many complications could be prevented if recommended treatment goals were achieved. However, limited resources and access to healthcare make it difficult to properly treat type 2 diabetes in LMICs (Villalpando et al., 2010), and even in HICs a large part of the diabetes population does not achieve treatment goals to prevent complications (Diabetes UK, 2012).

Primary prevention of diabetes or at least a delayed onset are further major goals of diabetes research and could be achieved by reducing the prevalence of the known risk factors such as obesity, an unhealthy diet, smoking and sedentary behaviour (World Health Organization, 2016). However, so far most approaches to prevent type 2 diabetes have not had the desired effect and may not always be realistic in very resource constrained settings (White, 2016). In particular efforts to reduce the biggest type 2 diabetes risk factors of obesity and overweight have been unsuccessful (Roberto et al., 2015).

1.1.4 The need for further economic research on diabetes

To design effective interventions and make qualified decisions about the use of primary and secondary prevention strategies of diabetes, researchers and policy makers need information about the current burden of diabetes, both in terms of health and economically. Information on all aspects of economic costs and the quality of the estimates has to be available optimally. In particular, in LMICs equity issues are likely to be of importance if the burden of diabetes varies by socioeconomic groups, potentially widening existing socioeconomic inequities. However, at the start of this thesis, little was known about the economic impact of diabetes in developing countries. There had never been a comprehensive systematic review of studies assessing the costs related to diabetes, both in terms of direct and indirect costs. Only one (non-systematic) review existed (Ettaro et al., 2004),

including cost-of-illness (COI) studies until the year 2001. Completely absent in this review were studies from LMICs. Further, considerable time had passed since this review and the methodological quality of research published since then needed to be assessed and areas of future research had to be identified. Also missing was a comprehensive overview of studies using quantitative methods to estimate the impact of diabetes on labour market outcomes, such as employment and wages.

These gaps in evidence are addressed in Chapter 2: *The Economic Costs of Type 2 Diabetes: A Global Systematic Review*. The review had several goals. One was to provide a first comprehensive global picture of the economic burden of type 2 diabetes, including both COI studies and studies on the labour market effects of diabetes. It was also expected to find evidence on the economic costs of diabetes in developing countries. Together, the aim was to provide information on the economic costs of diabetes for as many countries as possible. Another goal was the identification of areas, both in terms of methodology and topic, where evidence was lacking and/or current methodologies could be improved upon. This was supposed to guide the subsequent chapters of this thesis as well as other researchers interested in researching the economics of diabetes.

1.1.5 The labour market impact of type 2 diabetes

The review identified the labour market impact of diabetes in LMICs as a topic that had not received much attention. Apart from the lack of evidence from developing countries, there was also scope for methodological improvements compared to the existing HIC evidence. Further, information on the effect on sub-populations, i.e. comparisons between rich and poor and the formal and informal labour market were non-existent.

However, in order to carry out such an analysis, appropriate data needed to be identified. To this end a search for suitable household data from LMICs was carried out, using general search engines as well as specialized engines such as the World Bank Central Microdata Catalog `http://microdata.worldbank.org/`, the Demographic and Health Survey Database `http://dhsprogram.com/data/`,the Global Health Data Exchange Database `http://ghdx.healthdata.org/`, and the International Household Survey Network Catalog `http://catalog.ihsn.org/index.php/catalog`. The aim was to identify datasets containing information on self-reported or measured diabetes. Specialized websites providing an overview on household survey data in developing countries were also scoped to identify relevant data (such as `http://ipl.econ.duke.edu/dthomas/dev_data/index.html` and `https://sites.google.com/site/medevecon/development-economics/devecondata/micro` for household survey from developing countries, and an overview on data sets containing biomarker information provided by The Biomarker Network at `http://gero.usc.`

edu/CBPH/network/resources/studies/). An overview of the identified surveys is provided in Table 6.1 in the appendix.

Given the availability of data and the extend of diabetes in middle-income countries (MICs) compared to low-income countries (LICs), a decision was made to focus on MICs for the remainder of the thesis. In particular, Mexico was chosen to be one of the countries to investigate. The main reason to chose Mexico was the availability of suitable data provided by the Mexican Family Life Survey (MxFLS). It allowed for the investigation of the impact of diabetes on labour market outcomes by providing information on important covariates, including family background and diabetes itself, not available in other surveys. Further, Mexico is a country with particularly high obesity and diabetes rates making it an interesting case to study. Chapter 3 therefore investigated the causal effect of diabetes on employment probabilities in Mexico, forming research question two.

1.1.6 Identification of the causal effect of diabetes on labour market outcomes

As is eluded to in Chapter 3, identifying a causal relationship of diabetes with labour market outcomes is being complicated by the possibility of unobserved time-variant and -invariant heterogeneity. In Chapter 3, an instrumental variable (IV) approach was used, though as with all IVs, it was not possible to test if the used instrument satisfied all underlying assumptions, leaving the possibility of biased estimates. Several other strategies potentially exist to identify the true effect of diabetes on labour market outcomes using quasi-experimental econometric approaches (Antonakis et al., 2012). For example, a natural experiment—that would affect people's diabetes risk while at the same time have no direct effect on labour market outcomes such as employment probabilities or wages—may be used. However, exogenously introduced variation can be difficult to identify and may only provide information for a very—often geographically or economically—selected population that has been exposed to this natural experiment. Another strategy to improve inference is the use of panel data and in particular the fixed effects (FE) model, which does not depend on exogenously introduced variation. Relying only on within-individual variation the strategy allows for the elimination of all time-invariant factors that may affect diabetes and labour market outcomes simultaneously. This is likely of importance in the case of diabetes and economic outcomes, where the use of IVs has been motivated by the possibility that unobserved character trades—generally thought to be stable over time—such as motivation as well as early life experiences may be confounding the relationships (Seuring et al., 2015).

Therefore, part one of Chapter 4, used a recent addition of data to the MxFLS to apply a FE estimation approach, testing if the effects of diabetes on employment probabilities found in 3 remain using this alternative identification strategy. Further, it extended the number of investigated outcomes to three, adding wages and working hours.

1.1.7 Do the effects of diabetes change over time?

Diabetes is a lifelong disease whose debilitating complications generally appear after several years of elevated blood glucose levels (World Health Organization, 2016). So far, little is known about the exact time after diagnosis diabetes starts exhibiting potential adverse effects on labour market outcomes. However, in order to design strategies to mitigate the economic impact of diabetes this would be important to know as it would help in finding the most efficient point in time to intervene. If effects occur immediately after diagnosis, it may be because severe complications are already present at the point of diagnosis, leaving little possibilities to prevent the economic burden. This would suggest that much could be prevented by an earlier diagnosis and appropriate treatment and lifestyle changes. It could further indicate a potential effect of the diagnosis itself, for example on psychological health, causing reductions in employment probabilities or wages. If effects appear only years after the diagnosis, this could suggest that severe diabetes complications that have developed due to sub-optimal blood glucose management are causing reductions in productivity. This could hint at the possibility to mitigate the negative economic consequences of diabetes by secondary prevention through better diabetes management, even without an earlier diagnoses. The systematic review in Chapter 2 showed a lack of evidence in this area. Only one study by Minor (2013) investigated the long term consequences of diabetes, finding non-linear effects in a USA population. Apart from the need for additional evidence, several possibilities for methodological improvements exist. Part two of Chapter 4 therefore assessed the impact of diabetes duration, or time since diagnosis, on labour market outcomes, using both linear and non-linear specifications in a FE framework. Chapter 5 provided additional evidence from China.

1.1.8 Measurement of diabetes in household surveys

There are two possibilities of measuring diabetes in household surveys: (1) asking participants about their diabetes status or (2) trying to identify people with diabetes using biometric exams, such as fasting blood glucose or glycated hemoglobin (HbA1c) levels. Using self-reported information likely leads to the exclusion of a considerable part of the diabetes population that has not yet received a diagnosis by a health care professional

(Beagley et al., 2014). Using biomarker information, also previously "undiagnosed" cases can be identified. Blood glucose measurements provide information on blood glucose levels at the time of the blood draw but it is not possible to infer on blood glucose levels over time. They are also sensitive to food consumption and may lead to false positives if taken in a non-fasted state. HbA1c levels provide an indication of the average blood glucose levels over the preceding three months and are not sensitive to the blood glucose level at the time of the blood draw (World Health Organization, 2011). They are, however, sensitive to an array of disorders such as haemoglobinopathies, anaemias, and disorders associated with accelerated red cell turnover (World Health Organization, 2011). The cut-off points for diabetes detection for blood glucose measurement and HbA1c measurement are 126 mg/dl and 6.5%, respectively (World Health Organization, 2006, 2011).

Unfortunately, and largely due to data limitations, previous research had to rely mainly on self-reported diabetes information. It has therefore remained unclear if the found effects also extended to the diabetes population unaware of its condition. Part 3 of Chapter 4 used a relatively large sample of biomarker data with HbA1c measurements, made available in wave 3 of the MxFLS that was released in 2015, to investigate the extend of the undiagnosed population in Mexico and the association of diabetes with labour market outcomes for the entire and undiagnosed diabetes population. This part also addressed the question if current disease severity, as proxied by HbA1c levels, was related to labour market outcomes.

1.1.9 The effect of health information provided by a diabetes diagnosis

There is evidence that the adverse impact of diabetes could be at least partly prevented by changes in lifestyle and appropriate treatment (Wareham and Herman, 2016). A prerequisite to this is a diagnosis of diabetes to create awareness of the disease. As Chapter 4 has shown, a large part of the diabetes population is unaware of its condition. This is also true for other developing countries (Beagley et al., 2014). But even once a diagnosis has been made, appropriate changes towards a healthier lifestyle and appropriate medical treatment are a prerequisite to prevent complications. This is only possible if information about ways to achieve this is accessible to and understood by the person with diabetes. Therefore this information needs provided by a healthcare professional at diagnosis and thereafter and the person with diabetes needs to be capable of making the proposed changes and following treatment regimes. Relatively little is known about the extend to which people with diabetes are making such changes after a diagnosis, especially in LMICs where healthcare

access is likely more limited than in HICs (Mills, 2014).

China, similarly to Mexico, is a country where diabetes rates have increased dramatically over the last decades, now affecting about 100 million people or close to 10% of the adult population (NCD Risk Factor Collaboration, 2016). A large part of that population remains unaware of the condition (Wang, Zhou, et al., 2015). For those that are, studies on health literacy have shown that those that have received some diabetes information also achieve better blood glucose control and have better knowledge of beneficial health behaviours (Guo et al., 2012). However, less is known about the actual impact of a diagnosis on long term health behaviours and risk factor reduction such as smoking, alcohol consumption and weight management. Given the number of people with diabetes in China, small long term changes in these behaviours may make an important contribution to prevent the burden of diabetes. So far, only a study for the USA investigated a similar question, finding mostly short lived reductions in risk behaviours (Slade, 2012).

Research study three in Chapter 5 therefore investigated the effect of a diabetes diagnosis on health behaviours and economic outcomes in China, using six waves of very detailed panel data from the China Health and Nutrition Survey (CHNS). Because selection into diagnosis was likely related to socioeconomic characteristics and healthcare access as well as pre-diagnosis health behaviours, it was important to account for this by using appropriate econometric techniques. This was done applying two complementary econometric strategies. First, a FE approach was used to eliminate any bias due to unobserved time-invariant confounders. Second, marginal structural models (MSMs) were used to prevent selection bias due to pre-treatment determination of selection into diagnosis based on observed time-variant confounders.

1.1.10 Thesis methods and structure

Mainly quantitative methods were used to answer the research questions that together form this thesis. Given the good quality of the used data sources and the greater possibilities of including different countries compared to a more qualitative approach, this was considered an appropriate strategy.

A series of four independent research studies form this thesis. Chapters 2 and 3 have already been published and Chapter 4 is under review at the time of completion of the thesis and has been published as a discussion paper. Chapter 5 will be submitted within the next months. This is outlined in more detail in the publication and statement of ownership section. Each study addresses different research questions, but has the investigation of the labour market impact of diabetes as a unifying theme. Taken together the studies complement each other providing a better understanding of the economic impact

of diabetes in MICs. Each study is presented in a separate chapter. For Chapters 3, 4 and 5, a pre-amble precedes the actual study to contextualize the respective findings with the preceding chapter and the entire thesis.

2 The Economic Costs of Type 2 Diabetes: A Global Systematic Review

Abstract

There has been a widely documented and recognized increase in diabetes prevalence not only in high-income countries (HICs) but also in low- and middle-income countries (LMICs), over recent decades. It is less clear what is the economic burden associated with diabetes, especially in LMICs. We provide a systematic review of the global evidence on the costs of type II diabetes. Our review seeks to update and considerably expand the previous major review of the costs of diabetes by capturing the evidence on overall, direct and indirect costs of type II diabetes worldwide that was published since 2001. In addition we include a body of economic evidence that has hitherto been distinct from the cost-of-illness (COI) work, i.e. studies on the labour market impact of diabetes. PubMed, EMBASE, EconLit and IBSS were searched (without language restrictions) for studies assessing the economic burden of type 2 diabetes published from January 2001 to October 2014. Costs reported in the included studies were converted to international dollars ($) adjusted for 2011 values. Alongside the narrative synthesis and methodological review of the studies we conduct an exploratory linear regression analysis, examining the factors behind the considerable heterogeneity in existing cost estimates between and within countries. We identified 86 COI and 22 labour market studies. COI studies varied considerably in both methods and cost estimates, with most studies not using a control group, though the use of either regression analysis or matching has increased. Direct costs were generally found to be higher than indirect costs. Direct costs ranged from $242 for a study on out-of-pocket (OOP) expenditures in Mexico to $11917 for a study on the cost of diabetes in the USA, while indirect costs ranged from $45 for Pakistan to $16914 for the Bahamas. In LMICs—in much contrast to HICs—substantial part of the cost burden arose to patients from OOP treatment costs. Our regression analysis revealed that direct diabetes costs are closely and positive associated with a country's gross domestic product (GDP) per capita, and that the USA stood out as having particularly high costs, even after controlling for GDP per capita. Studies on the labour market impact of diabetes were almost exclusively confined to HICs and found strong adverse effects, particularly for male employment chances. Many of these studies also took into account the possible endogeneity of diabetes, which was not the case for COI studies. The reviewed studies indicate a large economic burden of diabetes, most directly affecting patients in LMICs. The magnitude of the cost estimates differs considerably between and within countries, calling for the contextualization of the study results. There remains large scope for adding to the evidence base on labour market effects of diabetes in LMICs. Further, there is a need for future COI studies to incorporate more advanced statistical methods in their analysis to account for possible biases in the estimated costs.

2.1 Introduction

Diabetes is a chronic disease that has spread widely, not only in high-income but also in many LMICs over the last decades. The most recent data from the International Diabetes Federation indicate that diabetes affected 382 million people worldwide in 2013, a number that is expected to grow to 592 million by 2035. The estimated global prevalence in 2013 amounts to 8.3 % among people aged 20–79 years, with the world's most populous countries India and China reaching prevalence rates between 9 and 10 %, corresponding to 65 and 100 million in absolute numbers, respectively. Particularly high prevalence rates are found in Mexico (12.6%) and Egypt (16.8%), surpassing the rates of most HICs, including the USA (9.2%) and Germany (8.2%).(International Diabetes Federation, 2014) Taken together, in 2013 about two-thirds of all individuals with diabetes lived in LMICs (International Diabetes Federation, 2014). The rising prevalence of diabetes in LMICs appears to be fuelled by rapid urbanization, nutrition transition and increasingly sedentary lifestyles (Hu, 2011). The most prevalent form of diabetes by far is type 2 diabetes, affecting about 90 % of people with diabetes while the remaining 10 % mainly have type 1 diabetes or gestational diabetes (International Diabetes Federation, 2014).

Due to its adverse effect on people's health diabetes also imposes an economic burden on individuals and households affected as well as on healthcare systems. The economic burden of diabetes was confirmed by in a review of COI studies on diabetes mellitus, published in 2004, covering the literature up to the year 2000. The authors concluded that the direct and indirect economic burden of diabetes was "large", and that costs had increased over time. However, the review also noted that significant variation in costing methodologies made it near impossible to directly compare the cost estimates. However, the studies reviewed by Ettaro et al. (2004) were almost exclusively focused on the USA, with a small part coming from European HICs and none from LMICs. The aim of this study is therefore to systematically review the literature on the economic costs of diabetes published since 2001 (i.e. the first year not covered by the Ettaro et al. (2004) review), as we expect a considerable number of new studies, also from LMICs. In addition to the COI studies we review the literature on labour market outcomes, with a specific interest in the methodological challenges involved. In doing so we substantively update and expand the scope of the Ettaro et al. (2004) review, allowing us to revisit its findings regarding the evidence base about the economic burden of type 2 diabetes globally.

COI studies generally assess the direct and indirect costs of a particular illness, where the former represent the opportunity cost of resources used for treatment. The indirect costs measure the value of resources lost due the illness, most commonly those caused by

losses in productivity due to mortality and morbidity as measured in lost earnings (Segel, 2006). In addition, another approach also focuses on estimating the impact of diabetes on labour market outcomes. However, rather than trying to estimate the monetary losses that arise from a decrease in productivity, these studies typically compare labour market outcomes (e.g. employment probabilities, earnings or lost work days) between people with and without diabetes, while accounting for differences in age, education and other demographic and socioeconomic variables, that might arise between both groups and that could affect labour market outcomes as well as the chances of developing diabetes. The aim of studies in this field is to obtain a clearer picture of how diabetes causally affects these labour market outcomes, without necessarily monetizing the results. Because of the different methodologies and data requirements, these studies tend to differ considerably from traditional COI studies, which is why we reviewed them separately. To the best of our knowledge this is the first review that systematically assesses the studies in this particular field.

2.2 Methods

Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were used as a basis for the overall study approach.(Moher et al., 2009)

2.2.1 Search strategy

The electronic search was based on the following search terms: "Diabetes Mellitus"[Mesh] AND ("Costs and Cost Analysis"[Mesh] OR "Cost of Illness"[Mesh] OR "Employment"[Mesh] OR "Labor Market"[All fields] OR "Labour Market"[All fields] OR "Productivity"OR "Willingness to pay"[All fields]). The above search was run in PubMed and was then adapted for searches in EMBASE, EconLit and the International Bibliography of the Social Sciences (IBSS). The search was carried out from October 2012 to October 2014 and restricted to studies published between January 2001 and October 2014, as the earlier review had covered COI studies until 2000 (Ettaro et al., 2004). No language restrictions were applied. The references were downloaded in RIS format where possible and then transferred to Mendeley. Authors were contacted for further information if clarification was needed after the full text analysis.

2.2.2 Inclusion and exclusion criteria

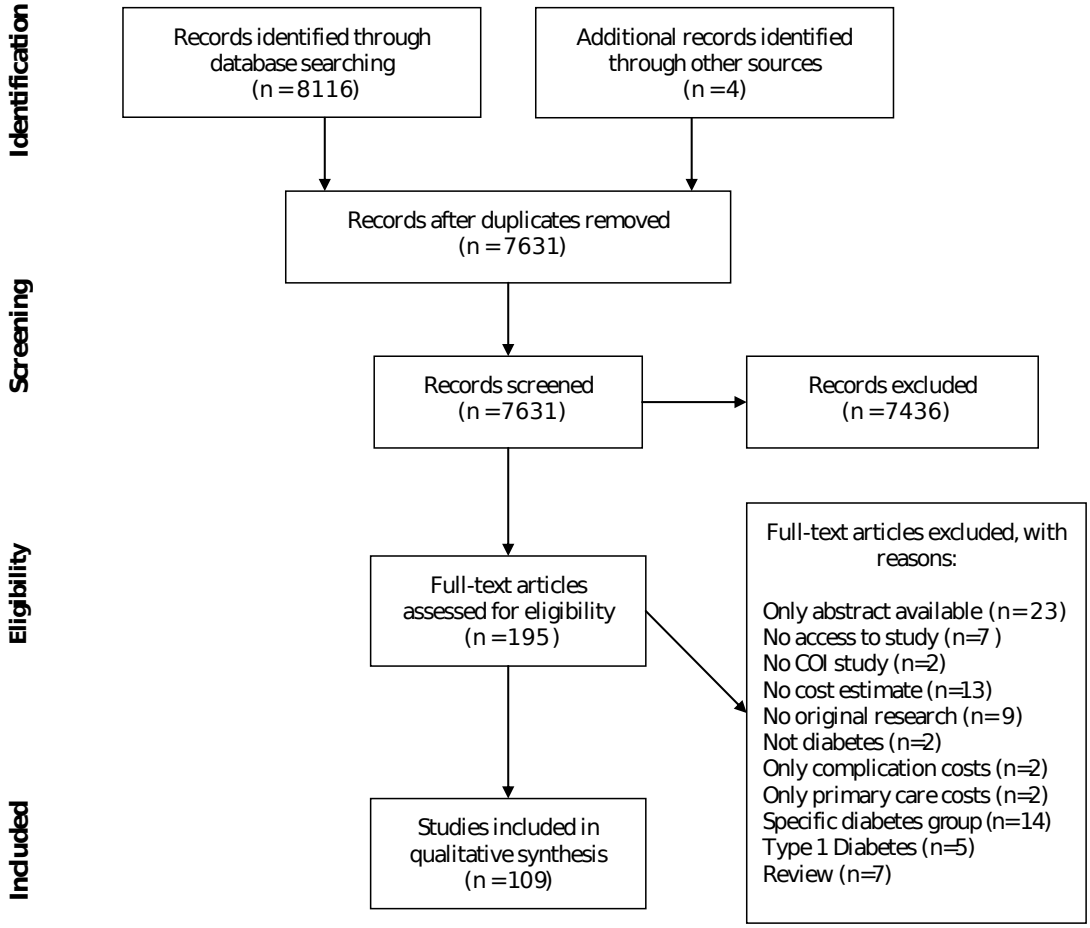
Studies were eligible if a monetary estimate of the direct and/or indirect costs of diabetes was presented in the results section or if studies provided an estimate of the impact of diabetes on labour market outcomes (employment chances, labour income, wages and lost work days). We did not exclude studies with a small sample size as this might have discriminated against studies in LMICs. Studies on types of diabetes explicitly different from type 2 diabetes were excluded. However, we included studies that did not explicitly mention the type of diabetes, given that type 2 diabetes accounts for about 90 % of all diabetes cases. Studies exclusively assessing the costs of diabetes complications or the costs of management strategies were excluded as were studies estimating the costs for specific groups with diabetes (e.g. costs for people with poorly controlled diabetes), since we were interested in the costs incurred to populations comprising the whole spectrum of people with type 2 diabetes. Editorials, reviews and studies for which the full text could not be retrieved or only an abstract was available were also excluded.

2.2.3 Data extraction and analysis

Data extraction was carried out by two investigators (TS and OA). After duplicates were removed, titles and abstracts were scanned by one researcher (TS) to identify studies suitable for a full text review. The process was checked by a second researcher (OA) on a random subsample of 2000 studies of the retrieved references. The full text was subsequently retrieved for the identified studies and they were reviewed by two researchers (TS and OA), with disagreements resolved by discussion. Finally, 109 studies were identified (see Figure 2.1) that fulfilled the inclusion criteria and data extraction was carried out using a pre-defined extraction table. Primary outcomes were the total costs, the direct costs, and the indirect costs of type 2 diabetes and the respective per capita estimates of these outcomes, as well as the impact of type 2 diabetes on employment chances, income, wages and lost work days. Secondary outcomes comprised the methodology used to assess the monetary costs of type 2 diabetes, the range of cost factors included in the analysis, as well as the methodology used to assess the labour market impact of diabetes. Further extracted information included the year of publication, year of data collection, the time horizon, the country or region studied, the data source, sample size and age as well as information on whether the study distinguished between types of diabetes.

We present the COI study results in per capita values to facilitate comparability across countries. For studies presenting overall population level estimates rather than per capita costs information, we calculated those costs, whenever possible, using the diabetes preva-

Figure 2.1: PRISMA flowchart.



lence mentioned in the respective study. If no total cost estimate was presented but information on direct and indirect costs was available, then direct and indirect costs were added up to produce a total cost estimate. We converted costs into purchasing-power-parity (PPP) adjusted estimates, also called international dollars and henceforth denoted with the $ sign, in order to further increase comparability. Since some studies did not present the data in the country's local currency but in USA$ or some other major currency, we used the exchange rate given in the article to convert the estimates back into the local currency. If no exchange rate was provided in the study itself, the average exchange rate (midpoint exchange rate according to OANDA historical exchange rates—[`http://www.oanda.com/currency/historical-rates/`]) for the reported year. The PPP adjusted estimates for the year 2011 were then calculated using the Campbell and Cochrane Economics Methods Group Evidence for Policy and Practice Information and Coordination Centre (CCEMG-EEPPI Centre) cost converter (Shemilt et al., 2010). For all additional analyses carried out in the following sections only studies for which a mean cost estimate was presented or could be calculated, were included. Further, in the case of a study presenting estimates for more than 1 year, only the estimate for the most recent year was used for the analysis. For studies presenting both incremental and total cost estimates, only the incremental cost estimate was taken into account.

Studies were further classified into two groups according to the level of economic development of the investigated country—(1) high-income and (2) LMICs (LMICs)—according to the historical World Bank income group classification of the respective country in the year that data collection for the respective study had taken place (World Bank, n.d.). Where necessary due to space constraints we used abbreviations for country names, as detailed in Table 2.7.

In order to explore the factors involved in the variation of direct costs reported in COI studies, we first plotted the direct per capita costs in relation to the gross-domestic-product (GDP) per capita of the respective country and provided an estimate of the relationship using linear regression. We then conducted an exploratory regression analysis, with the annual direct cost per patient as the dependent variable to investigate what other factors might explain the variation in direct cost estimates. The set of independent variables comprised (1) the estimation approach in each study, (2) the year of data used, (3) GDP per capita of the studied country in international dollars, (4) an indicator of whether the study was conducted in the USA, (5) an indicator of whether the study was deemed to be nationally representative, and (6) a variable indicating whether the study had explicitly taken diabetes-related complications into account. The year of the used data was considered because the development of social security systems and treatment

methods may affect how the direct costs evolve over time. We categorized this variable into groups: studies using data from before 1995, 1995 to 1999, 2000 to 2004, 2005–2009 and 2010–2004. The dummy variable for studies on the USA was included to account for the generally higher healthcare expenditures in the USA compared which other HICs with similar per capita income levels (Laugesen and Glied, 2011). Accounting for national representativeness should cancel out any effects that might be driven by those studies that estimate costs for sub-national, regional- or city-level population samples. Including an estimator for diabetes complications should account for the possible underestimation of diabetes costs in studies excluding complications. We exclude country estimates extracted from multi-country studies in our preferred specification, as their inclusion would lead to an over-statement of the cost effect of the estimation method employed in the given multi-country study.

2.3 Results

Due to the differences in methodologies, we first present the findings on the identified COI studies and subsequently turn to studies on labour market outcomes.

2.3.1 COI studies on type 2 diabetes

Number of studies

We identified a total of 86 relevant COI studies (see Table 2.8 for a detailed description of the included studies), of which 62 focused on HICs, 23 on LMICs, and one multi-country study covered both HICs and LMICs. Studies in LMICs increased over time, with the majority of the LMIC studies being published between 2007 and 2014. Six of the selected studies were multi-country studies, of which two (Kirigia et al., 2009; Smith-Spangler et al., 2012) did not provide detailed cost estimates for every country in the study and one did not provide a year for the estimated costs, so that we could not calculate estimates in international dollars (Boutayeb and Boutayeb, 2014). Therefore, we could not include these particular studies in our country-specific analysis.

Regional distribution

In terms of geographic regions, most studies were carried out on countries in Latin America and the Caribbean (n=38) and Europe (n=37), followed by the USA and Canada (n=26), East Asia and Pacific (n=11), the Middle East and North Africa (n=5), South Asia (n=4), Sub-Saharan Africa (n=4) and Australia (n=1). The number of countries studied is higher

than the number of articles reviewed due to four multi-country studies (Abdulkadri et al., 2009; Barceló et al., 2003; Boutayeb and Boutayeb, 2014; Jönsson, 2002), estimating costs for multiple countries. The USA were the most studied country (n=19), followed by Canada (n=7) and Germany (n=5). Mexico (n=6) and China (n=4) were the most frequently studied LMICs.

Data sources

Especially in LMICs, self-administered surveys represented a popular method to retrieve data on the cost of diabetes. These were mostly limited regionally, i.e. to a city or hospital, and usually only representative of these regional diabetes populations but not of a national population. In HICs, databases of insurance and healthcare providers were the main source of information in most studies. These data tended to be representative either at a national or at some sub-national level. As a result, the size of the samples in HICs was mostly between 1,000 and several million. By contrast, studies in low- and lower-middle-income countries were generally characterized by smaller sample sizes, ranging from 35 (Suleiman et al., 2006) to about 2,433 (Yang, Zhao, et al., 2012) in the studies reviewed here.

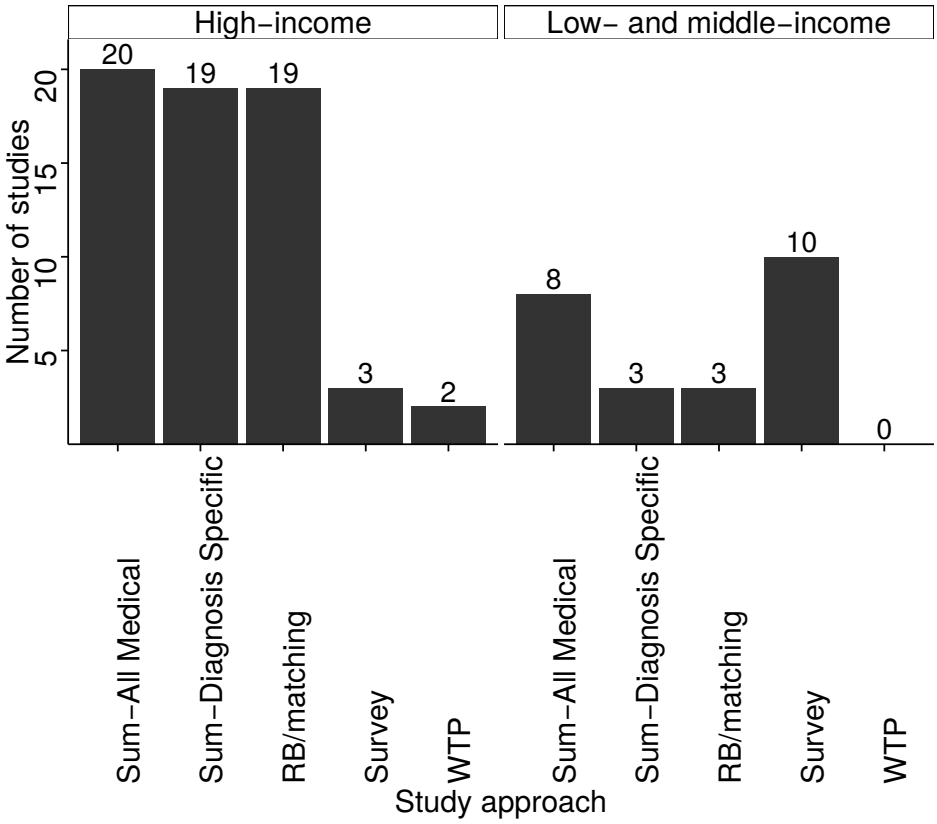
Variation in costing approaches

As discussed in more detail in Text Box 1, a range of costing approaches can be found in the COI literature. Figure 2.2 shows that the most common costing method for the direct costs of diabetes in HICs was the sum-all medical approach for people with diabetes without using control groups (Arredondo and Barcelo, 2007; Arredondo, Zúñiga, and Parada, 2005; Arredondo and De Icaza, 2011a; Arredondo and Zúñiga, 2004; Barceló et al., 2003; Bjegovic et al., 2007; Boutayeb and Boutayeb, 2014; Brandle et al., 2003; Camilo González et al., 2009; Chi et al., 2011; Condliffe and Link, 2014; Horak, 2009; Jönsson, 2002; Kirigia et al., 2009; Lau et al., 2011; Lee et al., 2006; Lucioni et al., 2003; Maciejewski and Maynard, 2004; Martin et al., 2007; Morsanutto et al., 2006; Nakamura et al., 2008; Nolan et al., 2006; Ohinmaa et al., 2004; Oliva et al., 2004; Peele et al., 2002; Pohar, Majumdar, et al., 2007; Redekop et al., 2002; Ringborg et al., 2008; Zhou, Isaman, et al., 2005). The disease-attributable costing approach (Abdulkadri et al., 2009; Ballesta et al., 2006; Bastida and Pagán, 2002; Buescher et al., 2010; Dall, Nikolov, et al., 2003; Davis et al., 2006; Honkasalo et al., 2014; Johnson et al., 2006; Lin et al., 2004; Mata et al., 2002; Rodríguez Bolaños et al., 2010; Simpson et al., 2003; Solli et al., 2010; Suleiman et al., 2006; Tunceli, Wade, et al., 2010) and the attributable-fraction approach

were also used widely, though mainly in the USA (Bolin et al., 2009; Dall, Mann, et al., 2008; Dall, Zhang, et al., 2010; Dawson et al., 2002; Honeycutt et al., 2009; Lesniowska et al., 2014; Schmitt-Koopmann et al., 2004). The incremental cost approach was applied primarily in studies on HICs (Birnbaum et al., 2003; Bruno et al., 2012; Chodick et al., 2005; Durden et al., 2009; Esteghamati et al., 2009; Honeycutt et al., 2009; Köster, Ferber, et al., 2006; Köster, Huppertz, et al., 2011; Köster, Schubert, et al., 2012; Linden et al., 2009; Marchesini et al., 2011; Norlund et al., 2001; O'Connell et al., 2012; Pohar and Johnson, 2007; Ramsey et al., 2002; Ricordeau et al., 2003; Rodbard et al., 2010; Smith-Spangler et al., 2012; Trogdon and Hylands, 2008; Tunceli, Wade, et al., 2010; Wiréhn et al., 2008; Yang, Zhao, et al., 2012). For LMICs, the survey approach was the most used (Biorac et al., 2009; Chan, Tsang, et al., 2007; Chatterjee et al., 2011; Druss et al., 2001; Elrayah-Eliadarous et al., 2010; Javanbakht et al., 2011; Khowaja et al., 2007; Al-Maskari et al., 2010; Ramachandran, Ramachandran, et al., 2007; Tharkar et al., 2010; Wang, Fu, Pan, et al., 2009; Wang, Fu, Zhuo, et al., 2010; Wang, McGreevey, et al., 2009).

By contrast, almost all indirect cost assessments followed the same methodology, i.e. the human capital approach. This approach considers all forgone labour earnings of a patient or caregiver that are attributable to diabetes. A minority of three studies (Chang, 2010; Gyldmark and Morrison, 2001; Tharkar et al., 2010), estimated the indirect costs using the WTP approach, which tries to measure how much individuals would be willing to pay to reduce the risk of an illness (Segel, 2006), here diabetes (or certain complications associated with it). One of the studies included WTP estimates in addition to the direct and indirect costs measured by the human capital approach (Tharkar et al., 2010) but did not include the WTP estimate in the overall cost estimate, while the other two studies estimated exclusively the WTP (Chang, 2010; Gyldmark and Morrison, 2001).

Figure 2.2: Number of COI studies, by costing approach and income group.



Notes For LMICs no willingness to pay (WTP) study is counted, because the only study (Tharkar et al., 2010) presenting a WTP estimate for a LMIC used primarily a different approach to estimate costs, and the WTP estimate was only presented additionally. Therefore this study was not counted under WTP here. Two studies are counted twice as they give estimates for a sum-diagnosis specific and a RB/matching approach.

Study perspective

Studies also varied in their perspective, again compromising direct comparability of the cost estimates across studies. Overall, most studies either took a societal (n=32) or healthcare system perspective (n=48). The former generally takes into account the direct and indirect monetary costs that arise to society, including costs to the healthcare system, costs due to lost productivity and sometimes OOP costs (Segel, 2006). The latter was especially common in HICs where many studies assessed the cost of diabetes to private or public health insurances. In LMICs, studies often took the patient perspective (n=5), estimating OOP expenditures and in some cases productivity losses, directly arising to the diabetes patient.

Text box 1 COI methodologies

Methodologies for COI studies can broadly be categorized into two main categories:(1) estimating the total disease costs and (2) estimating the incremental costs (Akobundu et al., 2006). Studies can then be divided further according to the specific approach used for estimation. Our categorization builds on that by Akobundu et al. (2006) in their review of COI methodologies.

1. Total disease costs
    a) Sum-All Medical: captures all medical expenditures of a person diagnosed with diabetes, irrespective of the relation of the expenditures with diabetes.
    b) Sum-Diagnosis Specific: includes the costs that are related to diabetes. This can be done by using a disease-attributable costing approach, using administrative claims databases to identify the cost of diabetes by respective International Statistical Classification of Diseases and Related Health Problems (ICD) codes that link the expenditures to a primary or secondary diagnosis of diabetes as the reason for the healthcare utilization. Alternatively, a similar technique used at the population level is the attributable-fraction approach, where the relative contribution of, e.g., diabetes, to the risk of developing another disease (e.g. renopathy or cardiovascular disease) is used to determine how much of the costs of this disease can be attributed to diabetes.
    c) Survey approach: while not specifically mentioned by Akobundu et al. (2006), for this review we create a separate category capturing studies using surveys of people with diabetes. This category differs from the two approaches a) and b) above in that estimations rely solely on the individual, reported experience of people with diabetes, without use of any diagnostic data at an aggregate level. The survey approach was also used as a separate category in the earlier review on diabetes COI studies by Ettaro et al. (2004).
2. Incremental disease costs

    There are two main approaches for the estimation of incremental medical costs:
    a) Regression approach: a statistical technique which can account for observable differences between the group with diabetes and the control group (i.e. those without diabetes) to find—ideally—the independent effect of diabetes on healthcare costs. The differences typically accounted for are age, region and gender.
    b) Matching approach: uses a control group to directly compare those with diabetes to those without diabetes after matching each person of the 'treatment' group to a 'similar' person of the control group, using various categories like age, region and gender to—again—find the independent effect of diabetes on healthcare cost (Akobundu et al., 2006).

All of the above approaches can be used in prevalence or an incidence based study. In the former case the costs of diabetes are estimated for a certain point in time, typically one year, while the latter approach estimates costs over a person's lifetime or several years, always starting with the point at which the disease is diagnosed. Both approaches may also be combined in studies estimating the future cost burden of type 2 diabetes by first taking a prevalence approach to calculate current costs and then using predictions about future diabetes incidence rates to arrive at an estimate of diabetes costs at a certain point in the future.

Costing components

Of the 75 studies that reported the cost components they used to estimate direct costs, 72 took into account outpatient hospital visits, 70 inpatient hospital visits, 63 physician visits, 58 drug costs, 51 laboratory costs for diagnostic tests and check-ups, 37 equipment costs and 21 non-medical and transportation costs. A total of 46 studies had at least included the costs of hospital, outpatient and physician visits as well as drugs (see Table 2.9 for a detailed description of cost components used in each study).

Cost estimates of diabetes using a prevalence approach

Two basic epidemiological approaches exist for the estimation of COI, and they are not directly comparable. The incidence approach follows people with diabetes, usually starting with their diagnosis at a common base year, estimating yearly costs for a sample of people at the same disease stage, finally giving an estimate of diabetes costs over a certain time period, such as from diagnosis to death or over a distinct period of, for example, 10 years. This approach can also document how costs of diabetes change and develop over the progression of the disease (Larg and Moss, 2011). By contrast, the prevalence approach estimates the costs of diabetes for a cross-section of people with diabetes at a certain point in time, normally a year, who are at different stages of the disease. It is most suitable for assessing the total economic burden of diabetes at a certain point in time. Due to this difference in time periods and the used data, the estimates of prevalence-based studies are not directly comparable with those of incidence-based studies. Hence, we present the cost estimates separately, starting with the prevalence approach.

Table 2.2 shows the range of direct cost estimates by estimation approach and income status. As can be observed, direct cost estimates varied widely, both between and within the different estimation approaches. Cost estimates for direct costs, irrespective of the costing method applied and the cost components included, ranged from $242 for Mexico Arredondo, Zúñiga, and Parada (2005) in 2010 to $11,917 for the USA Condliffe and Link (2014) in 2007. Also, studies from LMICs generally indicated smaller direct costs than studies from HICs.

For indirect costs, studies using the human capital approach estimated costs ranging from $45 for Pakistan (Khowaja et al., 2007) in 2006 to $16,914 for the Bahamas (Barceló et al., 2003) in 2000. Three studies estimated indirect costs by using the WTP approach and found costs ranging from $191 in a study on the WTP for a health insurance for type 2 diabetes in Denmark in 1993 (Gyldmark and Morrison, 2001), a WTP $4,004 per year for a cure of type 2 diabetes (Chang, 2010) in Taiwan and an annual payment of $4,737 to

halt disease progression/prevent future complications of diabetes in India (Tharkar et al., 2010).

Societal costs of type 2 diabetes, which are estimated by studies combining direct and indirect costs, ranged from $544 in a study on the economic costs of diabetes in Iran (Esteghamati et al., 2009) in 2001 to $18,224 for the Bahamas (Barceló et al., 2003) in 2000.

Table 2.1: Summary of direct costs by estimation approach and income status in international dollars $ (2011) for prevalence-based studies.

	High-income countries				Low- and middle-income countries			
	Sum-all medical costs	Sum-diagnosis specific	RB / matching	own survey	Sum-all medical costs	Sum-diagnosis specific	RB / matching	own survey
Min	1117	907	264	1495	242	662	443	456
Max	11917	9346	8306	5585	4129	4672	1136	3401
N	25[a]	19[a]	18	3	27[a]	5[a]	2	10

[a] Includes country estimates from multi-country studies; RB Regression based

In order to improve the cross-country comparability of the costs of diabetes we plotted the results from studies providing a direct per capita cost estimate against the GDP per capita estimate of the respective country (we limited this comparison to studies using samples representative of their entire population). Figure 2.3 confirms the expectation that costs do increase with economic wealth: GDP per capita explains about one-third of the variation in cost estimates (see r2 in Figure 2.3). Also, studies on the USA seem to estimate costs consistently higher than would be expected on the basis of its GDP per capita.

The USA, however, spend consistently more than what would be expected on the basis of its GDP per capita. Again, the wide variation in estimated costs for many countries underscores the point that the studies need to be contextualized and may not be directly comparable per se. On the whole—though by no means always—the matching and regression as well as the sum-diagnosis specific approaches appear to produce lower cost estimates than especially the total cost results, particularly so for HICs. In an inevitably crude attempt to quantitatively explore the driving factors behind the heterogeneity in cost estimates, we estimated a simple linear regression model with per capita direct costs

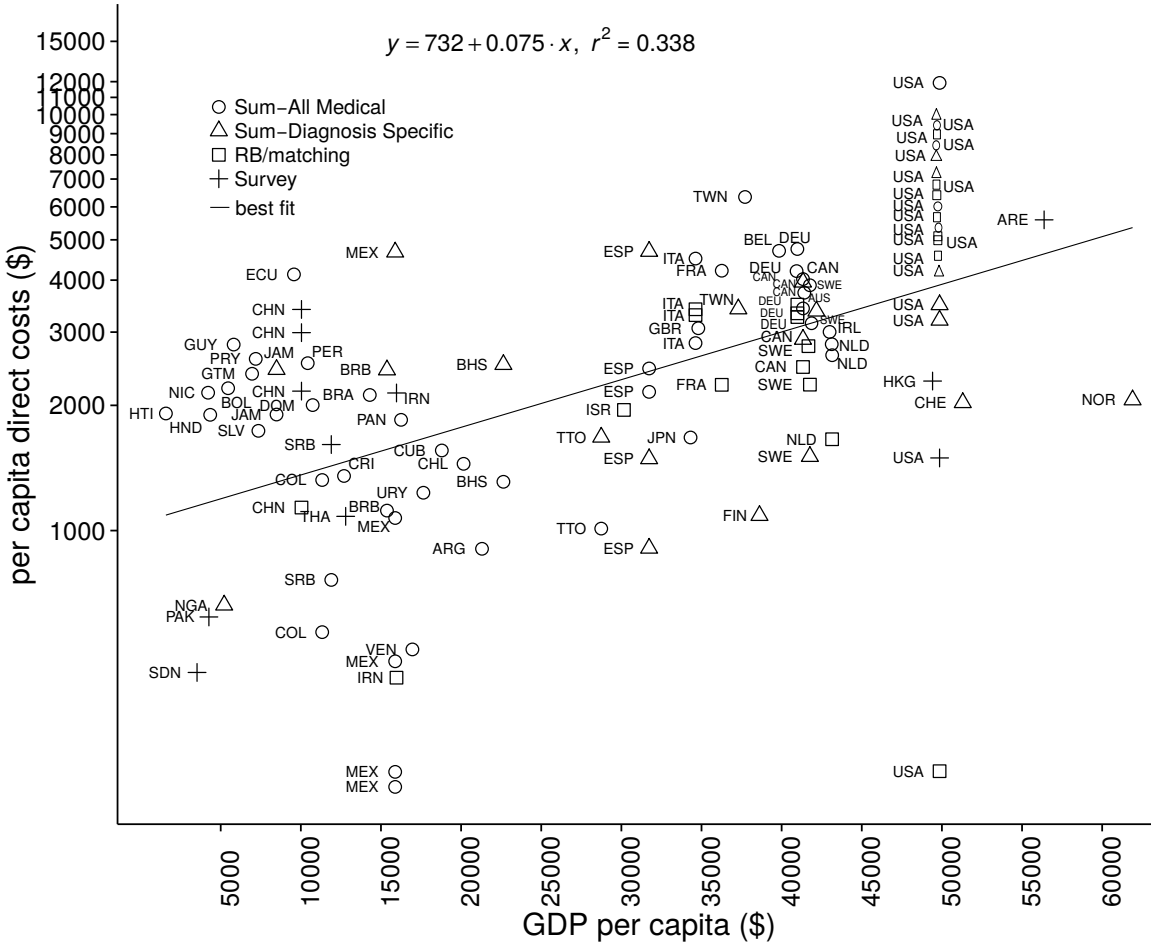
as the dependent variable; explanatory variables included GDP per capita, the estimation approach employed by the study, the number of included cost components, a dummy for studies carried out in the USA, the year of data collection, the representativeness of the study and if the study included diabetes complications as explanatory variables. The results, displayed in Table 2.2, show a strong relationship between GDP per capita and expenditures for diabetes, with every additional international dollar in per capita GDP translating into an average increase in direct diabetes expenditures of about $0.04. The estimation approach is not found to matter significantly, nor is the year of study. Estimates from USA studies put the costs at over $3,000 higher (on average) than studies from other countries, indicating that costs in the USA may indeed be unusually high. The number of costing components and the inclusion of complications likely also explain some of the variance in estimates, although they are just below and above the 10 % significance level, respectively. Overall, the included independent variables explain about 56 % of the variation in direct cost estimates. In a sensitivity analysis, we included the results from multi-country studies providing country estimates in the regression analysis. The only major difference to the presented analysis is that the inclusion of complications as well as the number of included cost components were now significant at the 1 and 5 % significance level, respectively. The effect size and significance of the other estimates did not change considerably.

The sensitivity of the cost results to the estimation approach was also examined by two studies that investigated the effect of different estimation techniques in diabetes COI studies. Honeycutt et al. (2009) compared the use of a regression-based and an attributable-fraction approach and found that the cost estimate of the former exceeded the latter by 43 %. Tunceli, Wade, et al. (2010) compared the matching and the diabetes (disease)-attributable costs approach and found a 14–29 % higher cost estimate using matching, depending on the used assumptions. Both studies concluded that an incremental cost approach results in a higher, and likely more exact, estimate of the direct costs of diabetes than disease-attributable approaches. The authors attributed this to the fact that a regression or matching approach can assign costs to diabetes that cannot be linked to diabetes otherwise. Those approaches are therefore in a position to account for all costs of co-morbidities caused by diabetes, while this is not automatically the case with the other approaches.

Direct and indirect costs of diabetes

To assess the relative importance of direct and indirect costs across countries, we plotted direct against indirect costs from studies that provided both estimates and drew a 45°line

Figure 2.3: GDP to direct costs ratio by estimation approach.



Notes The line depicts the best fit based on the linear regression of direct costs on GDP per capita in international dollars.

Table 2.2: Relationship between direct costs and study characteristics (robust linear regression).

	Estimate	Std. Error
Constant	2133	1773.922
GDP per capita ($)	0.045**	0.017
Estimation Approach		
Sum-All medical (Ref.)		
Sum-Diagnosis Specific	−413.880	528.766
RB/matching	−719.868	526.896
Survey	−689.806	671.020
At least four costing components	702.966*	403.968
USA study	3111.067***	533.534
Year of study		
<1995 (Ref.)		
1995-1999	−1744.799	1632.498
2000-2004	−816.647	1586.966
2005-2009	−1021.685	1592.595
2010-2014	−2744.739	1839.689
Study representative	−598.670	409.070
Complications	666.803	414.727
R-squared adj.	0.559	
N	70	

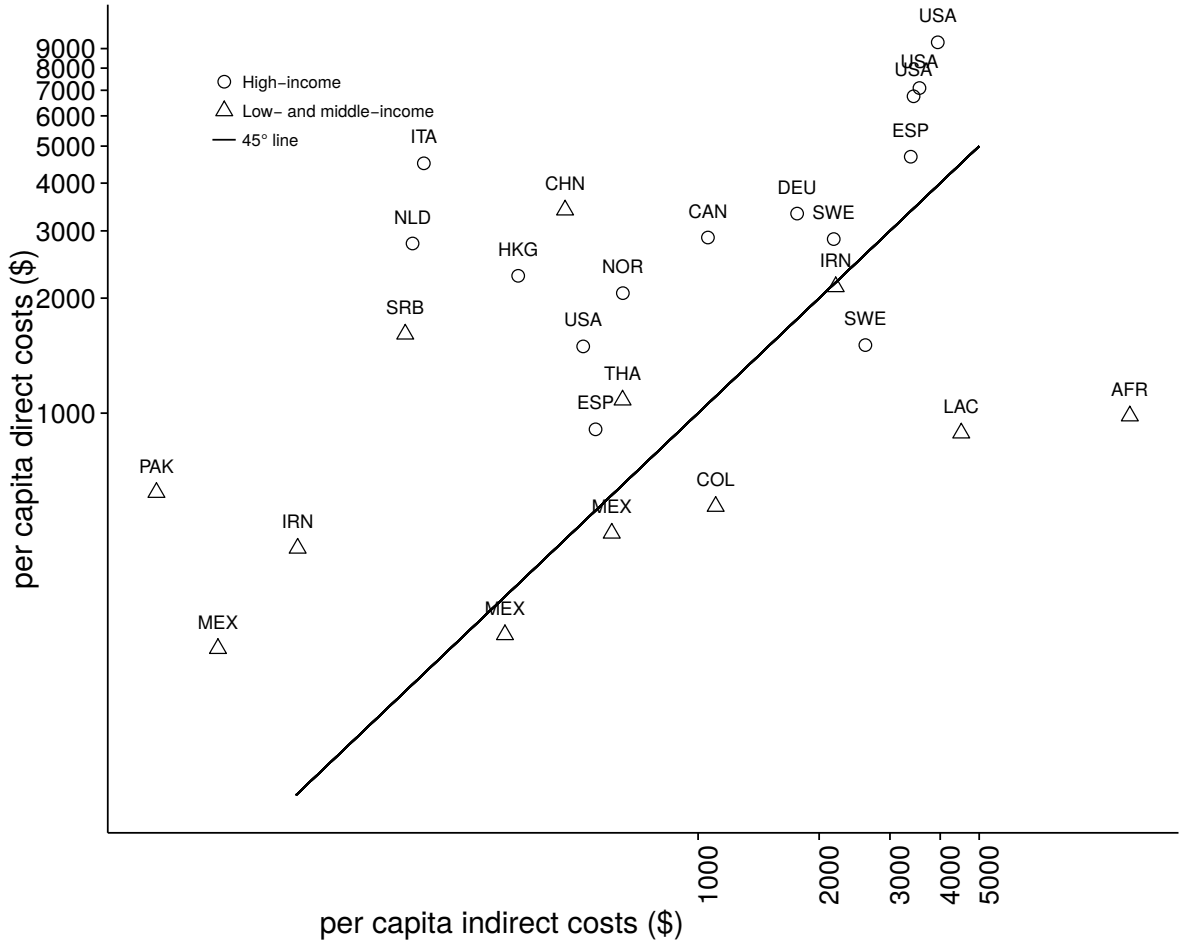
Standard errors in parenthesis. Ref. reference category.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

depicting the equal share of direct and indirect costs (see Figure 2.4).

Most studies found a larger share for direct costs in comparison with indirect costs (observations above the 45°line in Figure 2.4). This is especially true for HICs, where only a study on Sweden (Bolin et al., 2009) found a larger share for indirect costs. For LMICs, a study on Colombia (Camilo González et al., 2009) found considerably higher indirect costs, as did the multi-country study of Barceló et al. (2003) and a study on various countries in the African region (Kirigia et al., 2009), which both found higher indirect costs for almost every country in the study and also on average for the entire regions, represented as the mean overall study estimate in Figure 2.4. Both studies used similar approaches to estimate costs, and indirect cost estimates were likely so high because evidence from only a few countries within the region was used as a basis for estimating indirect costs for every other country in the respective study. Further, the studies took the countries' per capita

gross national product as a proxy for earnings, which might have led to an over-estimation of the indirect costs (Kirigia et al., 2009).

Figure 2.4: Direct and indirect cost relation in studies estimating total costs of type 2 diabetes.



Notes The 45°line depicts the points where direct and indirect costs would be equal. Above the line direct costs are higher than indirect costs and vice versa. For better visibility both coordinate axes are expressed in log scale

Studies using the incidence approach

The four studies that used an incidence approach (see Table 2.3 estimated the cost of diabetes either over a person's lifetime (Birnbaum et al., 2003; Camilo González et al., 2009) or over a certain period after diagnosis Johnson et al. (2006) and Martin et al. (2007). Camilo González et al. (2009) modelled the lifetime (direct and indirect) costs of a typical diabetes patient in Colombia, arriving at a mean cost estimate of $54,000. The

second study providing lifetime estimates by Birnbaum et al. (2003), estimated incremental lifetime healthcare costs for USA females with diabetes of $283,000.

Two studies followed patients over a limited time period and found different patterns in the development of type 2 diabetes-attributable healthcare costs. In Germany costs increased from $1634 in the first year after diagnosis to $4881 in the seventh year (Martin et al., 2007). In Canada, Johnson et al. (2006) found the highest costs in the year of diagnosis with $7635, up from $2755 the year prior to diagnosis. In the year after diagnosis costs decreased to $4273 and then only increased slightly to $4618 in year ten. In Germany and Canada, costs related to complications or hospital visits were the most important components and in Germany increased steadily over time. In Canada costs related to prescriptions increased the most.

Country level costs prediction studies

Four studies projected costs of diabetes over a certain period of time (Davis et al., 2006; Lau et al., 2011; Ohinmaa et al., 2004; Wang, McGreevey, et al., 2009), making assumptions about the future development of diabetes prevalence and population ageing (see Table 2.4). For Canada, a 1.7-fold increase from 2000 to 2016 (Ohinmaa et al., 2004) and a 2.4-fold increase from 2008 to 2035 in diabetes healthcare costs was estimated (Lau et al., 2011). Taking a health care system perspective, both studies found that the estimated increase would be mostly driven by an ageing population. For Australia, Davis et al. (2006) estimated a 2.5- to 3.4-fold increase in diabetes attributable healthcare costs from 2000 to 2051, depending on the underlying assumptions about population ageing and diabetes prevalence rates. For China, Wang, McGreevey, et al. (2009) extrapolated total costs of diabetes from the year 2007 to 2030, estimating the costs of diabetes to increase 1.8-fold, solely accounting for the expected increase in prevalence.

2.3.2 The impact of diabetes on employment chances and productivity

Besides studies that determined the cost of diabetes by costing related expenditures, another body of research has investigated—using econometric techniques—the impact of diabetes on 'productivity', a term used here to comprise outcomes including employment probabilities and lost work days and income or earnings. A recent study systematically reviewed evidence on the impact of diabetes on the ability to work, focusing on studies assessing the impact of diabetes on early retirement, lost work hours, absenteeism and presenteeism (Breton et al., 2013). We focused particularly on studies exploring the impact

Table 2.3: Incidence studies on the costs of diabetes

Ref.	Country	Time horizon	Population	Approach	Results
Johnson et al. (2006)	Canada	1992–2001	Incidence T2D patients from Saskatchewan Health's administrative database in Canada	Sum-all medical	Highest total healthcare costs at year of diagnosis with CAN$7343 ($7635), then increased from a low of CAN$3880 ($4034) 3 years after diagnosis to CAN$4441 10 years thereafter ($4618).
Camilo González et al. (2009)	Colombia	32 years	Hypothetical average Columbian T2D patient	Sum-all medical	Total lifetime costs (32 year period) of average diabetes patient, including direct and indirect costs, 57.565 million Colombian pesos ($54,351).
Martin et al. (2007)	Germany	1995–2003	Newly diagnosed T2D patients from randomly drawn practices across Germany	Sum-all medical	EUR 1,288 ($1635) for the first treatment year after diabetes diagnosis and increased to EUR 3845 ($4880) in the seventh year.
Birnbaum et al. (2003)	United States	1997–1998	Women employed by nationwide operating company and hypothetical women above age 64 receiving Medicare	RB/matching	$282973 incremental lifetime direct healthcare costs, using incidence-based, steady-state methodology.

Table 2.4: Country level costs prediction studies

Ref.	Country	Population	Approach	Time horizon	Results
Davis et al. (2006)	Australia	Australian population	Sum diagnosis Specific	2000–2051	If age and sex specific prevalence remains unchanged a 2.5-fold increase; if age and sex specific prevalence allowed to change as well a 3.4-fold increase.
Ohinmaa et al. (2004)	Canada	Canadian population	Sum-all medical costs	2000–2016	1.7-fold increase.
Lau et al. (2011)	Canada	Four Alberta Health and Wellness databases	Sum-all medical costs	2008–2035	2.4-fold increase.
Wang, McGreevey, et al. (2009)	China	In patients and outpatients in 20 hospitals	Own survey	2007 and 2030 (projection)	Increase from $73 billion in 2007 to $132 billion in 2030 (1.8 fold increase).

of diabetes on employment probabilities and earnings—both issues that were not covered in the mentioned review—and we took a more detailed look at the empirical challenges posed by the issue of endogeneity (see the Appendix for a more detailed discussion of endogeneity).

Tables 2.5 and 2.6 synthesize the relevant information from the 23 identified studies on the effect of diabetes on employment and other labour market outcomes. Almost all studies were conducted on HICs, mainly the USA (n=13) and European countries (n=4). Only one study focused on a LMIC. investigating the effect of diabetes on labour income in China.

Employment chances

Most studies examined the impact of diabetes on employment probability (n=17), applying a range of econometric techniques. These have evolved over time, and more recent studies took into account the possibility that diabetes might be endogenous: it is conceivable that especially personal traits such as motivation and drive could influence the propensity to develop type 2 diabetes as well as a persons' job market opportunities. Further, being employed or unemployed could also lead to changes in lifestyles, due to changes in income, stress or leisure time, that could themselves affect the chances of developing diabetes (Brown, Pagán, et al., 2005). Of the studies that tried to account for this problem (Brown, Pagán, et al., 2005; Harris, 2009; Latif, 2009; Lin, 2011; Minor, 2011; Zhang, Zhao, et al., 2009), the majority used an instrumental variable (IV) technique. This approach allows for the consistent estimation of the effect of diabetes on employment if a variable can be found that is causally related to diabetes without affecting the employment chances through any other unobserved pathway apart from its effect on diabetes (see Text Box 1). In the case of type 2 diabetes all studies used the family history of diabetes as an IV to exploit the fact that the development of type 2 diabetes is much more likely for individuals whose biological parents have also had diabetes. It is argued that, while controlling for education, age and other observable demographic and socioeconomic factors (e.g. wealth, regional and ethnic differences and the number of children in the household), having a family member with diabetes should not affect the person's employment status or other labour market outcomes, while strongly predicting the onset of type 2 diabetes.

Table 2.5: Studies estimating the relationship between diabetes and employment (2001 – 2014)

Ref	Survey year	Country	Age	Effect on employment	
				Males	Females
Harris (2009)	1999-2000	Australia	>24	Exogenous: 10.8 percentage points reduction to be in labour force; endogenous: 7.1 percentage points reduction and test indicates endogeneneity.	Exogenous: 10 percentage points to be in labour force; endogenous: Nine percentage points reduction and test indicates endogeneneity.
Zhang, Zhao, et al. (2009)	2001, 2004-2005	Australia	18-64	50-64: 11.5 percentage points less likely to be in labour force; 18-49: 3.9 percentage points less likely, all effects increase when other chronic diseases are present.	No significant effect for diabetes alone; significant negative effect if other chronic diseases are present.
Latif (2009)	1998	Canada	15-64	Exogenous: 19 percentage points less likely to be employed; endogenous: not significant and positive and test indicates endogeneity.	Exogenous: 17 percentage points less likely to be employed, endogenous: not significant and positive and test indicates exogeneity.

Table 2.5: Studies estimating the relationship between diabetes and employment (2001 – 2014)

Ref	Survey year	Country	Age	Effect on employment	
				Males	Females
Kraut et al. (2001)	1983-1990	Canada	18-64	With complications 2 times less likely to be in labour force; no significant effect on employment for those in labour force.[a]	
Norlund et al. (2001)	1992-1993	Sweden	>24	14.2 percentage points higher retirement rate (22.9 compared to 8.7).[a]	
Alavinia and Burdorf (2008)	2004	Sweden, Denmark, Netherlands, Germany, Austria, Switzerland, France, Italy, Spain, Greece	50-65	For whole dataset: no effect of diabetes on being unemployed, but increased odds ratio of 1.33 on being retired. No information on effects by country.[a]	

Table 2.5: Studies estimating the relationship between diabetes and employment (2001 – 2014)

Ref	Survey year	Country	Age	Effect on employment	
				Males	Females
Lin (2011)	2005	Taiwan	45-64	Exogenous: 9 percentage points less likely to be employed; endogenous: 19 percentage points less likely to be employed; test on whole sample indicates endogeneity.	Exogenous: 11 percentage points less likely to be employed, endogenous: not significant and negative.
Brown, Pagán, et al. (2005)		United States	>44	Exogenous: 7.4 percentage points less likely to be employed; endogenous: 10.6 percentage points less likely but test indicates exogeneity.	Exogenous: 7.5 percentage points less likely to be employed; Endogenous: no significant effect found and test indicates endogeneity.
Minor (2011)	2006	United States	>19 at diagnosis		Exogenous: 25.2 percentage points less likely to be employed, endogenous: 45.1 percentage points less likely to be employed.

Table 2.5: Studies estimating the relationship between diabetes and employment (2001 – 2014)

Ref	Survey year	Country	Age	Effect on employment	
				Males	Females
Vijan et al. (2004)	1992-2000	United States	51-61	More likely to be retired in 1992 (adjusted OR 1.3). Over 8 years follow up spent 0.14 incremental years in retirement.[a]	
Bastida and Pagán (2002)	1996-1997	United States	>44	7.5 percentage points less likely to be employed.	No significant effect on employment chances found.
Brown, Perez, et al. (2011)	2008	United States	35-64	Diabetes negatively related to employment (5 percentage points reduction); better diabetes management (HbA1c) positively affects employment probabilities; HbA1c lowering of 10% increases employment probability by 0.44 percentage points.	No significant effect on employment chances found.

Table 2.5: Studies estimating the relationship between diabetes and employment (2001 – 2014)

Ref	Survey year	Country	Age	Effect on employment	
				Males	Females
Tunceli, Bradley, et al. (2005)	1992,1994	United States	51-61	9 percentage points less likely to work without complications controlled for, with complications controlled for 7.1 percentage points less likely.	5.9 percentage points less likely to work without complications controlled for, with complications controlled for 4.4 percentage points less likely but not significant.
Tunceli, Zeng, et al. (2009)	1997-2005	United States	20-44 and 45-64	20-44: proportion with work limitations 3.1% higher; 45-64: proportion not working is 8.1% higher; the proportion work disabled is 3.4% higher; proportion with work limitations is 5.7% higher (all compared to similar age group without diabetes).[a]	
Valdmanis et al. (2001)	1990-1995	United States		Unemployment rate for persons with diabetes was 16% compared with 3% among matched comparison group.[a]	
Ng et al. (2001)	1989	United States	>29 at diagnosis	3.6% less likely of being employed (exogenous), 12% for those with complications.[a]	

Table 2.5: Studies estimating the relationship between diabetes and employment (2001 – 2014)

Ref	Survey year	Country	Age	Effect on employment	
				Males	Females
Minor (2013)	1979-2010	United States	>14	Average reduction of employment probability of 28 percentage points; strongest employment penalty in first 5 years after diagnosis.	Average reduction of employment probability of 36 percentage points; strongest employment penalty in first 15 years after diagnosis.

[a] No gender differentiation in study

Because IV estimation has worse asymptotic properties than single equation regression results when endogeneity is not an issue, studies tested for the existence of endogeneity to determine which results to rely on for inference (Brown, Pagán, et al., 2005; Latif, 2009; Lin, 2011; Minor, 2011). Interestingly, the reviewed studies found diabetes to be endogenous for either males (Latif, 2009) or females (Brown, Pagán, et al., 2005; Minor, 2011), but never for both. Further, the use of an IV sometimes increased the estimated effect(Lin, 2011; Minor, 2011) whereas in other cases the effect turned insignificant (Brown, Pagán, et al., 2005; Latif, 2009). As a result, no unambiguous conclusions can be drawn as to how endogeneity affects diabetes and whether or not it causes biased estimates. Most of the relevant studies also explored whether accounting for body mass index (BMI) or other diabetes-related chronic conditions would substantially alter the result and found this not to be the case (Brown, Pagán, et al., 2005; Latif, 2009; Minor, 2013).

Overall, studies more commonly found a significant adverse impact of diabetes on males, ranging from no effect in Canada (Latif, 2009) to a 19 percentage point reduction in Taiwan (Lin, 2011). Conversely, no effect was found for women in Taiwan (Lin, 2011), Australia (Zhang, Zhao, et al., 2009) or for Mexican Americans in Texas (Brown, Pagán, et al., 2005). However, a 45 % decrease in employment chances was observed for women in the USA (Minor, 2011). Extending the scope and looking at how diabetes duration affected labour market outcomes, using pooled longitudinal data from the USA, one study found that the main adverse effect on employment chances materialized within the first 5 years

after diagnosis for men and 11–15 years after diagnosis for women (Minor, 2013).

Productivity

For earnings, no effect was found for Mexican-American men in Texas (Bastida and Pagán, 2002), while the highest loss was found for women in the USA ($21392 per year) (Minor, 2011). Again looking at diabetes duration, a wage penalty was only found for USA men 6–10 years after diagnosis, reducing their wage by about 18 percentage points (Minor, 2013). The only study on a non-HIC, China, tried to tease out the psychological effect of a diabetes diagnosis on subsequent labour income, finding a reduction of 22 % in income for males, but not for females. Further, those with an HbA1c between 8–10 % experienced the most severe income penalty (29 %). The study further showed that the adverse effect of a diabetes diagnosis was concentrated among the poorest third of the study population (Liu and Zhu, 2014). Another study investigated the effect on earning losses for caregivers of people with diabetes in the United Kingdom (UK), finding a reduction of $2,609 per year, while the person with diabetes experienced a loss of $1,744 per year (Holmes et al., 2003). For income, a reduction of $6,250 per year was found for older USA adults who had been followed between the years 1992 and 2000 (Rivera, Barquera, González-Cossío, et al., 2004). In terms of lost workdays and work hours due to diabetes, the effects ranged from no impact on lost work days on older people (Rivera, Barquera, González-Cossío, et al., 2004) and females in the USA (Minor, 2011) to 3.2 lost work days in a USA population within a 2-week period if complications were present (Ng et al., 2001).

Table 2.6: Studies estimating the relationship between diabetes and other productivity outcomes (2001 – 2014)

Ref.	Survey year	Country	Age	Effect on other productivity outcomes	
				Males	Females
Kraut et al. (2001)	1983–1990	Canada	18–64	Effect on earnings only when complications are present: reduced to 72% of total income of controls.a	

Table 2.6: Studies estimating the relationship between diabetes and other productivity outcomes (2001 – 2014)

Ref.	Survey year	Country	Age	Effect on other productivity outcomes	
				Males	Females
Liu and Zhu (2014)	2009, 2011	China	not given	16.3% decrease in annual income; strongest effect for those in lower income quintiles.[a]	
Herquelot et al. (2011)	1989–2007	France	Male 40–50, females 35–50 in 1989	1.7 HR to transition from employed to disabled, 1.6 HR to be retired, 7.3 HR to be dead; between age 35 and 60 each person with diabetes lost 1.1 years of time in workforce.[a]	
Leijten et al. (2014)	2010–2013	Netherlands	45–64	Diabetes reduced work ability measured using Work Ability Index (WAI) by 2%. No significant effect on productivity was found.[a]	
Norlund et al. (2001)	1992–1993	Sweden	>24	9.4 more sick days.[a]	
Holmes et al. (2003)	1999	United Kingdom	<65	GBP 869 lost earnings per year with diabetes; GBP 1300 for carers of people with diabetes.[a]	

Table 2.6: Studies estimating the relationship between diabetes and other productivity outcomes (2001 – 2014)

Ref.	Survey year	Country	Age	Effect on other productivity outcomes	
				Males	Females
Minor (2011)	2006	United States	>19 at diagnosis		Exogenous: $2865 loss in earnings per year, Endogenous: $19655; Exogenous: 2 working hours less per week, no significant effect on missed workdays per year, endogenous: no significant effect on working hours or workdays missed.
Vijan et al. (2004)	1992–2000	United States	51–61	Lost income of $50004 from 1992–2000 per capita or $6250 per year, for whole USA population of same age $85.6 billion or $10.7 billion per year; people with diabetes more likely to have taken sick days in 1992 (adjusted OR 1.3).[a]	
Collins et al. (2005)	2002	United States	working age	No significant effect on work days.[a]	
Bastida and Pagán (2002)	1996–1997	United States	>44	No significant effect on earnings.	Women with diabetes earn 84% less.

Table 2.6: Studies estimating the relationship between diabetes and other productivity outcomes (2001 – 2014)

Ref.	Survey year	Country	Age	Effect on other productivity outcomes	
				Males	Females
Brown, Perez, et al. (2011)	2008	United States	35–64	Wages reduced by 0.74% due to diabetes; for every 10% reduction in A1C wages rise by 0.62 %. A1C >8 was related to decreasing wages.	No significant effect of diabetes on female earnings; no effect of blood sugar management for women, A1C levels just below 6 to just above 7 were related to lower wages.
Lenneman et al. (2011)	2005–2009	United States	>16	Lost earnings per year of $2146.[a]	
Tunceli, Bradley, et al. (2005)	1992, 1994	United States	51–61	No significant effect on number of work days.	2.5 more lost workdays per year.
Valdmanis et al. (2001)	1990–1995	United States		71% of the persons with diabetes had an annual income of less than $20000 compared with 59% of the matched respondents.[a]	
Ng et al. (2001)	1989	United States	>29 at diagnosis	No significant effect on work days for T2D, for those with complications 3.2 days lost within two weeks	

Table 2.6: Studies estimating the relationship between diabetes and other productivity outcomes (2001 – 2014)

Ref.	Survey year	Country	Age	Effect on other productivity outcomes	
				Males	Females
Brown, Estrada, et al. (2005)	NA	United States	>45	For every dollar of labor income lost by adults with diabetes, a further income reduction of $0.48 occurs in the community. Total output reduction for upper bound estimate is $300 million for the local economy.[a]	
Minor (2013)	1979–2010	United States	>14	no general effect of type 2 diabetes on wages; some evidence of wage penalty of about 18% 6–10 years after diagnosis	No strong evidence found for wage penalty for females

[a] No gender differentiation in study

In terms of the methodology used, these studies tended to rarely account for endogeneity, and they mostly used standard regression or matching methods to estimate the impact of diabetes. Three studies (Bastida and Pagán, 2002; Brown, Perez, et al., 2011; Minor, 2011) corrected for the possibility of a sample selection bias, to account for systematic differences between the working population and the overall population. Only one study additionally applied IV methods and found diabetes to be endogenous, so that its effects on earnings were dramatically understated using naive regression results (Minor, 2011). For working hours and days missed due to illness, the same study found no indication of endogeneity. Only one study applied an approach other than IV to account for endogeneity, using a difference-in-difference model and exploiting a recent diagnosis of diabetes, which was the result of the collection of biomarkers in the survey used, as a natural experiment to measure how income developed between those who were newly diagnosed and those without diabetes in the years following diagnosis (Liu and Zhu, 2014).

2.4 Discussion

The objectives of this systematic review were to identify new evidence on the economic impact of type 2 diabetes that emerged since 2001 and extend the scope of the review by including studies on the labour market impact of diabetes. We identified studies from a great variety of countries, with large differences in cost estimates across and within countries.

2.4.1 General findings and developments since the 2004 review of diabetes COI studies

An obvious development since the last review is the emergence of COI studies on LMICs. The economic burden related to diabetes found in these studies indicated a strong direct impact on those affected by diabetes. This is reflected in the substantial burden of OOP treatment costs incurred by patients (Arredondo and Barcelo, 2007; Chatterjee et al., 2011; Elrayah-Eliadarous et al., 2010; Esteghamati et al., 2009; Khowaja et al., 2007; Ramachandran, Ramachandran, et al., 2007; Smith-Spangler et al., 2012; Suleiman et al., 2006; Tharkar et al., 2010; Wang, Fu, Pan, et al., 2009; Wang, Fu, Zhuo, et al., 2010), with considerable proportions of the annual income being spent on diabetes care. This relative cost burden was generally higher for people with relatively lower household incomes (Khowaja et al., 2007; Ramachandran, Ramachandran, et al., 2007; Tharkar et al., 2010). Health insurance coverage had some protective effects against OOP expenditures, but mainly for those with higher incomes, while the poor often lacked coverage (Khowaja et al., 2007; Ramachandran, Ramachandran, et al., 2007; Tharkar et al., 2010).Nonetheless, once people were covered by health insurance their risk of incurring catastrophic expenditures decreased significantly (Smith-Spangler et al., 2012). An important cost factor that was predominantly investigated in studies on LMICs were non-medical costs for transportation, informal healthcare or food which were found to considerably add to the experienced diabetes cost burden (Chatterjee et al., 2011; Esteghamati et al., 2009; Tharkar et al., 2010; Wang, Fu, Pan, et al., 2009; Wang, McGreevey, et al., 2009).

In terms of the costing methodology applied in COI studies, the number of studies estimating the excess costs of diabetes increased since the Ettaro et al. (2004) review. Those studies either used regression analysis or matching to adjust for the differences between people with diabetes and those without, accounting at least for age and gender, but often also for other socioeconomic, geographic and demographic differences. Other widely used approaches to estimate direct healthcare costs from the perspective of the healthcare system or private insurance included the disease-attributable and—slightly less

frequently—the attributable-fraction approach. For cost assessment in LMICs, studies often either estimated total healthcare costs or carried out self-administered surveys. While Ettaro et al. (2004) recommended the use of disease-attributable approaches to arrive at more exact estimates of the costs of diabetes, the evidence found in this review indicates that using an incremental cost approach via matching or regression analysis could provide more accurate results, due to its ability to capture costs otherwise not directly traceable to diabetes. Nonetheless, the use of the estimation technique always hinges on the availability of appropriate data, with regression or matching analyses requiring information on people without diabetes to be used as a control group. Therefore the estimation approach needs to be tailored to the available data.

Compared with the evidence reviewed by Ettaro et al. (2004), the field has generally advanced with respect to the analysis of costs in different ethnic and age groups. Two studies investigated differences between racial groups in the USA, showing that while ethnic minorities spend less on diabetes healthcare than Whites, this difference seems to be mainly based on differences in access to care between Whites and Blacks or Hispanics (Buescher et al., 2010; Lee et al., 2006). In terms of age, studies found an increase in healthcare costs with age as well as with, in some cases, the duration of diabetes. A recurring problem was that many studies did not distinguish diabetes types, making it difficult to exactly attribute the costs to the respective diabetes types.

To explore the reasons for the wide heterogeneity in direct cost estimates across studies, we performed a regression analysis, which indicated that an important determinant for the cost variation across countries could be the economic wealth of the country (proxied by GDP per capita), similar to what was found in a review of indirect costs of various chronic diseases (Zhao, Xie, et al., 2013), possibly due to differences in the availability and affordability of diabetes care between HICs and LMICs (Cameron, Ewen, et al., 2009; Cameron, Roubos, et al., 2011).

Further, studies on the USA seem to estimate consistently higher costs than studies on other countries, even when accounting for differences in GDP per capita. The higher direct costs of diabetes estimated for the USA are in line with the generally higher healthcare expenditures in the USA compared with countries with similar income levels, and could be the result of exceptionally high service fees (Laugesen and Glied, 2011) and prices paid in the USA healthcare system (Lorenzoni et al., 2014; Squires, 2012).

Because of the small sample size on which our analysis was based, these results must be interpreted with caution, and other factors could still be important. For instance, other evidence suggests that different costing approaches have a considerable effect on diabetes cost estimates (Honeycutt et al., 2009; Tunceli, Wade, et al., 2010). Furthermore, the per-

spective taken, different data sources and populations investigated and decisions on the cost components included are likely important in explaining within-country heterogeneity. In particular, the inclusion of diabetes complications and decisions about which complication(s) to include, as well as the extend to which costs for these diseases are attributable to diabetes, can significantly affect the results. Not all studies in the review provide extensive information about how they include complications and some do not include them at all.

Finally, the quality of the data used could have affected the cost estimates. Many studies in LMICs relied on self-reported data from small household surveys, limiting their generalizability and leading their results to be prone to recall bias. Further, these studies often identified people with diabetes via their use of healthcare institutions, which excluded a potentially important section of the population in LMICs unable to access formal care, possibly leading to an overestimation of the average diabetes-related costs.

2.4.2 Labour market studies

Turning to the effects of diabetes on the labour market, the existing studies showed, almost consistently, with the exception of Canada (Latif, 2009) and one study on the USA (Minor, 2013), that the employment probabilities of men were affected more adversely by the disease than those of women. However, while most studies have tried to tentatively explain these gender differences, the reasons for this have not been investigated in depth. The studies also showed that, when interpreting this research, it is important to consider whether a study has tried to account for unobservable factors or reverse causality, as otherwise the results might be misleading. Nonetheless, all studies using IV techniques used similar instruments to achieve identification, providing scope for further research using different identification strategies to explore how endogeneity might affect the results. What has been apparent is the lack of research on labour market outcomes of diabetes in LMICs, with only one study investigating the effect of diabetes on labour income in China (Liu and Zhu, 2014). This deficit might be due to a limited availability of suitable data sources containing sufficient information to allow for a similar investigation of the topic.

The potential for rich, good-quality data sources to aid the investigation of the economic impact of diabetes can be illustrated by the several studies that used data from the Lower Rio Grande Valley in Texas. These studies demonstrate the evolution of methodology and data from the use of single equation regression models (Bastida and Pagán, 2002) to the use of IV methods (Brown, Pagán, et al., 2005) and—finally—biometric data on blood glucose values (Brown, Perez, et al., 2011). While the first two methods allowed the investigation of the general effect of diabetes on employment chances, the latter was able to assess the impact according to how diabetes was managed by the patient, as proxied

by the measured biomarkers. The study found that the main adverse effect was due to having diabetes regardless of how it was managed and that improvements in management only had minor positive effects. The authors concluded that investments in the prevention of diabetes would likely be more effective than improved diabetes management.

The latter study and the study by Liu and Zhu (2014) also show how biometric data (e.g. blood glucose values) can be used to arrive at a deeper understanding of the economic effects of diabetes. Biometric information makes it possible to investigate the impact of diabetes according to the severity of the disease and also allows for the consideration of previously undiagnosed people with diabetes, increasing the policy relevance of the research.

2.4.3 Comparison of COI and labour market studies: common themes and lessons learned

The results of both fields, COI and labour market studies, show a considerable adverse impact of diabetes in terms of costs to society, health systems, individuals and employers and in terms of a reduction in the productive workforce and productivity in general. Both research strands particularly indicate that the adverse effects of diabetes increase with diabetes duration as well as with the severity of the disease, judged by the high complication costs estimated in COI studies and the larger employment and income penalties for those with a longer disease duration or higher blood glucose levels.

Nonetheless, several lessons can be learned for each field from advancements in the other field. Future COI studies would, for instance, benefit from the more frequent use of biomarker data. This would allow for a more precise analysis of the costs of diabetes according to the severity of the disease and help inform researchers and policy makers about the possible economic effects of achieving certain treatment goals, e.g., a reduction in blood glucose values.

Also, and in contrast to the labour market outcomes literature, the endogeneity problem has hitherto not been addressed in any form in studies estimating direct healthcare or productivity costs, despite it being an equally important challenge in this domain. A possible bias could arise if some people developed diabetes as a result of an unobserved accident or illness, likely resulting in an overestimation of the costs. Endogeneity could also be introduced if people with diabetes became poorer as a result of the disease and consequently were not able to spend as much on their treatment as they would like to, leading to an underestimation of the true monetary cost of diabetes. Furthermore, an endogeneity bias would be introduced if diabetes was correlated with poverty so that diabetes prevalence

would be disproportionately high in subgroups with less resources and consequently less access to care. This would lead to an underestimation of the healthcare costs of diabetes. Endogeneity in COI studies has recently been addressed for the estimation of healthcare costs of obesity, suggesting that direct costs would have been underestimated, had the study not accounted for endogeneity (Cawley and Meyerhoefer, 2012). It appears that, on the basis of the studies identified in our review, a similar—worthwhile—approach could and should be applied to the case of type 2 diabetes.

Yet the labour market studies also stand to gain from adopting certain approaches that are more common in COI studies. To date, only few labour market studies have used the incidence approach found for COI studies to follow people with diabetes over a certain time period from their diagnosis onwards, in order to further explore how the effect of diabetes on employment and productivity measures develops over time.

Some further recommendations may be derived for future COI and labour market studies on diabetes:

1. For COI studies the estimation of incremental costs—wherever possible—appears to be most suitable for diabetes, as it more accurately accounts for costs of co-morbidities and for less obviously related disease costs (Honeycutt et al., 2009; Tunceli, Wade, et al., 2010). More information that can guide researchers in their choice of methods already exists and should be referred to when performing a COI study (Akobundu et al., 2006).

2. If possible, the use of convenience samples of people with diabetes visiting a health care institution should be avoided, particularly in LMICs, as it excludes those not able or willing to visit a clinic for treatment due to economic reasons, leaving out a potentially important proportion of diabetes patients.

3. The interpretation of the COI results always hinges on the amount of information provided about, among others, the aim of the study, the perspective adopted and the cost components included as well as the estimation approach used. A discussion of how these choices might affect the estimates should also be part of every COI study. Researchers should therefore consult available guidance from the literature that sets out what information should ideally be included in a COI study (Larg and Moss, 2011) to increase the transparency and usability of their research.

4. For labour market studies more evidence from LMICs is needed. There is scope for for exploring existing household datasets from LMICs that contain information on diabetes (Seuring et al., 2014). In some cases, panel data are (or may come)

available, which would allow the investigation of the effects of diabetes over time as well as to improve the degree of causal inference by controlling for unobserved heterogeneity.

5. As for labour market studies, other ways of achieving identification should be explored to reduce the reliance on IV methods using the family history of diabetes as the sole instrument. The increasing richness of information provided in recent data sets could be used to this effect, also taking into account other quasi-experimental econometric methods (Craig et al., 2012).

2.4.4 Limitations

A possible limitation of this review is the decision to refrain from excluding studies based on certain quality criteria, such as study design, costing methodology, sample size or reporting standards. This might have resulted in the inclusion of lower quality studies with less reliable estimates, compromising the comparability across countries, particularly between LMICs and HICs, as study designs differed considerably. On the other hand our overarching objective was to ensure a truly globally comprehensive overview of the literature on the economic impact of diabetes, including evidence from LMICs, which, for reasons often beyond the control of the researchers, may have been of limited quality and thus would have been excluded, had we applied stringent quality benchmarks. Further, any attempt to apply a quality threshold would have faced the challenge of dealing with the absence of a formal checklist to follow in critically appraising the quality of COI studies. Rather than interpreting it as a limitation, we see the identification and synthesis of LMIC studies as a unique added value of this review, when compared to the Ettaro et al. (2004) review.

Notably, we also abstained from any language restrictions, which would have particularly excluded evidence from Spanish speaking and Eastern European countries. Taken together, these factors have resulted in a large number of included studies, allowing for an (albeit exploratory) statistical investigation of the heterogeneity in diabetes cost estimates as a complement to the narrative analysis. We therefore feel that the advantages of refraining from too stringent inclusion criteria more than outweigh the possible negative consequences of including potentially lower-quality studies.

Further, our search was limited to studies after the year 2000. While for COI studies a previous review covered the literature until 2000, this is not the case for the literature on labour market effects of diabetes and we therefore cannot exclude the possibility of having missed some relevant (if old) studies. We have checked the references of our included

labour market studies for any relevant studies published before 2001. We could find only one relevant study from 1998 investigating how employment chances and family income were affected by diabetes in the USA, comparing samples from 1976, 1988 and 1992 and finding significant adverse effects of diabetes on employment chances but not on family income (Kahn, 1998). The effect for women decreased somewhat between 1976 and 1992, while the effect increased for men. The study did not account for the possible endogeneity of diabetes nor selection bias when estimating the effects on income.

2.5 Conclusion

This review has provided an updated and considerably expanded picture of the literature on the global economic impact of type 2 diabetes. The results show a considerable impact of diabetes in terms of costs to society, health systems, individuals and employers and in terms of a reduction in the productive workforce and productivity in general. Studies on the costs of diabetes now provide evidence from HICs as well as LMICs, using a variety of study designs to estimate the costs of diabetes. The evidence indicates a particularly strong and direct economic impact of type 2 diabetes on people's livelihoods in lower-income settings. Studies on labour market outcomes so far have been confined, almost exclusively, to HICs, leaving space for further studies in LMICs to provide additional evidence of the effect of diabetes in these countries. An issue not yet covered in diabetes COI studies—in striking contrast to labour market outcome studies—has been the possible bias introduced by endogeneity, providing an opportunity for advancing research in this area.

What is endogeneity?

Endogeneity is a statistical problem that occurs in regression models if the assumptions about the flow or direction of causality are incorrect. If endogeneity is ignored, it could be that claims about causality between two variables or the magnitude of the effect are false. In general, one can only be certain about a causal relationship of the effect of x on y if the following three conditions are met (Antonakis et al., 2012):

- y follows x temporally
- y changes as x changes (and this relationship is statistically significant)
- no other causes should eliminate the relation between x and y.

There are three major causes of endogeneity that violate the conditions above.

1. Omitted variables When a regression is run to determine the causal effect of variable x on variable y, but there are unobserved variables that affect variables x or x and y simultaneously, the estimated effect of x on y will be biased. For the case of type 2 diabetes and employment chances, there is the danger that, e.g., personal traits like ambition, which are hard to observe, could influence the probability of developing type 2 diabetes through their effect on a person's lifestyle, but they could also simultaneously affect the chances of employment through their influence on a person's determination to find work or to perform well at work. If we are not able to control for this, then our estimate of the effect of diabetes on employment chances might, at least partially, represent the effect of personal traits on employment chances. As a result, our estimate of the effect of diabetes is biased and does not represent the true size of the relationship between the two variables.

2. Simultaneity Simultaneity is present if our outcome variable y and our variable of interest x influence each other simultaneously, so that y not only is affected by x but x is also affected by y. In the case of type 2 diabetes and labour market outcomes, not only diabetes could influence employment chances or work related income, but also resulting changes in lifestyle due to employment or an increase in income could affect the probabilities of developing diabetes. Due to an increase in income people could change their diet or change towards a less active lifestyle which in turn would make them more likely to develop type 2 diabetes.

3. Measurement error Measurement errors occur when the independent variable x is imprecisely measured. Here this would be the case if people in a survey did not remember if they have been diagnosed with type 2 diabetes and gave a wrong answer.

There are several solutions to the problem of endogeneity, but only using IV techniques has the potential to deal with all three causes of endogeneity at once. Endogeneity is a problem, because the variable of interest, here diabetes, is correlated with the error term of the estimated model, which includes all omitted variables as well as the effect of y on x and if measurement error is present, the true values. To do this, one needs to find a suitable instrument that needs to fulfil the following conditions:

- it has to be causally related to the endogenous variable x and
- it should not be correlated to the dependent variable y other than through its correlation with x.

This instrument is then used in a first regression to obtain predicted values of the problematic endogenous regressor. Because the instrument is not correlated with the error term, these predicted values of the endogenous variable will be uncorrelated as well and can then be used in a second regression to predict the dependent variable y. The estimated coefficients of this second stage can then be regarded as consistent estimates.

In the case of type 2 diabetes and labour market outcomes, an instrument has to predict the development of diabetes without being otherwise causally related to any of the labour market outcomes, be it employment chances, wages or some other measure of productivity. The instrument of choice so far has been the family history of diabetes. It has been shown that a considerable part of the risk of developing type 2 diabetes is hereditary (Hemminki et al., 2010; Herder and Roden, 2011; The Interact Consortium, 2013). This fact is exploited when the instrument is used and it is assumed that this is the only pathway through which a family history of diabetes affects a person's diabetes risk, and also that, e.g., parental diabetes does not affect the person's labour market outcomes directly.

The most common estimation techniques for the estimation of IV regressions are the linear IV model and the bivariate probit model. The latter is often deemed more apt for models where both the outcome as well as the instrumental variable are binary, so either 0 or 1, which is the case for employment as an outcome variable as well as diabetes family history as an instrument. Nonetheless, there is some discussion in the econometrics literature regarding the best method to estimate these cases, as it also has been argued that because the linear IV technique does not depend on the assumption of normality of the error terms, in contrast to the bivariate probit model, its results are more reliable in the case of non-normality, but can sometimes lead to imprecise estimators which can no longer be interpreted meaningfully (Chiburis et al., 2012). Both methods can be found in the reviewed papers.

Country codes

Table 2.7: Country Codes

Country	Country code	Country	Country code
35 developing countries	LMIC	Jamaica	JAM
Argentina	ARG	Japan	JPN
Australia	AUS	Latin America and Caribbean	LAC
Bahamas	BHS	Mexico	MEX
Barbados	BRB	Netherlands	NLD
Belgium	BEL	Nicaragua	NIC
Bolivia	BOL	Nigeria	NGA
Brazil	BRA	Norway	NOR
Canada	CAN	Pakistan	PAK
Chile	CHL	Panama	PAN
China	CHN	Paraguay	PRY
Colombia	COL	Peru	PER
Costa Rica	CRI	Serbia	SRB
Cuba	CUB	Spain	ESP
Czech Republic	CZE	Sudan	SDN
Denmark	DNK	Sweden	SWE
Dominican Republic	DOM	Switzerland	CHE
Ecuador	ECU	Taiwan	TWN
El Salvador	SLV	Thailand	THA
Europe	EUR	The Bahamas, Barbados, Jamaica, Trinidad and Tobago	CARICOM
France	FRA	Trinidad and Tobago	TTO
Germany	DEU	United Arab Emirates	ARE
Guatemala	GTM	United Kingdom	GBR
Guyana	GUY	United States	USA
Haiti	HTI	Uruguay	URY
Honduras	HND	Venezuela	VEN
Hong Kong	HKG	WHO African Region	AFR

Table 2.7: Country Codes

Country	Country code	Country	Country code
India	IND		
Iran, Islamic Rep.	IRN		
Ireland	IRL		
Israel	ISR		
Italy	ITA		

Table 2.8: COI study characteristics and cost estimates

Ref.	Horizon	Country	Sample size	Population	Perspective	Approach	LCU	Aggregate costs (mill. $)			Per capita costs			
								Total	Direct	Indirect	Direct (LCU)	Direct ($)	Indirect (LCU)	Indirect ($)
Smith-Spangler et al. (2012)	2002–2003	35 LMIC	121051	General pop.	Patient	RB/M	$				3 at 50th percentile to 157 at 95th percentile	3.40 at 50th percentile to 178 at 95th percentile		
Boutayeb and Boutayeb (2014)	NA	Various Arab countries	NA	General pop.	Healthc. system	SAM	USD				UDD 529[j]			
Barceló et al. (2003)	2000	ARG	1250300	General pop.	Societal	SAM	ARS	16547	1130	15416[b]	597[a]	904[a]	8145[a]	12330[a]
Davis et al. (2006)	2000–2051	AUS	1294	General pop.	Healthc. system	SDS	AUD		1514 (2000), 2282 (2051)		3496[a] (2000)	3379[a] (2000)		
Barceló et al. (2003)	2000	BHS	12800	General pop.	Societal	SAM	BSD	43	25.2	16	1605	2507	1009	1575
Abdulkadri et al. (2009)	2001	BHS	10435	General pop.	Societal	SDS	BSD	233	17	216[b]	836[a]	1310[a]	10789[a]	16914[a]
Abdulkadri et al. (2009)	2001	BRB	28438	General pop.	Societal	SDS	BBD	75	69.2	5	2455	2433	204	202

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Ref.	Horizon	Country	Sample size	Population	Perspective	Approach	LCU	Aggregate costs (mill. $)			Per capita costs			
								Total	Direct	Indirect	Direct (LCU)	Direct ($)	Indirect (LCU)	Indirect ($)
Barceló et al. (2003)	2000	BRB	23300	General pop.	Societal	SAM	BBD	307	26	281[b]	1099[a]	1117[a]	11880[a]	12076[a]
Jönsson (2002)	1999	BEL	735 patients	General pop.	Healthc. system	SAM	EUR		1561		3295	4704		
Jönsson (2002)	1999		7000 (overall)	General pop.	Healthc. system	SAM	EUR				2834	Not possible because no country specific estimate		
Barceló et al. (2003)	2000	BOL	153900	General pop.	Societal	SAM	BOB	901	338	563[b]	3435[a]	2199[a]	5717[a]	3659[a]
Barceló et al. (2003)	2000	BRA	4532600	General pop.	Societal	SAM	BRL	54892	9598	45294[b]	1595[a]	2118[a]	1595[a]	9993[a]
Lau et al. (2011)	2008–2035	CAN	147498 with diabetes	Four Alberta Health and Wellness databases	Healthc. system	SAM	CAD		5934 (2007); 20032 (2035)		4563[a]	4023[a]		

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Ref.	Horizon	Country	Sample size	Population	Perspective	Approach	LCU	Aggregate costs (mill. $)			Per capita costs			
								Total	Direct	Indirect	Direct (LCU)	Direct ($)	Indirect (LCU)	Indirect ($)
Pohar, Majumdar, et al. (2007)	1993–2001	CAN	57774	Saskatchewan Canadians (excluding Indians)	Healthc. system	SAM	CAD				large urban: 3563 (1993), 3454 (2001), small urban:3321 (1993), 3427(2001), rural:3368 (1993), 3289 (2001)	large urban: 2665 (1993), 3591 (2001), small urban: 3453 (1993), 3563 (2001), rural: 3502 (1993), 3420 (2001)		

Table 2.8: COI study characteristics and cost estimates

Ref.	Horizon	Country	Sample size	Population	Perspective	Approach	LCU	Aggregate costs (mill. $)			Per capita costs			
								Total	Direct	Indirect	Direct (LCU)	Direct ($)	Indirect (LCU)	Indirect ($)
Pohar and Johnson (2007)	2001	CAN	5284 (Indians) + 41630 (general pop.) with diabetes, 11692 (Indians) + 98680 (general pop.) without diabetes	Registered Indians according to the Indian Act	Healthc. system	RB/M	CAD				Excess costs: Indians 2227, General pop. 2378 (total costs with diabetes: 3,622 for Indians/ 3253 in general pop., controls: 1,395 for Indians/ 875 for general pop.)	Excess costs: Indians 2316, General pop. 2473: (total costs with diabetes: 3766 for Indians/ 3382 in general pop., controls: 1450 for Indians/ 910 for general pop.)		
Barceló et al. (2003)	2000	CHL	496500	General pop.	Societal	SAM	CLP	5890	719	5171[b]	320601[a]	1447[a]	2307131[a]	10416[a]

Table 2.8: COI study characteristics and cost estimates

Ref.	Horizon	Country	Sample size	Population	Perspective	Approach	LCU	Aggregate costs (mill. $)			Per capita costs			
								Total	Direct	Indirect	Direct (LCU)	Direct ($)	Indirect (LCU)	Indirect ($)
Wang, Fu, Zhuo, et al. (2010)	2007	CHN	1478	T2D patients in these Chinese hospitals	Healthc. system	Survey	RMB				4564 (median), 7926 (mean)	1246 (median), 2164 (mean)		
Wang, McGreevey, et al. (2009)	2007 and 2030 (projection)	CHN	2040	In-patients and out-patients with DM in 20 hospitals	Societal	Survey	RMB	72916 (2007), 132472 (2030)	67946 (2007), 123187 (2030)	4982 (2007), 9058 (2030)	11555	3401	1586	467
Yang, Zhao, et al. (2012)	2009–2010	CHN	1232 (diabetes), 1201 (no diabetes)	General pop.	Healthc. system	RB/M	RMB				4135 (3.38 times greater than controls)	1136 (3.38 times greater than controls)		
Wang, Fu, Pan, et al. (2009)	2007	CHN	2054	T2D patients in these Chinese hospitals	Healthc. system	Survey	RMB				4800 (median), 10164 (mean)	1412 (median), 2991 (mean)		

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Ref.	Horizon	Country	Sample size	Population	Perspective	Approach	LCU	Aggregate costs (mill. $)			Per capita costs			
								Total	Direct	Indirect	Direct (LCU)	Direct ($)	Indirect (LCU)	Indirect ($)
extcite-Gonzalez2009b	32 years	COL	NA	Hypothetical average Columbian type 2 DM patient	Societal	SAM	COP	5.3	1.8	3.5	611750	570	1187000	1106
Barceló et al. (2003)	2000	COL	937700	General pop.	Societal	SAM	COP	7737	1241	6496[b]	923826[a]	1323[a]	4836001[a]	6928[a]
Barceló et al. (2003)	2000	CRI	154900	General pop.	Societal	SAM	CRC	1026	210	817[b]	192194[a]	1353[a]	749278[a]	5274[a]
Barceló et al. (2003)	2000	CUB	592400	General pop.	Societal	SAM	CUP	1721	923	798[b]	1219[a]	1558[a]	1054[a]	1347[a]
Horak (2009)	2007	CZE		Insured in health-care system (63.1% of pop.)	Healthc. system	SAM	CHK		190					
Gyldmark and Morrison (2001)	1993	DNK	948	General pop.	Societal	WTP	DKK						1128 (mean), 300 (median)	191 (mean), 51 (median)
Barceló et al. (2003)	2000	DOM	254100	General pop.	Societal	SAM	DOP	1410	509	901[b]	14580[a]	2003[a]	25801[a]	3545[a]

Table 2.8: COI study characteristics and cost estimates

Ref.	Horizon	Country	Sample size	Population	Perspective	Approach	LCU	Aggregate costs (mill. $)			Per capita costs			
								Total	Direct	Indirect	Direct (LCU)	Direct ($)	Indirect (LCU)	Indirect ($)
Barceló et al. (2003)	2000	ECU	267300	General pop.	Societal	SAM	USD	2830	1104	1727[b]	873[a]	4129[a]	1366[a]	6460[a]
Barceló et al. (2003)	2000	SLV	219400	General pop.	Societal	SAM	SVC	1385	381	1004[b]	626[a]	1737[a]	1650[a]	4577[a]
Honkasalo et al. (2014)	2005–2010	FIN	1890 with T2D	People with T2D in two cities in Finland	Healthc. system	SDS	EUR				1038	1087		
Ricordeau et al. (2003)	1998, 2000	FRA	704423 (1998), 1145603 (2000) with diabetes	Metropolitan France	Healthc. system	RB/M	EUR		2784 (1998), 3268 (2000)		1529 (1998), 1655 (2000)	2107 (1998), 2241 (2000)		
Jönsson (2002)	1999	FRA	751 patients	General pop.	Healthc. system	SAM	EUR		5478		3064	4214		
Jönsson (2002)	1999	DEU	809 patients	General pop.	Healthc. system	SAM	EUR		1653		3576	4752		
Köster, Ferber, et al. (2006)	2001	DEU	306736 (26971 with diabetes)	General pop.	Societal	RB/M	EUR		Excess: 19364 (total: 40650)		Excess 2507 (total 5262)	Excess: 3329 (total: 6987)	Excess 1328 (total: 5019)	Excess: 1763 (total: 6664)
Köster, Huppertz, et al. (2011)	2000–2007	DEU	320000 (2000) to 275000 (2007)	AOK Hessen	Healthc. system	RB/M	EUR		17299 (2000), 25614 (2007)		2400 (2000), 2605 (2007)	3493 (2007), 3218 (2000)		

Table 2.8: COI study characteristics and cost estimates

Ref.	Horizon	Country	Sample size	Population	Perspective	Approach	LCU	Aggregate costs (mill. $)			Per capita costs			
								Total	Direct	Indirect	Direct (LCU)	Direct ($)	Indirect (LCU)	Indirect ($)
Martin et al. (2007)	1995–2003	DEU	3268	Newly diagnosed T2D patients	Healthc. system	SAM	EUR				3210	4075		
Köster, Schubert, et al. (2012)	2000–2009	DEU	not given, only DM patients stated (30472)	AOK Hessen	Healthc. system	RB/M	EUR		21230 (2000), 26226 (2009)		2779 (2000), 2611 (2009)	3471 (2000), 3261 (2009)		
Barceló et al. (2003)	2000	GTM	368700	General pop.	Societal	SAM	GTQ	2535	878	1657[b]	6131[a]	2382[a]	11572[a]	4495[a]
Barceló et al. (2003)	2000	GUY	28400	General pop.	Societal	SAM	GYD	141	80	62[b]	131041[a]	2800[a]	102135[a]	2182[a]
Barceló et al. (2003)	2000	HTI	79500	General pop.	Societal	SAM	HTG	249	152	97[b]	12782[a]	1912[a]	8175[a]	1223[a]
Barceló et al. (2003)	2000	HND	193000	General pop.	Societal	SAM	HNL	772	366	405[b]	8750[a]	1898[a]	9680[a]	2100[a]

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Ref.	Horizon	Country	Sample size	Population	Perspective	Approach	LCU	Aggregate costs (mill. $)			Per capita costs			
								Total	Direct	Indirect	Direct (LCU)	Direct ($)	Indirect (LCU)	Indirect ($)
Chan, Tsang, et al. (2007)	2004	HKG	147	T2D patients attending the DM outpatient clinic at a public hospital	Societal	Survey	USD				11638	2288	1817[e]	357[e]
Ramachandran, Ramachandran, et al. (2007)	1998, 2005	IND	556 with T2D (urban=309, rural= 247)	T2D patients in India	Patient	Survey	INR				Median values: 10000 (urban), 6260 (rural)	Median values: 773 (urban), 484 (rural)		
Tharkar et al. (2010)	2009	IND	718	Diabetes patients in Chennai city	Societal	Survey	INR		268		25391 (median)	1557 (median)	4970 (median)	305 (median)
Javanbakht et al. (2011)	2009	IRN	4500	Diabetes patients from Tehran and Fars province	Societal	Survey	IRR	9611[h]	5187[h]	4420[h]	8358592	2142	8578816	2199

Table 2.8: COI study characteristics and cost estimates

Ref.	Horizon	Country	Sample size	Population	Perspective	Approach	LCU	Aggregate costs (mill. $)			Per capita costs			
								Total	Direct	Indirect	Direct (LCU)	Direct ($)	Indirect (LCU)	Indirect ($)
Esteghamati et al. (2009)	2004, 2005	IRN	710 (T2D), 904 (controls)	Pop. in Teheran	Societal	RB/M	IRR	401 (Teheran); 2117[h] (Iran)	327 (Teheran); 1727[h] (Iran)	74 (Teheran), 390[h] (Iran)	876622 (Teheran)	443 (Teheran)	200146 (Teheran)	101 (Teheran)
Nolan et al. (2006)	1999	IRL	701	T2D patients of four Irish hospitals	Healthc. system	SAM	EUR				2469	2867		
Chodick et al. (2005)	2001	ISR	24632	Insured patients in HMO	Healthc. system	RB/M	ILS		433		6002 (2001), 3926 (1999)	1950 (2001), 1275 (1999)		
Lucioni et al. (2003)	1998	ITA	1263	T2D patients from randomly drawn practices across Italy	Societal	SAM	EUR	8289[d]	7930	359	2991	4588	135[ac]	208[ac]
Bruno et al. (2012)	2003–2004	ITA	33792 (diabetes) and 863123 (no diabetes)	Turin pop.	Healthc. system	RB/M	EUR				2465 (3361 (diabetes), 896 (no diabetes)	3328 (4537 (diabetes), 1210 (no diabetes)		

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Ref.	Horizon	Country	Sample size	Population	Perspective	Approach	LCU	Aggregate costs (mill. $)			Per capita costs			
								Total	Direct	Indirect	Direct (LCU)	Direct ($)	Indirect (LCU)	Indirect ($)
Morsanutto et al. (2006)	2001–2002	ITA	299	T2D patients who visited a diabetologic center in Italy (DC)	Healthc. system	SAM	EUR				1910	2823		
Marchesini et al. (2011)	2006	ITA	311979	People with DM at 22 local health districts	Healthc. system	RB/M	EUR				2589	3296		
Abdulkadri et al. (2009)	2001	JAM	186036	General pop.	Societal	SDS	JMD	556	454	102	44647	2439	10046	549
Barceló et al. (2003)	2000	JAM	181400	General pop.	Societal	SAM	JMD	1037	345	693[a]	32251[a]	1901[a]	64787[a]	3818[a]
Nakamura et al. (2008)	1990–2001	JPN	4535	Community dwelling in Shiga	Healthc. system	SAM	JPY				189060 (diabetes), 99900 (non-diabetes)	1674 (diabetes), 884 for (non-diabetes)		

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								Total	Direct	Indirect	Direct (LCU)	Direct ($)	Indirect (LCU)	Indirect ($)
Barceló et al. (2003)	2000	LAC	Diabetes prevalence of 15.2 million	Pop. from all countries in Latin America and Caribbean	Societal	SAM	USD	82304	13529	68774[b]	703[a]	887[a]	3576[a]	4512[a]
Barceló et al. (2003)	2000	MEX	3738000	General pop.	Societal	SAM	MXN	30677	4006	26671[b]	4994[a]	1072[a]	33249[a]	7135[a]
Arredondo, Zúñiga, and Parada (2005)	2004, 2006	MEX	951417 estimated cases	All users of health care in public institutions	Societal	SAM	MXN	290[d]	229	61k	1472[a]	242[a]	386[a]	64[a]
Arredondo and De Icaza (2011a)	2010	MEX	Whole pop.	Population demanding services at Mexican healthcare institutions for T2D	Societal	SAM	MXN	1066	470	596	4016[a]	485[a]	5090[a]	610[a]

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								Total	Direct	Indirect	Direct (LCU)	Direct ($)	Indirect (LCU)	Indirect ($)
Arredondo and Barcelo (2007)	2005	MEX	Whole pop.	General pop.	Patient	SAM	MXN		284 OOP expenditures (52% of overall expenditures)					
Arredondo and Zúñiga (2004)	2003, 2005	MEX	Whole pop.	General pop. using public healthcare institutions	Societal	SAM	MXN	532 (2005)	235 (2005)	297 (2005)	1467[a] (2005)	263[a] (2005)	1852[a] (2005)	331[a] (2005)
Rodríguez Bolaños et al. (2010)	2002, 2004	MEX	497	IMSS insured	Healthc. system	SDS	MXN		661 (2004)		35622[a] (2004)	4672[a] (2004)		
Redekop et al. (2002)	1998	NLD	1371 with T2D	T2D patients in the Netherlands	Societal	SAM	NLG	1014[d]	953	61	4023	2780	282[a]	195[a]
Linden et al. (2009)	2000–2004	NLD	2.5 million (641200 with diabetes)	Dutch people with diabetes	Healthc. system	SDS	EUR		571 (2000), 1063 (2004)		974 (2000), 1283 (2004)	1259 (2000), 1658 (2004)		

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								Total	Direct	Indirect	Direct (LCU)	Direct ($)	Indirect (LCU)	Indirect ($)
Jönsson (2002)	1999	NLD	909 patients	General pop.	Healthc. system	SAM	EUR		671		1827	2761		
Barceló et al. (2003)	2000	NIC	136100	General pop.	Societal	SAM	NIO	442	292	150[b]	7922[a]	2145[a]	4082[a]	1105[a]
Suleiman et al. (2006)	July 2003–June 2004	NGA	35	Diabetes patients in outpatient clinic in Nigeria	Patient	SDS	NGN				29366	662		
Solli et al. (2010)	2005	NOR	4.6 million from register data of entire pop.	General pop.	Societal	SDS	NRK	319	242	76	20492[a]	2061[a]	5067[a]	650[a]
Khowaja et al. (2007)	2006	PAK	345	Diabetes patients in Karachi	Societal	Survey	PKR				11580[f]	620[f]	840[e]	45[e]
Barceló et al. (2003)	2000	PAN	120500	General pop.	Societal	SAM	PAB	926	222	704[b]	866[a]	1846[a]	2741[a]	5840[a]
Barceló et al. (2003)	2000	PRY	94300	General pop.	Societal	SAM	PYG	738	244	495[b]	2661903[a]	2587[a]	5397747[a]	5245[a]

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								Total	Direct	Indirect	Direct (LCU)	Direct ($)	Indirect (LCU)	Indirect ($)
Barceló et al. (2003)	2000	PER	606800	General pop.	Societal	SAM	PEN	5627	1533	4094[b]	2890[a]	2526[a]	7717[a]	6746[a]
Lesniowska et al. (2014)	2009	POL	Whole pop.	All Polish diabetes patients	Healthc. system	SAM	RSD	3396	1910	1486				
Biorac et al. (2009)	2007	SRB	99	T2D patients in health centre in Svilajnac	Societal	Survey	RSD	7579[h]			47865	1610	5548	187
Bjegovic et al. (2007)	2002	SRB	360433 people with T2D in Serbia	Serbian T2D patients	Healthc. system	SAM	RSD		280		12457[a]	761[a]		
Mata et al. (2002)	1998	ESP	1004	Diabetes patients from 29 primary healthcare centres	Healthc. system	SDS	EUR				771	1488		
Ballesta et al. (2006)	1999	ESP	517	People with DM in region of Cadiz	Societal	SDS	EUR				2560	4690	1844	3379

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								Total	Direct	Indirect	Direct (LCU)	Direct ($)	Indirect (LCU)	Indirect ($)
Oliva et al. (2004)	2002	ESP	1675304 to 2010365 depending on assumed prevalence	Diabetes patients in National Health System	Healthc. system	SAM	EUR		4010 (6% prev.)– 4461 (5% prev.)		1290 (6% prev.)– 1476 (5% prev.)	2155 (6% prev.)– 2466 (5% prev.)		
Jönsson (2002)	1999	ESP	1004 patients	General pop.	Healthc. system	SAM	EUR		3679		1305	2453		
Bastida, Aguilar, et al. (2002)	1998	ESP	Whole pop. (exact number not given)	Canary Island pop. with diabetes	Societal	SDS	Pts (pre Euro)	75	47	28	78240	907	47928[b]	556[b]
Elrayah-Eliadarous et al. (2010)	2005	SDN	822	Patients with T2D in Khartoum state in Sudan	Patient	Survey	USD				438	456		
Bolin et al. (2009)	1987 and 2005	SWE	Whole pop.	General pop.	Societal	SDS	SEK	499 (1987), 1045 (2005)	223 (1987), 383 (2005)	276 (1987), 662 (2005)	12102 (1987), 12287 (2005)	1484 (1987), 1507 (2005)	15000[a] (1987), 21253[a] (2005)	1840[a] (1987), 2606[a] (2005)
Norlund et al. (2001)	1993	SWE	70786 (1677 with diabetes)	Southern Sweden	Societal	RB/M	SEK				19411	2855	14777	2174

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								Total	Direct	Indirect	Direct (LCU)	Direct ($)	Indirect (LCU)	Indirect ($)
Wiréhn et al. (2008)	2005	SWE	415990 (19226 with diabetes)	Whole Östergötland population	Healthc. system	RB/M	EUR				18293	2243		
Jönsson (2002)	1999	SWE	773 patients	General pop.	Healthc. system	SAM	SEK		929		24927	3319		
Ringborg et al. (2008)	2004	SWE	8230	Diabetes patients in Uppsala county	Healthc. system	SAM	SEK				33210	3888		
Schmitt-Koopmann et al. (2004)	1998	CHE	1479	T2D patients from randomly drawn practices across Switzerland	Healthc. system	SDS	CHF		561		3004	2030		
Lin et al. (2004)	1998–1999	TWN	20757185 (in 1998), 21089859 (in 1999)	People with DM in National Health Insurance	Healthc. system	SDS	TWD				62617 (1998), 60775 (1999)	3499 (1998), 3396 (1999)		

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Ref.	Horizon	Country	Sample size	Population	Perspective	Approach	LCU	Aggregate costs (mill. $)			Per capita costs			
								Total	Direct	Indirect	Direct (LCU)	Direct ($)	Indirect (LCU)	Indirect ($)
Chang (2010)	2006–2007	TWN	498	Diabetes patients in outpatient clinics in northern Taiwan	Societal	WTP	TWD			4003			68118	4004
Chi et al. (2011)		TWN	16094	Elderly with DM in Taiwan	Healthc. system	SAM			51		111982	6338		
Chatterjee et al. (2011)	2008	THA	475	Diabetes patients treated in district hospital	Societal	Survey	TWD				17638	1082	10569	649
Barceló et al. (2003)	2000	TTO	71300	Pop. from all countries in Latin America and Caribbean	Societal	SAM	TTD	540	72	468[b]	3358[a]	1011[a]	21780[a]	6560[a]

Table 2.8: COI study characteristics and cost estimates

Ref.	Horizon	Country	Sample size	Population	Perspective	Approach	LCU	Aggregate costs (mill. $)			Per capita costs			
								Total	Direct	Indirect	Direct (LCU)	Direct ($)	Indirect (LCU)	Indirect ($)
Abdulkadri et al. (2009)	2001	TTO	135093	General pop.	Societal	SDS	TTD	852	227	625	5722	1677	15797	4628
Al-Maskari et al. (2010)	2004	ARE	150	Diabetes patients in Al-Ain District	Healthc. system	Survey	AED				no complication: 5906, with complications: 20774, overall: 16115	no complications: 2047, with complications: 7199, overall: 5585		
Jönsson (2002)	1999	GBR	756 patients	General pop.	Healthc. system	SAM	GBP		244		1558	3065		
Dall, Zhang, et al. (2010)	2007	USA	Diabetes prevalence of 16.5 million	General pop.	Societal	SDS	USD	167862	111257	56604	6414	6751	3263	3434
Buescher et al. (2010)	1998	USA	127991	Medicaid pop.	Healthc. system	SDS	USD		540		4098	4221		

Table 2.8: COI study characteristics and cost estimates

Ref.	Horizon	Country	Sample size	Population	Perspective	Approach	LCU	Aggregate costs (mill. $)			Per capita costs			
								Total	Direct	Indirect	Direct (LCU)	Direct ($)	Indirect (LCU)	Indirect ($)
Dall, Nikolov, et al. (2003)	2002	USA	Diagnosed DM prevalence of 12.1 million	General pop.	Societal	SDS	USD	161896	112947	48948	7601[a]	9346[a]	3294[a]	4050[a]
Druss et al. (2001)	1996	USA	23200	General pop.	Societal	Survey	USD	78518	13768	4771	1097	1495	380[ac]	518[ac]
Durden et al. (2009)	2000, 2005	USA	21592 (2000), 127254 (2005)	Employees of large, privately-insured companies	Healthc. system	RB/M	USD				7365 (2000), 7327 (2005)	8349 (2000), 8306 (2005)		
Trogdon and Hylands (2008)	2000–2004	USA	3790 (diabetes), 42413 (no diabetes)	General pop.	Healthc. system	RB/M	USD				5035[i]	5708[i]		
Brandle et al. (2003)	2000	USA	1364	People with T2D enrolled in managed care programs	Healthc. system	SAM	USD				3715 (median)	4747 (median)		

Table 2.8: COI study characteristics and cost estimates

Ref.	Horizon	Country	Sample size	Population	Perspective	Approach	LCU	Aggregate costs (mill. $)			Per capita costs			
								Total	Direct	Indirect	Direct (LCU)	Direct ($)	Indirect (LCU)	Indirect ($)
O'Connell et al. (2012)	2005	USA	32052	American Indians in and around Phoenix, Arizona	Healthc. system	RB/M	USD				5542	6282		
Peele et al. (2002)	1996	USA	20937 with diabetes	Employed DM patients	Healthc. system	SAM	USD		126		4430 (17.9% OOP)	6039 (17.9% OOP)		
Rodbard et al. (2010)	2006	USA	3551 (diabetes), 8686 (no diabetes)	General pop.	Patient	RB/M	USD				233	264		
Honeycutt et al. (2009)	1998–2003	USA	96873 (5289 had diabetes)	General pop.	Healthc. system	SDS and RB/M	USD		61958 (regression), 43452 (attributable fraction)		4240 (regression), 2980 (attributable fraction)	4966(regression), 3490 (attributable fraction)		
Maciejewski and Maynard (2004)	1998	USA	429918	USA veterans	Healthc. system	SAM	USD		2214		3888[a]	5150[a]		

Table 2.8: COI study characteristics and cost estimates

Ref.	Horizon	Country	Sample size	Population	Perspective	Approach	LCU	Aggregate costs (mill. $)			Per capita costs			
								Total	Direct	Indirect	Direct (LCU)	Direct ($)	Indirect (LCU)	Indirect ($)
Birnbaum et al. (2003)	1997–1998	USA	3759 (diabetes), 3759 (without diabetes)	Employed and retired women	Healthc. system	RB/M	USD				5.500 for women <age 65 per year, 25000 for women >= age 65 per year, 233000 lifetime costs	6680[f] or women <age 65 per year, 30362 for women >= age 65 per year, 282973 lifetime costs		
Zhou, Isaman, et al. (2005)	10 year follow up	USA	1223 with T2D	People with DM in Michigan	Healthc. system	SAM	USD				7100 (undiscounted per year over 10 year period)	9072 (undiscounted per year over 10 year period)		
Dall, Mann, et al. (2008)	2007	USA	Diagnosed DM prevalence of 17.5 million	General pop.	Societal	SDS	USD	185682	123788	62108	6649	7095	3328	3552

Table 2.8: COI study characteristics and cost estimates

Ref.	Horizon	Country	Sample size	Population	Perspective	Approach	LCU	Aggregate costs (mill. $)			Per capita costs			
								Total	Direct	Indirect	Direct (LCU)	Direct ($)	Indirect (LCU)	Indirect ($)
Tunceli, Wade, et al. (2010)	2007	USA	256245 (T2D), 256223 (controls)	Non-institutionalized adults	Healthc. system	SDS and RB/M	USD				Matching: 4217, Disease attributable: 3002	Matching: 4500, Disease attributable: 3204		
Condliffe and Link (2014)	2007	USA	7514 with diabetes	USA pop. with positive healthcare expenditures in survey	Healthc. system	SAM	USD				11167[g]	11917[g]		
Ramsey et al. (2002)	1998	USA	8748 diabetes patients, 8748 matched controls	Employees of large, privately-insured companies	Employer	RB/M	USD				3842	5021	568	743

Table 2.8: COI study characteristics and cost estimates

Ref.	Horizon	Country	Sample size	Population	Perspective	Approach	LCU	Aggregate costs (mill. $)			Per capita costs			
								Total	Direct	Indirect	Direct (LCU)	Direct ($)	Indirect (LCU)	Indirect ($)
Lee et al. (2006)	2000	USA	984 with DM (540 white, 210 African American, 234 Hispanic)	White, African Americans and Hispanics in the USA	Healthc. system	SAM	USD				6616 (6887 if white, 6162 if African American, 5647 if Hispanic)	8453 (8799 if white, 7873 if African American, 7215 if Hispanic)		
Barceló et al. (2003)	2000	URY	119000	General pop.	Societal	SAM	UYU	1202	147	1055[b]	9619[a]	1233[a]	69171[a]	8867[a]
Barceló et al. (2003)	2000	VEN	610800	General pop.	Societal	SAM	VEF	4820	317	4503[b]	342[a]	518[a]	2100[a]	7373[a]
Kirigia et al. (2009)	2005	WHO African region	7020000	General pop.	societal	SAM	USD	28610	9090	19520	876	983	10556	11845

DM Diabetes Mellitus Healthc. System Healthcare system LCU Local currency unit Pop. Population Prev. Prevalence Ref. Reference RB/M regression based/matching SAM Sum-all medical SDS Sum-diagnosis specific.

[b] [a] Own calculation dividing presented aggregate cost estimate by number of people with diabetes in study. Total and direct cost estimates were presented in paper and indirect costs calculated, but not explicitly stated. We calculated indirect costs by deducting the presented direct costs estimate from the presented total costs estimate to arrive at an indirect costs estimate.

[c] Calculated the number of people with diabetes by dividing the aggregated direct costs and the per capita direct costs estimate as presented in the study.

[d] Calculated total costs of diabetes for papers summing up direct and indirect costs.

[e] Calculated per capita indirect costs deducting direct from total cost estimate presented in study.

[f] Costs originally presented per visit, to arrive at yearly costs had to multiply costs per visit by number of visits per year.

[g] Per capita direct costs were presented for different groups of diabetics, calculated average costs for person with diabetes by summing up and weighting costs people with diabetes + hypertension, people with diabetes + obesity, people with diabetes + obesity + hypertension.

[h] The study assumes sample would be nationally representative.

Table 2.8: COI study characteristics and cost estimates

Ref.	Horizon	Country	Sample size	Population	Perspective	Approach	LCU	Aggregate costs (mill. $)			Per capita costs			
								Total	Direct	Indirect	Direct (LCU)	Direct ($)	Indirect (LCU)	Indirect ($)

[i] Study only reported the adjusted incremental cost ratio of 2.39 compared to the average healthcare expenditures of people without diabetes of USA$3630. To calculate the incremental costs of a person with diabetes we multiplied the average healthcare expenditures of people without diabetes by the given cost ratio .

Table 2.9: COI study costing components

Ref.	Country (year of cost data)	Hospital Visits	Outpatient Visits	Physician Visits	Drugs	Laboratory	Equipment	Non-medical	Other Costs	Two main cost contributors
Smith-Spangler et al. (2012)	LMIC (2002-2003)	No breakdown of costs provided								
Kirigia et al. (2009)	AFR (2000-2005)	x	x	x	x	x	x	x	x	No exact information on share in expenditures is available
Davis et al. (2006)	AUS (1993-1996)	x	x	x	x	x	x			No exact information on share in expenditures is available
Lau et al. (2011)	CAN (1995-2007)	x	x	x						Hospital, physician
Pohar, Majumdar, et al. (2007)	CAN (1993-2001)	x	x	x	x	x	x			Hospital, medication
Ohinmaa et al. (2004)	CAN (1996)	x	x	x	x	x	x			Hospital, medication
Dawson et al. (2002)	CAN (1998)	x	x	x	x	x				No exact information on share in expenditures is available
Johnson et al. (2006)	CAN (1992-2001)	x	x	x	x					Hospital
Simpson et al. (2003)	CAN (1991-1996)	x	x	x	x					Hospital, prescription drugs
Pohar and Johnson (2007)	CAN (1991-2001)	x	x	x						Hospital

Table 2.9: COI study costing components

Ref.	Country (year of cost data)	Hospital Visits	Outpatient Visits	Physician Visits	Drugs	Laboratory	Equipment	Non-medical	Other Costs	Two main cost contributors
Wang, Fu, Zhuo, et al. (2010)	CHN (2007)	x	x	x				x		Complications, insulin therapy
Wang, McGreevey, et al. (2009)	CHN (2007)	x	x					x		Hospital, outpatient visits
Yang, Zhao, et al. (2012)	CHN (2009-2010)	x	x	x	x	x	x			Hospital, medication
Wang, Fu, Pan, et al. (2009)	CHN (2007)	x	x	x	x	x	x	x		No exact information on share in expenditures available
Camilo González et al. (2009)	COL (2007)	No breakdown of costs provided								
Horak (2009)	CZE (2007)	x	x	x	x	x	x			Hospital, medication
Honkasalo et al. (2014)	FIN (2005-2010)	x	x	x	x	x	x			
Ricordeau et al. (2003)	FRA (1998,2000)	x	x	x				x		Hospital, medication
Köster, Ferber, et al. (2006)	DEU (2001)	x	x	x	x	x	x	x		Hospital, medication
Köster, Huppertz, et al. (2011)	DEU (2000-2007)	x	x	x	x	x	x	x	x	Hospital, other services (medical devices, remedies, professional home nursing, transportation)
Martin et al. (2007)	DEU (1995-2003)	x	x	x	x	x	x			No exact information on share in expenditures available

Table 2.9: COI study costing components

Ref.	Country (year of cost data)	Hospital Visits	Outpatient Visits	Physician Visits	Drugs	Laboratory	Equipment	Non-medical	Other Costs	Two main cost contributors
Köster, Schubert, et al. (2012)	DEU (2000-2009)	x	x	x	x	x	x	x	x	Hospital, medication
Jönsson (2002)	EUR (1999)	x	x	x	x	x	x	x		Hospital, medication
Chan, Tsang, et al. (2007)	HKG (2004)	x	x	x	x	x	x	x	x	Hospital, outpatient clinic visits
Ramachandran, Ramachandran, et al. (2007)	IND (2005)	x	x	x	x	x	x			Hospital/surgery, medication
Tharkar et al. (2010)	IND (2009)	x	x	x				x		Hospital, medication
Javanbakht et al. (2011)	IRN (2009)	x	x	x	x	x	x	x	x	Complications, medication
Esteghamati et al. (2009)	IRN (2004;2005)	x	x	x	x	x	x	x		Hospital, medication and devices
Nolan et al. (2006)	IRL (1999-2000)	x	x	x	x	x				Hospital, ambulatory/drug costs
Chodick et al. (2005)	ISR (1999-2001)	x	x	x	x					Medication and lab/diagnostics
Lucioni et al. (2003)	ITA (1999)	x	x	x	x	x				Hospital, drugs
Bruno et al. (2012)	ITA (August 2003-July 2004)	x	x		x	x				Hospital, drugs
Morsanutto et al. (2006)	ITA (Jan 2001-Aug 2002)	x		x	x	x				Hospital, drugs
Marchesini et al. (2011)	ITA (1997-2006)	x		x	x	x	x			Hospital, drugs

Table 2.9: COI study costing components

Ref.	Country (year of cost data)	Hospital Visits	Outpatient Visits	Physician Visits	Drugs	Laboratory	Equipment	Non-medical	Other Costs	Two main cost contributors
Nakamura et al. (2008)	JPN (1990-2001)	No breakdown of costs provided								
Barceló et al. (2003)	LAC (2000)	x	x	x	x					Medication, complications
Arredondo, Zúñiga, and Parada (2005)	MEX (1989-2003)	x	x	x	x	x				No exact information on share in expenditures available
Arredondo and De Icaza (2011a)	MEX (1990-2008)	x	x	x	x	x				Medication, complications
Arredondo and Zúñiga (2004)	MEX (1989-2002)	x	x	x	x	x				Drugs, complications
Arredondo and Barcelo (2007)	MEX (2002-2004)	x	x	x	x	x				Drugs, complications
Rodríguez Bolaños et al. (2010)	MEX (2002-2004)	x	x	x	x	x	x		x	Hospital, administrative costs
Redekop et al. (2002)	NLD (1998)	x	x	x	x	x	x	x		Hospital, medication
Linden et al. (2009)	NLD (2000-2004)	x			x					Hospital, medication
Suleiman et al. (2006)	NGA (2003-2004)		x		x	x	x	x	x	Drugs, diagnostic tests
Solli et al. (2010)	NOR (2005)	x	x	x	x		x		x	Drugs, medical devices
Khowaja et al. (2007)	PAK (2006)		x		x	x		x		Medicine cost, laboratory costs

Table 2.9: COI study costing components

Ref.	Country (year of cost data)	Hospital Visits	Outpatient Visits	Physician Visits	Drugs	Laboratory	Equipment	Non-medical	Other Costs	Two main cost contributors
Lesniowska et al. (2014)	POL (2005-2009)	x	x	x	x	x	x			Medication, primary care
Biorac et al. (2009)	SRB (2007)	x	x	x	x	x	x			Medication, medical services (incl. ambulatory and hospital costs)
Bjegovic et al. (2007)	SRB (2002)		x	x	x	x	x			No exact information on share in expenditures available
Mata et al. (2002)	ESP (1998-1999)	x	x	x	x	x	x			Drugs, hospital
Ballesta et al. (2006)	ESP (1999)	x	x	x	x		x		x	Medication, hospital
Oliva et al. (2004)	ESP (2002)	x	x	x						Hospital, medication
Bastida, Aguilar, et al. (2002)	ESP (1998)	x	x	x	x	x				Hospital, medication
Elrayah-Eliadarous et al. (2010)	SDN (2005)		x		x	x				Outpatient clinic, drugs
Bolin et al. (2009)	SWE (1987 and 2005)	x	x		x					Hospital, drugs
Norlund et al. (2001)	SWE (1992-1993)	x	x	x				x		Hospital, home help hours
Wiréhn et al. (2008)	SWE (2005)	x	x	x						Hospital, medication
Ringborg et al. (2008)	SWE (2000-2004)	x	x		x	x	x			Hospital, outpatient visits

Table 2.9: COI study costing components

Ref.	Country (year of cost data)	Hospital Visits	Outpatient Visits	Physician Visits	Drugs	Laboratory	Equipment	Non-medical	Other Costs	Two main cost contributors
Schmitt-Koopmann et al. (2004)	CHE (1998-1999)	x	x	x						Hospital, medication
Lin et al. (2004)	TWN (1998-1999)	x	x	x	x	x				No exact information on share in expenditures available
Chi et al. (2011)	TWN (2000)	x	x							Outpatient visits
Chatterjee et al. (2011)	THA (2007-2008)	x	x		x	x		x	x	Informal care, hospitalizations
Abdulkadri et al. (2009)	CARICOM (2001)	x	x	x	x	x				Medication and lab/diagnostics
Al-Maskari et al. (2010)	ARE (2004-2005)	x	x	x	x	x				Hospital (information on other cost components not presented)
Dall, Zhang, et al. (2010)	USA (2007)	x	x	x	x	x	x	x	x	No exact information on share in expenditures available
Ramsey et al. (2002)	USA (1998)	x	x	x	x	x	x		x	Inpatient, outpatient
Buescher et al. (2010)	USA (1998)	x	x	x	x	x	x	x	x	Physician visits, hospital
Dall, Nikolov, et al. (2003)	USA (1998-2000)	x	x	x	x	x	x			Institutional care (nursing home stays, hospital), outpatient care
Druss et al. (2001)	USA (1996)	No breakdown of costs provided. Only self reported healthcare cost estimate.								

Table 2.9: COI study costing components

Ref.	Country (year of cost data)	Hospital Visits	Outpatient Visits	Physician Visits	Drugs	Laboratory	Equipment	Non-medical	Other Costs	Two main cost contributors
Durden et al. (2009)	USA (2000, 2005)	x	x	x	x	x	x			Hospital, outpatient services
Trogdon and Hylands (2008)	USA (2000-2004)	No breakdown of costs provided. Only self reported healthcare cost estimate.								
Brandle et al. (2003)	USA (2000-2001)	x	x		x	x				No exact information on share in expenditures is available
O'Connell et al. (2012)	USA (2004-2005)	x	x	x						Hospital, medication
Peele et al. (2002)	USA (1996)	x	x	x		x				No exact information on share in expenditures available
Rodbard et al. (2010)	USA (2006)	No breakdown of costs provided.								
Honeycutt et al. (2009)	USA (1998-2003)	x	x	x	x	x	x			No exact information on share in expenditures available
Maciejewski and Maynard (2004)	USA (1998)	x	x							Hospital
Birnbaum et al. (2003)	USA (1997-1998)	No breakdown of costs provided. Only self reported healthcare cost estimate.								
Zhou, Isaman, et al. (2005)	USA (2000)	x	x	x	x	x	x			No exact information on share in expenditures available

Table 2.9: COI study costing components

Ref.	Country (year of cost data)	Hospital Visits	Outpatient Visits	Physician Visits	Drugs	Laboratory	Equipment	Non-medical	Other Costs	Two main cost contributors
Dall, Mann, et al. (2008)	USA (2006)	x	x	x						Hospital, medication
Tunceli, Wade, et al. (2010)	USA (2006-2007)	x	x	x						Hospital, medication
Condliffe and Link (2014)	USA (2004-2007)	No breakdown of costs provided.								
Lee et al. (2006)	USA (2000)		x	x				x	x	Medication, ambulatory

3 The Impact of Diabetes on Employment in Mexico

Pre-amble

The systematic review in Chapter 2 identified a paucity of studies on the labour market impact of diabetes in non-high-income countries (HICs). Further, even studies on HICs did not provide much information regarding the heterogeneity of effects accross different socioeconomic subgroups. There was no evidence on how diabetes may affect those in the formal compared to the informal labour market or across the wealth distribution. Further, it was unclear what the effects were for people unaware of their disease. Chapters 3 and 4 therefore investigate the labour market impact of diabetes in a more comprehensive way than previous literature.

This study will use cross-sectional data from a large household survey in Mexico, assessing the impact of diabetes on employment probabilities. An instrumental variable (IV) strategy inspired by preceding studies from HICs is used to account for the potential endogeneity of diabetes due to unobserved heterogeneity. Especially personal characteristics such as ambition and family background could affect both the probability to develop diabetes, in particular type 2 diabetes, and the probability to be employed. The aim is to investigate if diabetes has a causal effect on employment probabilities and to provide evidence for the subgroup of those in the informal labour market and the relatively poor, populations of particular relevance in middle-income countries (MICs).

Abstract

This study explores the impact of diabetes on employment in Mexico using data from the Mexican Family Life Survey (MxFLS) (2005), taking into account the possible endogeneity of diabetes via an instrumental variable estimation strategy. We find that diabetes significantly decreases employment probabilities for men by about 10 percentage points ($p<0.01$) and somewhat less so for women—4.5 percentage points ($p<0.1$)—without any indication of diabetes being endogenous. Further analysis shows that diabetes mainly affects the employment probabilities of men and women above the age of 44 and also has stronger effects on the poor than on the rich, particularly for men. We also find some indication for more adverse effects of diabetes on those in the large informal labour market compared to those in formal employment. Our results highlight—for the first time—the detrimental employment impact of diabetes in a developing country.

3.1 Introduction

Diabetes, similar to other conditions that have been coined "diseases of affluence", has traditionally been seen as mostly a problem of the developed, more affluent countries. Only in recent years the awareness has been growing of the sheer size of the problem in health terms (Hu, 2011; Yach et al., 2006). Mexico is one example of a middle-income country that has seen diabetes rates increase sharply over the last years, from about 7.5% in 2000 (Barquera, Campos-Nonato, et al., 2013) to 12.6% in 2013 (International Diabetes Federation, 2014). The high prevalence of diabetes in Mexico reflects an epidemiological transition from a disease pattern previously characterized by high mortality and infectious diseases to low-mortality rates and non-communicable diseases (NCDs) affecting predominantly adults (Stevens et al., 2008). This transition has likely been reinforced by nutritional changes away from a traditional diet towards an energy dense, but nutritionally poor diet with an increasing amount of processed foods and sugars (Barquera, Hernandez-Barrera, et al., 2008; Basu et al., 2013; Rivera, Barquera, González-Cossío, et al., 2004), a reduction in physical activity, as well as what appears to be a particular genetic predisposition of many Mexicans to develop type 2 diabetes (Williams et al., 2014). While many of the high-income countries may be in a position to cope resource-wise with the health care consequences of diabetes, this will be less so the case for Mexico and other low- and middle-income countries (LMICs). The most recent "cost-of-illness" estimates put the costs of diabetes to the Mexican society at more than US$778 million in 2010, with a large part of these costs being paid out-of-pocket (Arredondo and De Icaza, 2011b).

While the above includes some estimate of indirect costs, meant to capture the cost burden attributable to foregone productivity resulting from diabetes, there exists no rigorous, econometric assessment of the effect of diabetes on employment chances for Mexico, as the research has thus far focused on high-income countries (Bastida and Pagán, 2002; Brown, Pagán, et al., 2005; Latif, 2009; Lin, 2011; Minor, 2011; Vijan et al., 2004; Zhang, Zhao, et al., 2009).

There are several reasons to expect a significant adverse effect of diabetes on employment chances in Mexico and that this effect might be stronger than in high-income countries. In Mexico type 2 diabetes is increasingly affecting people in their productive age, raising the possibility that a larger share of people with diabetes will have to cope with debilitating complications already relatively early in life (Barquera, Campos-Nonato, et al., 2013; Villalpando et al., 2010). Further, only a minority of Mexicans appears to successfully manage their diabetes condition, with as much as 70% of the people with diabetes having poor control over their disease (Villalpando et al., 2010). In addition, many Mexicans are working in the large informal economy[1], possibly limiting their access to quality health care and hence to appropriate treatment options. All these factors are likely to both increase the risk of developing debilitating diabetes complications as well as to reduce productivity as a result. Against this background, the aim of this study is to investigate how diabetes affects employment probabilities in a middle-income country such as Mexico. To the best of our knowledge this is the first such paper on Mexico and indeed on any LMIC. We also investigate if the impact of diabetes on employment chances differs across age groups and—again for the first time in this field—by wealth, as well as between those formally and informally employed.

The majority of the more recent studies on the labour market impact of diabetes tried to account for the possible endogeneity of diabetes using family history of diabetes as an instrument. Endogeneity might arise due to reverse causality: employment status and its effect on a person's lifestyle may also influence the odds of developing diabetes. A job with long office working hours might push a person's diet or exercise pattern towards a more unhealthy and sedentary lifestyle due to reduced leisure time, increasing the person's risk for diabetes. In addition, unobserved factors, such as personal traits, could simultaneously influence a person's employment as well as his or her diabetes status and introduce an omitted variable bias. A less ambitious person could be less productive in a job, increasing the risk of being laid off, and he or she could simultaneously have only modest, if any, exercise goals or healthy eating habits, thereby increasing the chances of developing

[1]In 2005 around 58% of the working population in Mexico were employed in the informal sector (Aguila et al., 2011).

diabetes.

Brown, Pagán, et al. (2005) estimated the impact of the disease on employment in 1996–1997 in an older population of Mexican Americans in the USA close to the Mexican border, using a recursive bivariate probit model. They found diabetes to be endogenous for women but not for men. The results of the IV estimation suggested no significant effect on women which, compared to the adverse effect found in the probit model, indicated an overestimation of the effect for women when endogeneity was not accounted for. For men, the probit estimates showed a significant adverse effect of about 7 percentage points. Latif (2009) estimated the effect of the disease on employment probabilities in Canada in 1998. Contrary to Brown, Pagán, et al. (2005), he found diabetes to be exogenous for females and endogenous for males; taking this into account he obtained a significant negative impact on the employment probabilities for women, but not for men. Because the simple probit model showed a significant negative effect for males, Latif (2009) concluded that not accounting for endogeneity resulted in an overestimation of the effect on male employment chances. Minor (2011) investigated the effect of diabetes on female employment, among other outcomes, in the USA in 2006. This particular study differed from earlier work in that it not only analysed the effects of diabetes in general, but also of type 1 and type 2 diabetes separately. The study found diabetes to be endogenous and underestimated if exogeneity was assumed. In the IV estimates, type 2 diabetes had a significant negative effect on female employment chances. For Taiwan, Lin (2011) found diabetes to be endogenous, with the IV results showing significant changes in the employment effect of diabetes. The impact was found to be significantly negative for men in the IV model indicating an underestimation in the standard probit model, where the diabetes coefficient was also significant but much smaller in size. For women, no significant effect was found in the IV estimation after the probit model had indicated a significant and negative impact of diabetes.

Accordingly, at least in some cases, there seems to be the risk of biased estimates of the impact of diabetes on employment, when exogeneity is assumed, with an a priori ambiguous bias. Hence, our decision in this study to also assess if diabetes is endogenous and how precisely taking account of endogeneity might affect the estimates. In order to account for this possible endogeneity we use data from the second wave of the Mexican Family Life Survey (MxFLS) from 2005, which not only provides information on people's diabetes status and socioeconomic background, but also on parental diabetes, enabling us to construct an instrumental variable similar to what has been used in the previous literature on high-income countries.[2] The data also allows the extension of the analysis to

[2]Studies that have used the family history of diabetes as an instrument for diabetes are Brown, Pagán,

test if the inclusion of information on parental education as an additional control variable affects the IV parameter estimates.

The remainder of the paper is structured as follows. Section 3.2 provides details about the used dataset and the econometric specification; and section 4.5 presents and discusses the empirical results. Section 4.6 concludes.

3.2 Methodology

3.2.1 Dataset and descriptive statistics

The dataset used for the empirical analysis is the Mexican Family Life Survey (MxFLS). It is a nationally representative household survey which was conducted in 2002 and 2005. We use data from the second wave in 2005, which includes almost 40,000 individuals. Interviews were conducted with all household members aged 15+, and information on a wide range of social, demographic, economic and health related topics was collected (Rubalcava and Teruel, 2008). While there are more recent datasets available on Mexico, none of these provide as extensive information on parental characteristics as does the MxFLS which includes information on parental diabetes and education status, even if parents were not alive anymore or were living in a non-surveyed household at the time of the survey. Diabetes is self-reported and 3.7% of males and 5.1% of females report a diagnosis by a doctor.[3] Unfortunately we cannot—with the data at hand—distinguish between the different types of diabetes. It can be assumed, however, that about 90% of the reported diagnoses are due to type 2 diabetes, which is by far the most common type of diabetes (Sicree et al., 2011). The sub-sample used for analysis is limited to the age group of 15 to 64 years, which represents the majority of the working population. To allow for heterogeneity in the coefficients across gender, the sample has been split to estimate the male and female groups separately.

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et al. (2005) for a Mexican-American community, Latif (2009) for Canada, Minor (2011) for females in the USA and Lin (2011) for Taiwan.

[3] This is well below the estimated prevalence rate for 2013 of almost 12%. This is likely due to the fact that, according to the International Diabetes Federation (IDF), more than half of the people with diabetes in Mexico are undiagnosed and consequently did not report it (International Diabetes Federation, 2014). Further, the sample in the survey at hand is restricted to people between the age of 15 to 64, which does not match exactly with the population the IDF used for the diabetes prevalence estimates (20 – 79). Hence, our used sample includes a greater share of young people with a very low diabetes prevalence and excludes people above 64 years of age, which likely have a higher than average prevalence rate. Taken together, this—as well as a further increase in prevalence since 2005—should explain the difference between the diabetes prevalence in our sample and the one estimated by the IDF.

Table 3.1: Summary statistics for males and females with and without diabetes

	Males			Females		
	Mean with diabetes	Mean without diabetes	p (t-test)	Mean with diabetes	Mean without diabetes	p (t-test)
Employed	0.714	0.804	0.000	0.229	0.313	0.000
Age	50.945	35.016	0.000	48.955	34.717	0.000
Age 15–24	0.008	0.294	0.000	0.036	0.282	0.000
Age 25–34	0.043	0.232	0.000	0.076	0.250	0.000
Age 35–44	0.161	0.196	0.162	0.180	0.221	0.042
Age 45–54	0.392	0.166	0.000	0.366	0.159	0.000
Age 55–64	0.396	0.111	0.000	0.342	0.089	0.000
Rural	0.337	0.399	0.047	0.391	0.399	0.723
Small city	0.082	0.126	0.038	0.144	0.123	0.204
City	0.145	0.102	0.028	0.103	0.098	0.737
Big city	0.435	0.372	0.042	0.362	0.379	0.475
Southsoutheast	0.208	0.203	0.864	0.184	0.206	0.270
Central	0.243	0.184	0.017	0.231	0.195	0.062
Westcentral	0.173	0.213	0.124	0.191	0.210	0.343
Northeastcentral	0.196	0.177	0.446	0.209	0.186	0.236
Northwestcentral	0.180	0.223	0.112	0.184	0.202	0.355
No education	0.090	0.062	0.070	0.151	0.081	0.000
Primary	0.518	0.352	0.000	0.607	0.368	0.000
Secondary	0.231	0.308	0.009	0.171	0.314	0.000
Highschool	0.059	0.158	0.000	0.043	0.138	0.000
College or university	0.102	0.120	0.379	0.029	0.098	0.000
Indigenous	0.137	0.121	0.448	0.133	0.118	0.341
Married	0.812	0.535	0.000	0.663	0.539	0.000
Children (under 15)	1.118	1.510	0.000	1.207	1.600	0.000
Wealth	0.179	-0.010	0.003	0.004	-0.003	0.885
Diabetes	1.000	0.000	.	1.000	0.000	.
Diabetes father	0.180	0.071	0.000	0.146	0.079	0.000
Diabetes mother	0.251	0.107	0.000	0.236	0.113	0.000
Education parents	0.596	0.697	0.001	0.528	0.699	0.000
Formal employment	0.286	0.306	0.508	0.083	0.140	0.001
Informal employment	0.529	0.560	0.342	0.191	0.220	0.155
N	255	6031		445	7798	

The descriptive statistics presented in Table 3.1 suggest that the groups of respondents with and without diabetes differ significantly in various aspects. Both males and females with diabetes have a lower employment rate than their counterparts. This would suggest that diabetes has a negative impact on the employment chances of both males and females with diabetes. However, since the groups with diabetes are also significantly older and differ in terms of education, this may be a spurious relationship. As a result, only a multivariate analysis will provide more reliable information on how diabetes truly affects employment probabilities.

3.2.2 Econometric specification

We first estimate a probit model with the following specification

$$Employed_i = \beta_0 + \beta_1 Diabetes_i + \beta_2 X_i + u_i \tag{3.1}$$

where diabetes is assumed to be exogenous. $Employed_i$ takes the value of 1 if person i is employed and 0 if unemployed. Employment status is defined as having worked or carried out an activity that helped with the household expenses for at least ten hours over the last week. This explicitly includes those employed informally, for instance people working in a family business.

$Diabetes_i$ denotes the main independent variable of interest, taking the value of 1 if individual i has reported a diagnosis of diabetes and 0 otherwise.

X_i contains various control variables. Because no information on job history is available in the data to adequately account for work experience, we need to rely on the combination of age and education to proxy for work experience (Aaronson, 2010). The effect of age is captured through dummy variables for age intervals. Education is taken into account by dummy variables indicating if the highest level of schooling attained was either primary school, secondary school, high school, university or some other form of higher education with no education serving as the reference category, to control for the impact of education on employment and to account for the relationship between diabetes and education (Agardh et al., 2011).

Since Mexico is a large and diverse country with regional socioeconomic differences we also include dummies for five different Mexican regions[4]. Apart from the more obvious effects economic differences between regions can have on employment chances and

[4]The region variables have been constructed after recommendations on the MxFLS-Homepage. South-southeastern Mexico: Oaxaca, Veracruz, Yucatan; Central Mexico: Federal District of Mexico, State of Mexico, Morelos, Puebla; Central northeast Mexico: Coahuila, Durango, Nuevo Leon; Central western Mexico: Guanajuato, Jalisco, Michoacan; Northwest Mexico: Baja California Sur, Sinaloa, Sonora.

diabetes through their impact on employment opportunities and lifestyles, the dummies should also account for less obvious effects that macroeconomic problems, such as a high unemployment rate, could have on employment chances and diabetes by affecting psychological well-being and sleeping patterns (Antillón et al., 2014). Because differences in economic opportunities and lifestyles should also be expected between rural and urban areas, three dummy variables are included to capture the effects these factors might have on employment chances and diabetes, with living in a rural area being the reference category[5] (Villalpando et al., 2010). Further, to control for labour market discrimination and possible differences in genetic susceptibility to diabetes of indigenous populations (Yu and Zinman, 2007), a dummy for being a member of an indigenous group is included. We also account for for the marital status to control for the impact of marriage on employment chances and lifestyle habits. Further a variable capturing the number of children residing in the household below the age of 15 is inlcuded, to control for their impact on employment chances and for the effect of childbearing and related gestational diabetes on the probabilities of women to develop type 2 diabetes (Bellamy et al., 2009).

To account for the effect that household wealth might have on diabetes and employment chances, we use the well established method of principal component analysis of multiple indicators of household assets and housing conditions to create an indicator for household wealth (Filmer and Pritchett, 2001). Our composite wealth index consists of owning a vehicle, owning a house or other real estate, owning another house, owning a washing machine, dryer, stove, refrigerator or furniture, owning any electric appliances, owning any domestic appliances, owning a bicycle and owning farm animals. It further accounts for the physical condition of the house, proxied by the floor material of the house, and the type of water access.

The error term is denoted as u_i. We do not control for the general health status and other diabetes related chronic diseases as they are likely determined by diabetes itself and, hence, could bias the estimates and compromise a causal interpretation of the effect of diabetes on employment (Angrist and Pischke, 2008).

As diabetes could be endogenous, the probit model might deliver biased estimates. Therefore we employ an IV strategy, using a bivariate probit model to estimate the following two equations simultaneously:

$$Diabetes_i = \delta_0 + \delta_1 X_i + \delta_2 diabetesmother_i + \delta_3 diabetesfather_i + \eta_i \tag{3.2}$$

[5]Rural: $<$ 2,500 inhabitants; Small city: 2,500 to 15,000 inhabitants; City: 15,000 to 100,000 inhabitants; Big city: $>$ 100,000 inhabitants.

$$Employed_i = \beta_0 + \beta_1 Diabetes_i + \beta_2 X_i + u_i \tag{3.3}$$

In equation 3.2, $Diabetes_i$ is a dummy variable and is modelled as a function of the same socioeconomic and demographic factors X_i as in equation 3.1 and of the instrumental dummy variables $diabetesmother_i$ and $diabetesfather_i$, indicating if the father or the mother had been diagnosed with diabetes. The error term is denoted as η_i. Equation 4.2 is identical to the probit specification (equation 3.1) and estimates the effect of diabetes on employment, now taking into account the possible endogeneity of diabetes. Diabetes is exogenous if the error terms of both equations are independent of each other ($Cov(u_i\eta_i) = 0$). Endogeneity is tested using a likelihood ratio test based on the idea that if $Cov(u_i\eta_i) = 0$, the log-likelihood for the bivariate probit will be equal to the sum of the log-likelihoods from the two univariate probit models (Knapp and Seaks, 1998). If u_i and η_i are correlated, the estimation of equation 3.1 using a probit model will not provide consistent estimates of the impact of diabetes on employment. In this case the simultaneous estimation of both equations using the bivariate probit should be preferred. For the estimation of the bivariate probit model it is assumed that u_i and η_i are distributed randomly and bivariate normal. To test the assumption of normality, we use Murphey's goodness-of-fit score test with the null-hypothesis of bivariate normally distributed errors, as suggested by Chiburis et al. (2012).[6]

We choose the bivariate probit model over the linear IV model to account for endogeneity, as there is evidence that it performs better if the sample is relatively small (<5,000) and—more important in our case—when treatment probabilities are low. In such cases the linear IV can produce uninformative estimates while the bivariate probit model has been shown to provide much more reasonable results (Chiburis et al., 2012). Because only 4% of males and 5.4% of females report a diagnosis of diabetes, treatment probabilities are indeed low in the given case, providing good justification for the use of the bivariate probit model.

In order to fulfil the conditions of a valid instrument, parental diabetes needs to impact the diabetes risk of the offspring while at the same time being unrelated to the offspring's employment chances. It has been shown that there is a strong hereditary component of type 2 diabetes which predisposes the offspring of people with diabetes to develop the condition as well (Herder and Roden, 2011; The Interact Consortium, 2013). This is supported by the notion that genes seem to play a crucial role, besides the recent

[6] Murphey's score test "... embeds the bivariate normal distribution within a larger family of distributions by adding more parameters to the model and checks whether the additional parameters are all zeros using the score for the additional parameters at the bivariate probit estimate." (Chiburis et al., 2012, p. 19).

epidemiological transition and the migration from rural to urban areas, in explaining Mexico's high diabetes prevalence according to a recent study by Williams et al. (2014). The authors identified a specific gene particularly prevalent in Mexican and other Latin American populations with native American ancestry, which is associated with a 20% increase in the risk of developing type 2 diabetes. Furthermore, research has shown that parental lifestyle factors, socioeconomic background as well as parental body mass index (BMI) can explain but a very small fraction of the increased risk of type 2 diabetes in the offspring, which is why we assume that the increased risk is mainly due to genetic factors unrelated to lifestyle (Herder and Roden, 2011; The Interact Consortium, 2013). This is supported by Hemminki et al. (2010), who find that adoptees whose biological parents had type 2 diabetes, had an increased risk of developing type 2 diabetes even though they were living in a different household, while if their adopted parents had the disease, they had no elevated risk.

Nonetheless, there might still be the chance that parental diabetes decreases the offspring's employment chances. The additional financial burden of diabetes or an early death due to diabetes could have prevented the parents from investing in their children's education the way they would have liked to or it could have led to the child dropping out of school in order to support the family. However, controlling for education should account for these effects if they exist. Therefore parental diabetes should be a valid instrument which predicts diabetes while not affecting employment probabilities through other unobserved pathways. To further improve instrument validity we also account for the possibility that parental education is simultaneously correlated with the parental diabetes status as well as their children's employment chances, by including a dummy variable indicating if any of the parents had attained more than primary education.

A possible limitation of using parental diabetes as our instrument is that it might directly affect the offspring's employment decision through other pathways than education. Conceivably, diabetes might deteriorate parental health in such a way that the offspring has or had to give up its own employment in order to care for its parents or is forced to take up work to financially provide for the parents. With the data at hand we are unable to account for this, but if this effect exists it should be picked up by the overidentification test.

We also estimate the linear IV model as it is consistent even under non-normality (Angrist and Pischke, 2008). The linear IV model takes the following form of a first (Equation 3.4) and a second stage (Equation 3.5).

$$Diabetes_i = \pi_0 + \pi_1 X_i + \pi_2 diabetesmother_i + \pi_3 diabetesfather_i + \eta_i \qquad (3.4)$$

$$Employed_i = \beta_0 + \beta_1 Diabetes_i + \beta_2 X_i + u_i \tag{3.5}$$

In the second stage, the potentially endogenous actual diabetes values are replaced with the predicted values from the first stage. The covariates are the same as in the bivariate probit case described in equations 3.2 and 4.2. In the linear IV model the Hausman test is used to identify endogeneity. Validity of the instruments is tested using first stage diagnostics of the linear IV model, as similar tests are not available for the bivariate probit model. Average marginal effects are presented for the probit and bivariate probit models.

3.3 Results

This section presents the estimation results using 1) a probit model model that assumes diabetes to be exogenous and 2) IV models with parental diabetes as an instrument for diabetes, to determine if diabetes is endogenous or if instead the results from the probit model can be used.

3.3.1 Probit results

Table 3.2 indicates that the effect of diabetes is negative for both sexes. For males, it reduces the probability of being employed by 10 percentage points ($p<0.01$).

For females, the effect is also negative but smaller, and shows a reduction in employment probabilities of about 4.5 percentage points ($p<0.1$).

The other covariates largely show the expected relationships. Employability increases with age and is highest for the 35–44 years age group. Especially for women, living in a more urban environment increases employment chances compared to women living in rural areas. Also, women seem to benefit substantially from higher education in terms of employment chances. For men the effects of education are also positive, though, not as marked as for women. Perhaps surprisingly, being part of an indigenous population does not affect employment probabilities, neither for males or females.

The probit results suggest a significant negative effect of diabetes on the employment probabilities of males and likely also females in Mexico. In light of the concern that diabetes could be endogenous the following section presents the results of the IV estimations.

Table 3.2: Impact of diabetes on employment probabilities (probit)

	(1) Males		(2) Females	
Age 25–34	0.124***	(.011)	0.121***	(.017)
Age 35–44	0.133***	(.012)	0.232***	(.018)
Age 45–54	0.085***	(.014)	0.170***	(.022)
Age 55–64	−.034	(.020)	0.039	(.026)
Small city	−.013	(.017)	0.043**	(.020)
City	−.036*	(.019)	0.042**	(.021)
Big city	0.029**	(.013)	0.101***	(.014)
Central	0.027	(.015)	−.032*	(.018)
Westcentral	0.020	(.015)	−.008	(.018)
Northeastcentral	0.003	(.016)	−.053***	(.017)
Northwestcentral	−.037**	(.016)	−.100***	(.016)
Primary	0.056***	(.020)	−.006	(.022)
Secondary	0.051**	(.021)	0.058**	(.025)
Highschool	0.040*	(.023)	0.126***	(.029)
College or university	0.047**	(.023)	0.297***	(.033)
Indigenous	0.005	(.016)	−.005	(.020)
Married	0.092***	(.012)	−.231***	(.012)
Children (under 15)	0.010**	(.004)	−.018***	(.004)
Wealth	0.002	(.006)	0.037***	(.007)
Education parents	−.007	(.013)	0.000	(.013)
Diabetes	−.100***	(.029)	−.045*	(.023)
Log likelihood	−2897.807		−4508.573	
N	6286		8243	

Marginal effects; Robust standard errors in parentheses.

* p < 0.1, ** p < 0.05, *** p < 0.01

3.3.2 IV results

Using the bivariate probit model, the diabetes coefficient for males increases in size and remains negative whereas for females it decreases but also remains negative. However, standard errors increase in both models and the results turn insignificant, suggesting considerable loss of efficiency (see Table 3.3). The likelihood-ratio test does not reject the null hypothesis of no correlation between the disturbance terms of equations 3.2 and 4.2 for males and females, suggesting exogeneity of diabetes. The test for normality of the error term does not reject the null hypothesis of normality for the male and the female model, increasing our confidence in the estimates. Nonetheless we also consider the results of the linear IV model: the test statistics indicate sufficiently strong and valid instruments, as shown by the Kleibergen-Paap Wald F statistic for weak instruments of 20.48 for men and 27.71 for women, being above the critical value of 19.93 for ten %IV size and well above the rule of thumb of 10 for weak identification not to be considered a problem (Baum et al., 2007; Staiger and Stock, 1997). The Sargan test does not reject the null hypothesis of instruments uncorrelated with the error term and instruments correctly excluded from the estimated equation. The coefficients of the linear IV model are very different from the bivariate probit model, turning positive for males and females, but also very imprecise as indicated by the large standard errors (see Table 3.4 displaying the main results and Table 3.8 presenting the complete first and second stage estimates). As mentioned before, Chiburis et al. (2012) show that the estimates of the linear IV model are likely to be imprecise when low treatment probabilities exist and can differ substantially from the bivariate probit model, which seems to be the case here.[7] Since the linear IV models fail to reject exogeneity of diabetes as well, we are confident that the standard probit model provides unbiased and efficient estimates of the effect of diabetes on employment chances in Mexico and should therefore be used for inference.

The next section investigates the effects of diabetes for two different age groups, 15–44 and 45–64, to explore whether, and if so, how the effect of diabetes on employment chances differs between older and younger people. There might be reason to believe that diabetes has a more adverse effect in older age groups, when those suffering from diabetes are likely to have accumulated more years lived with diabetes, and hence are more likely to develop complications.

[7] It could also be the case that the difference in estimates is due to the fact that while the bivariate probit model estimates the average treatment effect (ATE) of the variable of interest for the whole sample, the linear IV model estimates the local average treatment effect (LATE), which estimates the effect of diabetes on employment only for those that have diabetes and whose parents have or have had diabetes as well. Therefore, the estimates of both models can be different (Angrist and Pischke, 2008; Chiburis et al., 2012).

Table 3.3: Impact of diabetes on employment probabilities (bivariate probit)

	(1) Males		(2) Females	
Age 25–34	0.125***	(.012)	0.109***	(.015)
Age 35–44	0.134***	(.012)	0.207***	(.016)
Age 45–54	0.089***	(.016)	0.149***	(.021)
Age 55–64	−.025	(.025)	0.032	(.029)
Small city	−.014	(.017)	0.039**	(.018)
City	−.035**	(.018)	0.038**	(.019)
Big city	0.030**	(.013)	0.093***	(.013)
Central	0.027	(.018)	−.030*	(.015)
Westcentral	0.019	(.018)	−.007	(.016)
Northeastcentral	0.002	(.018)	−.049***	(.017)
Northwestcentral	−.038**	(.017)	−.091***	(.015)
Primary	0.057***	(.020)	−.006	(.021)
Secondary	0.052**	(.023)	0.052**	(.022)
Highschool	0.040	(.025)	0.113***	(.027)
College or university	0.046*	(.025)	0.273***	(.032)
Indigenous	0.006	(.017)	−.005	(.016)
Married	0.093***	(.012)	−.215***	(.011)
Children (under 15)	0.010**	(.004)	−.016***	(.004)
Wealth	0.002	(.006)	0.033***	(.007)
Parental education	−.006	(.013)	0.000	(.012)
Diabetes	−.185	(.143)	−.021	(.108)
Instruments				
Diabetes father	0.048***	(.011)	0.041***	(.010)
Diabetes mother	0.037***	(.008)	0.054***	(.008)
Log likelihood	−3737.766		−5939.588	
Score goodness-of-fit (H0=normality of errors)	12.32		8.85	
p value	0.196		0.451	
Endogeneity (H0: Diabetes exogeneous)	0.443		0.039	
p value	0.506		0.844	
N	6286		8243	

Notes Marginal effects; Robust standard errors in parentheses. The presented coefficients and standard errors for the instruments result from the estimation of the model specified in Equation II, indicating the effect of parental diabetes on a person's diabetes risk.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$)

Table 3.4: Impact of diabetes on employment probabilities (linear IV)

	(1) Males		(2) Females	
Diabetes	0.098	(.215)	0.239	(.214)
R2	0.067		0.120	
F stat (H0: weak instruments)	20.483		27.706	
Sargan test (H0: valid instruments)	0.862		0.295	
p value	0.353		0.587	
Endogeneity (H0: Diabetes exogenous)	0.864		1.796	
p value	0.353		0.180	
N	6286		8243	

Notes Robust standard errors in parentheses. Instruments: diabetes of mother, diabetes of father. Other control variables: age, region, urban, education, indigenous, marital status, children, wealth, parental education. Critical values for weak identification test F statistic: 10% maximal IV size 19.93, 15% maximal IV size 11.59, 20% maximal IV size 8.75, 25% maximal IV size 7.25.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$)

3.3.3 Differences by age groups

When divided into an older and younger age group using the cut-off point of 45 years, the negative effect of diabetes is mainly found in the older age group, for males and females alike (see Table 3.5), where 12.5% report having diabetes, compared to only 1.7% in the younger age group. The probability of being employed is reduced by about 10 percentage points for men between 45 and 64 years at the 1% significance level, while there is no significant effect on younger men. For women, the employment probability is reduced by about 6 percentage points, with the effect being significant at the 5% level. Similar to men, there is no effect of diabetes on younger women. To investigate in more detail for which age group the effect is strongest, we run separate regressions for both age groups above 44 years. The results (Table 3.9) show that for men the strongest effect appears in the oldest age group (i.e. 55–64 years), where employment chances are reduced by almost 13 percentage points. For females, a significant effect is found solely for those between 45 and 54 years, where employment chances are reduced by 7.6 percentage points. Hence, there appear to be relevant differences between males and females in the age at which the biggest adverse effect of diabetes on employment chances occurs.

Table 3.5: Impact of diabetes on employment probabilities by age group (probit)

	15-44		45-64	
	(1) Males	(2) Females	(3) Males	(4) Females
Diabetes	−.009	−.004	−.110***	−.057**
	(.062)	(.042)	(.034)	(.025)
Log likelihood	−1987.285	−3354.003	−925.409	−1167.491
N	4415	5997	1871	2246

Notes Marginal effects; Robust standard errors in parentheses. For the younger age group, the model contains the age categories 25–34 and 35–44 with 15–24 as the reference category. For the older age group, the model contains the age category 55–64 with 45–54 as the reference category. Other control variables: region, urban, education, indigenous, marital status, children, wealth, parental education.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$)

The use of IV methods in the age stratified samples is compromised due to a reduction in instrument power, sample size and particularly treatment probabilities. Especially for the younger age group, where treatment probabilities are close to zero, a meaningful

interpretation of the IV results is difficult. Further, because no endogeneity was found in the pooled samples for males and females presented in section 3.3.2, we would not expect endogeneity of diabetes in the age stratified samples. We nonetheless test for the possibility of diabetes being endogenous using the bivariate probit model and an approach suggested by Lewbel (2012), to improve instrument strength (see Table 3.11 and Table 3.12).

3.3.4 Differences by wealth

To explore the heterogeneity of the effect of diabetes on employment across different levels of wealth, we divide the sample into two wealth groups at the 50^{th} percentile of our constructed wealth index.

We run separate regressions for both groups stratified by gender, finding the strongest negative effect for less wealthy males, where employment chances are reduced by 15 percentage points, and a smaller and less significant effect for less wealthy females (see Table 3.6). Whereas the coefficients for wealthier males and females have a negative sign, they are not significant at the 10% significance level. This indicates that mainly the less wealthy experience an adverse effect from diabetes. To further explore this, we stratified the sample into wealth quartiles (see Table 3.10), finding that significant adverse effects for males appear in the first and second wealth quartile, where employment chances are reduced by about 14 percentage points. For females a highly significant and strong effect is only found in the poorest quartile, were employment chances are reduced by 10 percentage points. Together these results indicate that the impact of diabetes on employment chances varies with wealth, with men and women being more affected when being in the lower wealth quartiles.

To consider the possible endogeneity of diabetes in the upper and lower wealth half, we again present the results of the IV models. The stratification into wealth groups significantly reduces instrument power as well as sample size. For none of the wealth groups the bivariate probit model indicates endogeneity (see Table 3.13). This does not change even when using the Lewbel approach to increase instrument strength and we therefore rely on the probit results for inference.

Table 3.6: Impact of diabetes on employment probabilities by wealth group (probit)

	Poor		Rich	
	(1) Males	(2) Females	(3) Males	(4) Females
Diabetes	−.150***	−.047*	−.060	−.038
	(.047)	(.027)	(.038)	(.035)
Log likelihood	−1459.235	−2040.517	−1408.746	−2421.910
N	3140	4091	3106	4117

Notes Marginal effects; Robust standard errors in parentheses.Other control variables: region, urban, education, indigenous, marital status, children, wealth, parental education.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$)

3.3.5 Differences by employment type

To investigate the effect of diabetes on the employment chances in the formal and informal labour market, respectively, we estimate separate models with being employed in the formal and informal sector as the respective dependent variables. We define formal employment on the basis of having a written labour contract. Informal employment is defined as working without a written contract or being self-employed.

Table 3.7: Impact of diabetes on employment probabilities by employment status (probit)

	Males		Females	
	(1) Informal	(2) Formal	(3) Informal	(4) Formal
Diabetes	−.063**	−.041	−.051**	0.019
	(.031)	(.043)	(.022)	(.022)
Log likelihood	−1780.023	−1021.771	−3818.588	−1859.048
N	4604	2204	6983	5652

Notes Marginal effects; Robust standard errors in parentheses.Other control variables: region, urban, education, indigenous, marital status, children, wealth, parental education.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$)

For this investigation we use two restricted samples: for the estimation of the effect of diabetes on informal employment we exclude those currently in formal employment and for

the effect of diabetes on formal employment we exclude those in informal employment from our sample. We further assume that those who have worked previously and are currently unemployed are looking for employment in the same sector, i.e. if they were previously employed in the informal (formal) labour market they are again looking for an informal (formal) employment. We therefore exclude those previously working in the informal (formal) labour market from our estimation of the effect of diabetes on employment in the formal (informal) labour market. The respective sample thus only contains those currently working in the informal (formal) labour market, those previously employed in the informal (formal) labour market and those that have never worked before. Using this assumption allows the use of a normal probit model and the investigation of a possible endogeneity bias using IV techniques.

Admittedly, the assumption that the currently unemployed look for work in the same labour market they had previously worked in is quite strong and is likely not true for everybody. We therefore additionally estimate a multinomial logit model which is most useful if the decision to work is not binary but there are more than two choices, such as the choice of being either unemployed, employed in the informal or employed in the formal labour market (Wooldridge, 2002). Being unemployed is used as the reference category.

All estimated models (see Tables 3.7 and 3.15), regardless of the estimation approach, indicate that diabetes significantly reduces the chances of being in informal employment, while it has no effect on formal employment.[8] This applies to both males and females. This indicates that people with diabetes are less likely to be working in the informal labour market relative to being unemployed, while there is no difference for those working in the formal labour market. We further find no indication of endogeneity (see Tables 3.16 and 3.17). Overall, there seem to be strong differences in terms of the impact of diabetes on people in formal and informal employment, with diabetes having a stronger negative effect for those without a written contract.

3.4 Conclusion

The contribution of this paper has been to analyse—for the first time for a LMIC—the impact of diabetes on employment in Mexico, taking into account the potential endogeneity

[8]Please note, however, that the coefficients of the multinomial logit and the probit model cannot be directly compared as they are based on different assumptions. The former takes into account that a person can choose from more than two employment outcomes (i.e. being unemployed, being formally employed or being informally employed), while the latter only allows for a binary outcome without considering any other options (e.g. being unemployed or informally employed without considering the possibility of formal employment).

in the relationship between diabetes and employment chances. The presented results add to the growing literature on the adverse economic effects of diabetes. They indicate that having diabetes substantially reduces the chances to work for men and likely also for women. Hence, diabetes may contribute to a reduction in the pool of the productive workforce available to the Mexican economy.

We have also shown that diabetes reduces employment chances particularly in older people, likely because in this age group people are more common to already have developed diabetes-related complications which reduce their productivity and eventually force them into unemployment. Further, particularly for men the effects of diabetes on employment chances seem to be particularly strong when they belong to the poorer half of the population. While there might be some self-selection into the poorer group by those who lost their job due to diabetes and as a result descended into the lower wealth group, this finding is indicative of potentially substantial adverse equity impacts. This is also in line with our finding that diabetes reduces employment chances particularly for the informally employed, whereas those in formal employment seem to be less affected. Nonetheless, in order to establish causality more research in this area will be needed.

While in parts of the earlier literature diabetes was found to be exogenous only for either males or females (Brown, Pagán, et al., 2005; Latif, 2009), our study found diabetes to be exogenous using the samples stratified into males and females, allowing the use of the more efficient probit model to arrive at a consistent estimate of the effect of diabetes on employment chances. Further, we found no endogeneity of diabetes for the sample comprised of the age group above the age of 44, for the samples stratified into an upper and lower wealth half and for the samples stratified by employment type. For the younger age group the bivariate probit model only indicated exogeneity of diabetes for males, while for females diabetes was shown to be endogenous and showing a significant positive effect of diabetes on employment. This result is rather counterintuitive because there is no obvious reason why diabetes should increase employment chances. Because all samples stratified into age, wealth and employment groups suffered from reduced instrument strength which could cause biased IV estimates, we used a method proposed by Lewbel (2012) to create additional instruments and increase instrument power. Using this method we no longer found a significant positive effect of diabetes on female employment chances in the younger age group and could not reject the assumption of exogeneity of diabetes in this sample. Also, for all other wealth, age and employment samples, the Lewbel IV method did not reject the assumption of exogeneity. We are therefore confident that we can rely on the probit estimates for inference.

Why was diabetes found to be exclusively exogenous in the Mexican case? We can

only speculate on the potential reasons. Diabetes being exogenous seems to indicate that a person's employment status might not have such a strong effect on his or her diabetes risk through the potential pathways such as lifestyle changes. Rather, the rapid epidemiological transition experienced in Mexico over the last decades (Barquera, Hotz, et al., 2006; Barquera, Hernandez-Barrera, et al., 2008; Rivera, Barquera, Campirano, et al., 2002) together with the heightened genetic susceptibility of Mexicans to diabetes (Williams et al., 2014), seem to have increased the risk of developing diabetes in both employed and unemployed Mexicans.

Taking our results for the older age group and comparing them to those of Brown, Pagán, et al. (2005) for the USA, whose sample of Mexican Americans 45 years and older might be the best suited for a meaningful comparison, our findings indicate a stronger negative impact of diabetes on males and particularly females residing in Mexico.[9] This finding lends some support to our hypothesis that the adverse impact of diabetes on employment could be larger in LMICs than in high-income countries. Comparing the study to Lin (2011) for Taiwan, who also used a sample of people between 45 and 64 years of age, our results are similar in that a larger absolute effect is found for males than for females. However, when compared to other studies in more developed countries, with more advanced health systems and very different populations, such as Latif (2009) for Canada and Minor (2011) for women in the US, our results differ in that they do find effects for men and potentially also women.

While the results for women in the main analysis do not reach the levels of statistical significance that those for men do, the negative impact on women is supported by the subgroup analysis. When we take into account the lower overall female employment rates (31%) compared to men (80%), the absolute reduction in employment chances in women translates into a an even larger decrease in absolute levels of over 16% compared to 12.5% for men. This suggests that diabetes affects employment chances of both sexes were considerable.

A limitation of this study is the use of cross-sectional data, which does not allow for the use of fixed effects and hence for the control of unobserved time-invariant heterogeneity. Data spanning a longer time period would be required to be able to observe changes in the diabetes and employment status which would allow the use of fixed effects. A further limitation is the somewhat old data from 2005, which precedes the main implementation period of the public health insurance scheme called Seguro Popular. This should be taken into account when interpreting our results as the effects might be different today, where

[9]This is based on comparing our estimates to the appropriate models in Brown, Pagán, et al. (2005) based on their test for endogeneity, which indicates the use of the bivariate probit results for women and the probit results for men.

most Mexicans have access to some sort of health insurance (Knaul et al., 2012). The presented results rather show the effects of diabetes on employment chances in 2005 in an environment were insufficient healthcare coverage was common for parts of the Mexican population. We nonetheless deliberately chose this particular data as it provided us with a sensible instrument in parental diabetes as well as an array of other socioeconomic information which—as far as we have been able to ascertain—is not provided by any other dataset in LMICs. Finally, due to data limitations, we were not able to investigate the relationship between diabetes duration and employment chances and how long it takes for an employment penalty to develop. Recent research by Minor (2013) on the US has shown that the effect of diabetes on employment chances changes with the duration of diabetes and is strongest in the first five years after diagnosis for males, whereas for females a strong effect appears only about 11–15 years after diagnosis.

Looking ahead, it would evidently be worthwhile to investigate the effects of diabetes on employment in Mexico using more recent data. In light of the recently completed implementation of Seguro Popular—which increased its coverage from about 10 million people in 2005 to over 50 million in 2012 and now provides almost all previously uninsured Mexicans with access to healthcare (Knaul et al., 2012)—the results of this paper might be used as a baseline to judge the success of Seguro Popular in reducing the adverse effects of diabetes on employment. In addition, the reasons for the differences between males and females in the estimated effects remain a matter of speculation and more research is needed to explore the underlying pathways. This information would be valuable in the design of more effective measures to reduce the negative effects of diabetes for both males and females.

In conclusion, this paper shows that diabetes represents a large burden for people in Mexico and likely in other LMICs, not only due to the associated disease and medical cost burden but also because of its effect on employment chances. This is particularly a problem for the poor who are more adversely affected by diabetes than the more affluent. To alleviate some of the negative effects of diabetes, Seguro Popular may provide an opportunity to further improve the prevention and treatment of diabetes in the poor, especially if the health system adapts to the challenges presented by chronic diseases (Samb et al., 2010). Evidence of possible cost-effective interventions for secondary prevention in the context of Seguro Popular already exists (Salomon et al., 2012). There remains, however, an evidence gap on cost-effective strategies for the primary prevention of diabetes.

Linear IV estimates (1st and 2nd stage)

Table 3.8: Impact of diabetes on employment probabilities (linear IV, 1st and 2nd stage)

	linear IV male				linear IV female			
	(1) Diabetes		(2) Employed		(3) Diabetes		(4) Employed	
Age 25–34	−.001	(.005)	0.151***	(.015)	0.003	(.005)	0.111***	(.015)
Age 35–44	0.016*	(.009)	0.154***	(.019)	0.032***	(.008)	0.198***	(.017)
Age 45–54	0.081***	(.014)	0.098***	(.028)	0.108***	(.014)	0.122***	(.028)
Age 55–64	0.101***	(.016)	−.052	(.039)	0.198***	(.021)	0.001	(.040)
Small city	0.001	(.010)	−.010	(.019)	−.005	(.011)	0.034**	(.017)
City	0.014	(.014)	−.041**	(.020)	−.009	(.013)	0.032*	(.019)
Big city	0.008	(.008)	0.027*	(.014)	−.004	(.009)	0.093***	(.013)
Central	0.011	(.011)	0.024	(.017)	0.015	(.011)	−.035**	(.017)
Westcentral	−.002	(.010)	0.021	(.017)	−.002	(.010)	−.006	(.018)
Northeastcentral	0.007	(.012)	0.005	(.017)	0.009	(.012)	−.051***	(.017)
Northwestcentral	−.006	(.009)	−.033**	(.017)	0.007	(.011)	−.095***	(.017)
Primary	−.009	(.020)	0.060**	(.027)	0.017	(.018)	−.011	(.019)
Secondary	−.003	(.020)	0.056*	(.030)	−.005	(.018)	0.052**	(.021)
Highschool	−.027	(.020)	0.045	(.031)	−.008	(.020)	0.117***	(.026)
College or university	−.018	(.023)	0.057*	(.032)	−.028	(.020)	0.291***	(.025)
Indigenous	0.009	(.010)	0.005	(.017)	0.012	(.013)	−.006	(.018)
Married	0.015**	(.007)	0.086***	(.012)	−.002	(.007)	−.216***	(.011)
Children (under 15)	−.005**	(.002)	0.010**	(.004)	0.003	(.002)	−.016***	(.004)
Wealth	0.003	(.004)	−.001	(.007)	0.003	(.004)	0.030***	(.006)
Parental education	0.019**	(.009)	−.010	(.013)	0.014	(.009)	−.001	(.011)
Diabetes father	0.068***	(.020)			0.035**	(.014)		
Diabetes mother	0.043***	(.016)			0.055***	(.013)		
Diabetes			0.098	(.215)			0.239	(.214)
Constant	−.015	(.022)	0.607***	(.036)	−.020	(.021)	0.289***	(.027)
R2	0.075		0.067		0.090		0.120	
F stat (H0: weak instruements)			20.483				27.706	
Sargan test (H0: valid instruments)			0.862				0.295	
p value			0.353				0.587	
Endogeneity (H0: Diabetes exogenous)			0.864				1.796	
p value			0.353				0.180	
N	6228		6286		8186		8243	

Notes Robust standard errors in parentheses. Instruments: diabetes of mother, diabetes of father. Other control variables: age, region, urban, education, indigenous marital status, children, wealth, parental education.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$)

Results for older age groups

Table 3.9: Impact of diabetes on employment probabilities by age groups older than 44 (probit)

	45-54		55-64	
	(1) Males	(2) Females	(3) Males	(4) Females
Diabetes	−.083*	−.076**	−.128**	−.033
	(.048)	(.034)	(.056)	(.039)
Log likelihood	−451.544	−764.722	−458.632	−392.174
N	1101	1399	770	847

Notes Marginal effects; Robust standard errors in parentheses. Other control variables: region, urban, education, indigenous, marital status, children, wealth, parental education.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$)

Results for wealth quartiles

Table 3.10: Impact of diabetes on employment probabilities by wealth quartile (probit)

	1st		2nd		3rd		4th	
	(1) Males	(2) Females	(3) Males	(4) Females	(5) Males	(6) Females	(7) Males	(8) Females
Diabetes	−.142*	−.101***	−.144**	0.028	−.082	−.026	−.040	−.053
	(.077)	(.029)	(.060)	(.048)	(.053)	(.044)	(.046)	(.048)
Log likelihood	−776.619	−937.144	−672.633	−1092.280	−689.910	−1266.304	−703.495	−1144.588
N	1577	2039	1563	2052	1516	2143	1590	1974

Notes Marginal effects; Robust standard errors in parentheses.Other control variables: region, urban, education, indigenous, marital status, children, wealth, parental education.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$)

Instrumental variable analysis for age groups

The results of the bivariate probit models do not indicate endogeneity for the older age group and for males in the younger age group (see Tables 3.11 and 3.12), suggesting that particularly for males the results of the more efficient probit model (Table 3.5) show the true effect of diabetes on employment chances. Only for females in the younger age group the test for endogeneity rejects the assumption of exogeneity and the diabetes coefficient—surprisingly—shows a strong positive effect of diabetes on female employment chances. Instrument strength, however, is reduced significantly, which together with the very low treatment probabilities questions the validity of the IV results for the sample of the younger age group, as weak instruments possibly introduce a bias similar to or stronger than the potential bias in the probit estimates (Staiger and Stock, 1997). We therefore additionally apply a method proposed by Lewbel (2012), which uses heteroscedasticity in the estimated models to construct additional instruments. Instruments are generated by multiplying the heteroscedastic residuals from the first-stage regressions with a subset of the included exogenous variables. Lewbel (2012) recommends the use of this method when traditional instruments are not available or if it is suspected that the traditional instrument is too weak for identification, which is the issue at hand. The approach has been widely used over the last years both in health economics (Brown, 2014; Drichoutis et al., 2011; Kelly et al., 2014; Schroeter et al., 2012) and in other economic disciplines (Denny and Oppedisano, 2013; Emran and Shilpi, 2012; Huang et al., 2009). Using this method to construct additional instruments by using our age group dummies, we are able to increase instrument strength significantly in the younger age group and the overidentification test indicates validity of the instruments. The results of the linear IV model with the additional instruments show exogeneity of diabetes for males and females and do not indicate a significant positive effect of diabetes on employment chances.

Apart from the results of the Lewbel approach, we also think that there are theoretical reasons why diabetes is likely exogenous in the younger age group. While we cannot distinguish between the types of diabetes with the data at hand, it is likely that a relatively large proportion of the people reporting diabetes in this age group have type 1 diabetes, which people tend to get at a younger age (Maahs et al., 2010). The disease has a strong genetic component and it is very unlikely that there are unobserved factors that affect the chances to develop type 1 diabetes and being employed at the same time, nor that employment status would affect the development of type 1 diabetes. Therefore, for a large part of the people reporting diabetes in the younger age group, endogeneity should not present a problem because they have type 1 diabetes. Furthermore, it is also less likely that reverse causality is a problem for those having type 2 diabetes in this age group,

because any effects of being employed on developing type 2 diabetes take time to develop. It would be reasonable to expect that if being employed affected a person's weight or any other diabetes risk factor, this would happen by changing the person's lifestyle due to changes in income or available leisure time, or by reducing or increasing a person's activity levels at work. Until these changes are expressed in changes in weight or any other risk factor for diabetes and finally cause a development of type 2 diabetes, a considerable time period of various years has likely passed and people have reached an advanced age. We therefore believe, that the risk of diabetes being affected by employment is much lower in the younger age group based on the nature of the disease, compared to the older age group. Hence we think that the assumption of exogeneity of diabetes in the younger age group is valid—which is also supported by the Lewbel estimates—and that the endogeneity indicated for younger females in the bivariate probit model is likely the result of the low prevalence rates, and consequently the very low treatment probabilities, together with weak instruments, making a meaningful IV analysis difficult (Chiburis et al., 2012). We are therefore confident that we can rely on our probit estimates for inference.

Table 3.11: IV estimates for the age group 15–44

	BP		Lewbel IV	
	(1) Males	(2) Females	(3) Males	(4) Females
Diabetes	0.171***	0.496***	0.007	0.051
	(.046)	(.080)	(.053)	(.071)
R2			0.093	0.143
Score goodness-of-fit (H0=normality of errors)	9.56	14.25		
p value	0.387	0.114		
F stat (H0: weak instruments)	4.288[a]	10.835[a]	366.480	65.872
Sargan test (H0: valid instruments)	0.008[a]	0.044[a]	1.817	3.487
p value	0.930[a]	0.834[a]	0.611	0.322
Endogeneity (H0: Diabetes exogenous)	1.422	12.948	1.065	1.429
p value	0.233	0.000	0.302	0.232
N	4415	5997	4415	5997

Notes Marginal effects for bivariate probit (BP); robust standard errors in parentheses. Instruments: diabetes of mother, diabetes of father; for Lewbel additionally created age groups instruments. The models contain the age categories 25–34 and 35–44 with 15–24 as the reference category. Other control variables: region, urban, education, indigenous, marital status, children, wealth, parental education. [a] The test statistics are taken from the linear IV model not presented here.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$)

Table 3.12: IV estimates for the age group 45–64

	BP		Lewbel IV	
	(1) Males	(2) Females	(3) Males	(4) Females
Diabetes	−.022	−.112	−.178	−.042
	(.138)	(.111)	(.160)	(.104)
R2			0.058	0.118
Score goodness-of-fit (H0=normality of errors)	7.00	11.10		
p value	0.637	0.269		
F stat. (H0: weak instruments)	15.408[a]	18.305[a]	12.534	18.897
Sargan test (H0: valid instruments)	2.717[a]	0.482[a]	4.397	1.688
p value	0.067[a]	0.487[a]	0.111	0.430
Endogeneity (H0: Diabetes exogenous)	0.688	0.574	0.082	0.024
p value	0.407	0.449	0.774	0.876
N	1871	2246	1871	2246

Notes Marginal effects for bivariate probit (BP); robust standard errors in parentheses. Instruments: diabetes of mother, diabetes of father; for Lewbel additionally created age groups instruments. The models contain the age categories 55–64 with 45–54 as the reference category. Other control variables: region, urban, education, indigenous, marital status, children, wealth, parental education. [a] The test statistics are taken from the linear IV model not presented here. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$)

Instrumental variable analysis for wealth groups

To consider the possible endogeneity of diabetes in the upper and lower wealth half, we again present the results of the bivariate probit and the Lewbel model. The stratification into wealth groups significantly reduces instrument power as well as sample size. For none of the wealth groups the bivariate probit model indicates endogeneity (see Table 3.13 and Table 3.14*)*. This does not change even when using the Lewbel approach to increase instrument strength. Accordingly, we do not find any indication of endogeneity of diabetes in the wealth groups and rely on our probit estimates for inference.

Table 3.13: IV results for lower wealth half

	BP		Lewbel IV	
	(1) Males	(2) Females	(3) Males	(4) Females
Diabetes	−.354	−.064	−.142***	−.054*
	(.241)	(.139)	(.050)	(.032)
R2			0.071	0.099
Score goodness-of-fit (H0=normality of errors)	NA[a]	7.41		
p value	NA[a]	0.594		
F stat (H0: weak instruments)	6.322[b]	15.420[b]	2589.091	1311.647
Sargan test (H0: valid instruments)	0.342[b]	1.106[b]	4.169	2.804
p value	0.558[b]	0.293[b]	0.525	0.730
Endogeneity (H0: Diabetes exogenous)	1.190	0.016	0.005	0.156
p value	0.275	0.901	0.941	0.693
N	3169	4111	3169	4111

Notes Marginal effects for bivariate probit (BP); robust standard errors in parentheses. Instruments: diabetes of mother, diabetes of father; for Lewbel additionally created age groups instruments. Other control variables: region, urban, education, indigenous, marital status, children, wealth, parental education. [a] The test statistics are taken from the linear IV model not presented here. The command SCOREGOF failed to produce the test statistic for this subsample.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$)

Table 3.14: IV results for upper wealth half

	BP		Lewbel IV	
	(1) Males	(2) Females	(3) Males	(4) Females
Diabetes	−.142	0.103	−.057	−.000
	(.199)	(.203)	(.037)	(.039)
R2			0.089	0.142
Score goodness-of-fit (H0=normality of errors)	11.40	12.92		
p value	0.249	0.166		
F stat (H0: weak instruments)	14.003[a]	13.215[a]	28673.088	1225.456
Sargan test (H0: valid instruments)	0.848[a]	0.019[a]	10.180	5.787
p value	0.357[a]	0.889[a]	0.070	0.327
Endogeneity (H0: Diabetes exogenous)	0.238	0.730	0.955	1.807
p value	0.626	0.393	0.329	0.179
N	3117	4132	3117	4132

Notes Marginal effects for bivariate probit (BP); robust standard errors in parentheses. Instruments: diabetes of mother, diabetes of father; for Lewbel additionally created age groups instruments. Other control variables: region, urban, education, indigenous, marital status, children, wealth, parental education. [a] The test statistics are taken from the linear IV model not presented here.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$)

Multinomial logit and IV results for formal and informal employment

Table 3.15: Impact of diabetes on employment probabilities by employment status (multinomial logit)

	Males		Females	
	(1) Informal	(2) Formal	(3) Informal	(4) Formal
Diabetes	−.073**	0.031	−.044**	0.008
	(.031)	(.026)	(.019)	(.018)
Log likelihood	−4997.064	−4997.064	−6267.941	−6267.941
N	6286	6286	8243	8243

Notes Average marginal effects. Base category is being unemployed. Other control variables: region, urban, education, indigenous, marital status, children, wealth, parental education.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$)

To consider the possible endogeneity of diabetes when estimating its effect on formal and informal employment, we again present the results of the bivariate probit and the Lewbel model. The stratification into formal and informal employment groups significantly reduces instrument power as well as sample size. For none of the employment groups the bivariate probit model indicates endogeneity (see Table 3.16 and Table 3.17). This does not change even when using the Lewbel approach to increase instrument strength. Accordingly, we do not find any indication of endogeneity of diabetes for the stratification into formal and informal employment and rely on our probit estimates for inference.

Table 3.16: IV results for informal employment

	BP		Lewbel IV	
	(1)	(2)	(3)	(4)
	Male	Female	Male	Female
Diabetes	−.046	0.069	−.048	−.037
	(.123)	(.130)	(.030)	(.025)
R2			0.103	0.088
Score goodness-of-fit (H0=normality of errors)	13.84	17.37		
p value	0.128	0.043		
F stat (H0: weak instruments)	13.565[a]	25.123[a]	5349.118	2536.362
Sargan test (H0: valid instruments)	0.551[a]	1.684[a]	4.067	4.063
p value	0.458[a]	0.194[a]	0.540	0.540
Endogeneity (H0: Diabetes exogenous)	0.025	1.152	1.128	0.722
p value	0.873	0.283	0.288	0.395
N	4604	6983	4604	6983

Notes Marginal effects for bivariate probit (BP); robust standard errors in parentheses. Instruments: diabetes of mother, diabetes of father; for Lewbel additionally created age groups instruments. The models contain the age categories 55–64 with 45–54 as the reference category. Other control variables: region, urban, education, indigenous, marital status, children, wealth, parental education. [a] The test statistics are taken from the linear IV model not presented here. Base category is being unemployed.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$)

Table 3.17: IV results for formal employment

	BP		Lewbel IV	
	(1) Male	(2) Female	(3) Male	(4) Female
Diabetes	0.098	−.103	−.022	0.003
	(.195)	(.069)	(.049)	(.021)
R2			0.256	0.262
Score goodness-of-fit (H0=normality of errors)	12.95	8.03		
p value	0.165	0.531		
F stat (H0: weak instruments)	8.518[a]	19.996[a]	2764.273	1647.887
Sargan test (H0: valid instruments)	1.111[a]	1.075[a]	9.286	6.741
p value	0.292[a]	0.300[a]	0.098	0.241
Endogeneity (H0: Diabetes exogenous)	0.516	1.833	1.602	0.318
p value	0.473	0.176	0.206	0.573
N	2204	5652	2204	5652

Notes Marginal effects for bivariate probit (BP); robust standard errors in parentheses. Instruments: diabetes of mother, diabetes of father; for Lewbel additionally created age groups instruments. The models contain the age categories 55–64 with 45–54 as the reference category. Other control variables: region, urban, education, indigenous, marital status, children, wealth, parental education. [a] The test statistics are taken from the linear IV model not presented here. Base category is being unemployed.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$)

4 The Impact of Diabetes on Labour Market Outcomes in Mexico: a Panel Data and Biomarker Analysis

Pre-amble

This study builds on the results of the preceding chapter. Instead of using an instrumental variable (IV) approach to address the issue of endogeneity, it takes advantage of the recently released third wave of the Mexican Family Life Survey (MxFLS) to allow the construction of a longitudinal data set containing three waves. This enables the use of panel data methods to arrive at a causal interpretation of the estimates, without having to rely on the untestable assumptions underlying the IV approach.

Further, the study provides additional novel evidence for the effect of self-reported diabetes on wages and working hours in a developing country. Finally it addresses another area identified by the systematic review in 2 investigating in how far self-reported diabetes can be used to draw conclusions about the entire diabetes population, including those unaware of the condition using biomarker information. This area has hitherto received little research but is of great importance due to the large unaware diabetes population in high-income countries (HICs) and low- and middle-income countries (LMICs). Using biomarker data it investigates in how far self-reported diabetes identifies the entire diabetes population and if findings based on self-reports can be extended to those unaware of the condition. This should help to better interpret estimates using self-reported diabetes as provided in Chapter 3.

Abstract

There is limited evidence on the labour market impact of diabetes, and existing evidence tends to be weakly identified. Making use of Mexican panel data to estimate individual fixed effects models, we find evidence for adverse effects of self-reported diabetes on employment probabilities, but not on wages or hours worked. Complementary biomarker information for a cross section indicates that a large diabetes population is unaware of the disease. When accounting for this, the negative relationship of self-reported diabetes with employment remains, but does not extend to those unaware of their diabetes. Further analysis suggests that this difference stems from worse general health among the self-reports rather than more severe diabetes.

4.1 Introduction

Diabetes, and particularly its most common variant, type 2 diabetes, has increased worldwide and is expected to continue to rise over the next decades (NCD Risk Factor Collaboration, 2016). It has become a problem for middle-income countries (MICs) and HICs alike, with over two-thirds of people with diabetes living in the developing world (International Diabetes Federation, 2014). Mexicans and Mexican-Americans appear to be particularly affected by diabetes, also in comparison to other Latino populations living in the USA (Schneiderman, Llabre, et al., 2014). In Mexico itself, diabetes prevalence has been estimated to have grown from 6.7% in 1994 to 14.4% in 2006, including both diagnosed and undiagnosed cases (Barquera, Campos-Nonato, et al., 2013), and is expected to increase further over the next decades (Meza et al., 2015). Already now, diabetes is the number one cause of death in Mexico (Barquera, Campos-Nonato, et al., 2013).

The observed trend has been attributed to a deterioration in diet and a reduction in physical activity (Barquera, Hernandez-Barrera, et al., 2008; Basu et al., 2013), while genetic predisposition among Mexicans with pre-hispanic ancestry may also have played a role (Williams et al., 2014). Recent evidence indicates that the onset of diabetes has been occurring at an ever earlier age in Mexico (Villalpando et al., 2010). With treatment as ineffective as it currently is—only a minority achieves adequate blood glucose control (Barquera, Campos-Nonato, et al., 2013)—the earlier onset will increase the likelihood of complications during the productive lifespan.

Diabetes is a term used to describe various conditions characterized by high blood glucose values, with the predominant disease being type 2 diabetes accounting for about 90 %of all diabetes cases (Sicree et al., 2011). The elevated blood glucose levels that are a result of the body's inability to use insulin properly to maintain blood glucose at

normal levels, can entail a range of adverse health effects for the individual concerned. However, via effective self-management of the disease much if not all of the complications can be avoided (Gregg et al., 2012; Lim et al., 2011). In the absence of effective self-management—or in the case of inadequate treatment—diabetes has been documented to lead to conditions such as heart disease and stroke, blindness, kidney problems, and nerve problems which together with impaired wound healing can lead to the loss of limbs (Reynoso-Noverón et al., 2011). These conditions can be seriously debilitating and may therefore reduce an individual's economic activity, including its productivity and labour market participation.

The effect of diabetes on labour market outcomes has been studied predominantly in HICs—with the exception of a study on Mexico (Seuring et al., 2015) and one on China (Liu and Zhu, 2014) each. In the HIC studies diabetes has been found to be associated with reductions in employment probabilities as well as wages and labour supply (Brown, Pagán, et al., 2005; Brown, Perez, et al., 2011; Brown, 2014; Latif, 2009; Minor, 2011, 2013; Minor and MacEwan, 2016; Seuring, Archangelidi, et al., 2015).

While these studies have provided useful evidence on the potential labour market effects of diabetes, many of the complexities of the relationship have not been comprehensively addressed in any given study. First of all, unobserved heterogeneity presents a challenge to estimate the relationship between diabetes and labour outcomes. Especially time-invariant unobserved individual characteristics, e.g. health endowments—often related to health during uteru, infant and child years, and to low household income or adverse health shocks during these early years—as well as risk preferences have been shown to adversely affect health in general and the propensity to develop type 2 diabetes more specifically (Ewijk, 2011; Li et al., 2010; Sotomayor, 2013). These and other unobserved personal characteristics (e.g. ability) may also affect employment probabilities, wages or working hours directly through their effects on contemporaneous productivity (Currie and Vogl, 2013) and indirectly by limiting educational attainment and human capital accumulation (Ayyagari et al., 2011). Further, only focusing on the overall effect of a self-reported diabetes diagnosis does not reveal when potential labour market penalties appear, given the dynamic aspect of diabetes and the potential differences in its effects over time. Additionally, apart from its health impact diabetes might also affect labour market outcomes through other channels. For instance, people aware of their condition may be less inclined to continue working if this interferes with their disease management or be suffering from psychological consequences (depression, anxiety) of becoming aware of the disease; they may also use the diagnosis as a justification for decreasing their labour supply, leading to a potential justification bias in the estimated effect of diabetes (Kapteyn

et al., 2009). Importantly, for these reasons the labour market effects may also be distinct for people with self-reported versus those unaware of their condition, potentially leading to biased estimates if the analysis is solely based on self-reports.

The objective of this study is to provide new evidence on the impact of diabetes on labour outcomes, while improving upon previous work by paying close attention to the above challenges. We use three waves of panel data from Mexico covering the period 2002–2012, provided by the MxFLS. The MxFLS is particularly useful for the analysis of diabetes as it allows us to account for the above complexities in a more refined way than has been the case so far. Using individual level fixed effects (FE) analysis for the first time in this literature, we take account of time-invariant heterogeneity when assessing the impact of self-reported diabetes and self-reported diabetes duration on labour market outcomes.[1] Further, we add to the current literature in exploring the role of undiagnosed diabetes, using novel and rich biomarker data—an issue of considerable importance in light of the large prevalence of undiagnosed diabetes (see Beagley et al. (2014)) that remained unaccounted for in most earlier studies which typically rely on self-reported information. Doing so sheds light on the issue of measurement error and the potentially differential effects of self-reported and undiagnosed diabetes.

Our results using self-reported diabetes suggest an economically important decrease in the employment probability of people aware of their disease. Wages and working hours, however, do not appear to be negatively associated with self-reported diabetes. We further find that employment probabilities are reduced with each additional year since diagnosis, with some evidence for an even larger effect per year after the initial 10 years.

The biomarker analysis indicates that self-reported diabetes entails a significant employment penalty, while biometrically measured diabetes does not. Overall, undiagnosed diabetes does not appear to affect any of the labour market outcomes examined here, suggesting that adverse effects mainly occur to those self-reporting a diagnosis. We argue that, nonetheless, the effects found for self-reported diabetes in this study are largely unbiased as long as inference is not extended to the unobserved undiagnosed population, and are economically important in light of the sheer size of the diagnosed population in Mexico.

4.2 Diabetes and labour outcomes—existing evidence

Several studies have investigated the effects of diabetes on labour market outcomes.

For the USA, Brown, Pagán, et al. (2005) estimate the impact on employment in 1996–

[1] We are not aware of any other evidence on the effect on wages and working hours in a MIC.

1997 in an elderly population of Mexican Americans living close to the Mexican border, using a bivariate probit model. The study finds diabetes to be endogenous for women but not for men. For the latter, the estimates show a significant adverse effect of 7 percentage points. For women, the negative effect becomes insignificant when using IV estimation. In another study, again for a cross-sectional sample of Mexican-Americans, Brown, Perez, et al. (2011) look at how diabetes management, inferred from measured glycated hemoglobin (HbA1c) levels, is associated with employment chances and wages. The authors detect a linear negative association between HbA1c levels and both employment chances and wages for men.

Two further studies also examine the impact of diabetes on employment and productivity for the USA: Minor (2011) focuses on the effect of diabetes on female employment, earnings, working hours and lost work days in 2006, finding diabetes to be endogenous and its effect underestimated if exogeneity is assumed. In the IV estimates, diabetes has a significant negative effect on female employment as well as annual earnings but not on working hours. In a later study Minor (2013) investigates the relationship of diabetes duration and labour market outcomes using a cross-sectional analysis, providing evidence of a non-linear relationship, with employment probabilities declining shortly after diagnosis for men and after about 10 years for women; wages are not affected by duration. Finally, a recent study by Minor and MacEwan (2016) investigates the association of self-reported diabetes and undiagnosed diabetes with employment probabilities and working hours in an adult USA population, using cross-sectional data. This study indicates a reduction in the coefficient size of diabetes if undiagnosed diabetes cases are included in the diabetes indicator instead of only self-reported diabetes. Further, they find that there is no association of undiagnosed diabetes with employment probabilities itself. However, the results of the study, particularly those for undiagnosed diabetes, are based on a very small number of cases, warranting further investigation.

For Canada, Latif (2009) estimate the effect of the disease on employment probabilities using an IV strategy similar to Brown, Pagán, et al. (2005). His results suggest diabetes to be exogenous for females, and both endogenous and overestimated for males in the univariate model, with the estimates of the bivariate model indicating a significant negative impact on the employment probabilities for women, but not for men. For Australia, Zhang, Zhao, et al. (2009) analyse the effects of diabetes on labour force participation using a multivariate endogenous probit model. Their results demonstrate reduced labour market participation for males and females as a result of diabetes, with the effects appearing overstated if the endogeneity of diabetes is unaccounted for.

To the best of our knowledge only two studies exist for non-HICs. Liu and Zhu (2014)

investigate the effect of a diabetes diagnosis on labour income in China, exploiting a natural experiment to identify causality and find a significant reduction in income for those with a recent diagnosis. An earlier study for Mexico explored the effect of self-reported diabetes on the probability of employment using only cross-sectional data from the 2005 wave of the MxFLS, and found a significant ($p<0.01$) reduction in employment chances for males by about 10 percentage points and for females by about 4.5 percentage points ($p<0.1$), using parental diabetes as an IV (Seuring et al., 2015). The scarcity of evidence for LMICs is also documented in a recent systematic review of the economic cost of diabetes (Seuring, Archangelidi, et al., 2015).

Overall, the majority of existing studies, including those on high income countries, tend to suffer from at least four key limitations:

1. They rely exclusively on cross-sectional data, limiting the possibilities to account for unobserved individual characteristics.

2. The use of the family history of diabetes, which has been the sole instrumental variable employed so far, relies on the genetic and heritable component of type 2 diabetes that could theoretically provide valid identification of the true effect of diabetes. However, it remains unclear whether the variable fully satisfies the exclusion restriction, as it may also proxy for other genetically transferred traits, including unobserved abilities that impact labour outcomes directly. This traditional identification strategy also abstracts from intrahousehold or intergenerational labour supply effects (Seuring et al., 2015).[2]

3. The use of self-reported diabetes can introduce non-classical measurement error due to systematic misreporting which has been shown to cause estimates of economic impacts to be potentially biased and overstated (Cawley, Maclean, et al., 2015; O'Neill and Sweetman, 2013; Perks, 2015).

4. A final potential limitation lies in the selection into diagnosis as a result of disease severity: those who are more severely ill are more likely to have visited a medical doctor and be diagnosed.

To overcome some of these limitations, this paper applies an individual level FE panel estimation strategy and makes use of biomarker data. We also estimate models for different types of employment, i.e. non-agricultural wage employment, agricultural employment and self-employment, as ill health may have distinct effects across these activities.

[2]It is conceivable that diabetes might deteriorate parental health in such a way that the offspring either has to give up their employment to provide care, or has to increase labour supply to compensate for lost income.

4.3 Data

We use the Mexican Family Life Survey (MxFLS), a nationally representative, longitudinal household survey, which has three waves conducted in 2002, 2005–2006 and 2009–2012. All household members aged 15 and above were interviewed, covering information on a wide range of social, demographic, economic and health characteristics of the individuals and their families (Rubalcava and Teruel, 2013). Apart from self-reported diabetes information that is available in all rounds, we also use information on the self-reported year of diagnosis as well as biomarker data including HbA1c levels for a subsample of respondents. Our main analysis uses all three waves taking advantage of the large amount of observations and the panel structure of the data. Our variable of interest is self-reported diabetes, which is based on the survey question: "Have you ever been diagnosed with diabetes?".

Because the response to this question may well suffer from measurement error due to recall bias, we investigate and try to increase the consistency of the self-reported diabetes variable, using disease information from earlier and ensuing waves to infer on the current, missing or inconsistent, diabetes status. One of the key advantages of panel data is the repeated measurement giving more than one data point for many of the individuals, thereby allowing to uncover inconsistencies for those with at least two observations. While we are not aware of any literature investigating the issue of inconsistencies in self-reported diabetes over time, a study by Zajacova et al. (2010), on the consistency of a self-reported cancer diagnosis over time in a USA population, found that 30% of those who had reported a cancer diagnosis at an earlier point did report at a later point that they never had received a cancer diagnosis. They also found that a more recent diagnosis was reported with greater consistency possibly due to increasing recall problems and/or reduced salience as time since diagnosis progresses.

We also find inconsistencies in the diabetes self-reports over the three waves of the MxFLS data, with between 10–20% of those reporting diabetes in one wave not doing so in one of the subsequent waves. In order to reduce the amount of inconsistencies, we were interested in the validity of diabetes self-reports. While we could not find a study assessing the validity of self-reported diabetes in Mexico, a study from China has shown that specificity of self-reported diabetes, i.e. those who self-report a diabetes diagnosis actually have diabetes, was very high (>98% for China), while sensitivity, i.e. how many people with diabetes, diagnosed or undiagnosed, actually self-report the disease, was low (40% for China) (Yuan et al., 2015). This indicates that people who report a diabetes diagnosis are likely to indeed have the condition while many of those not reporting a diabetes diagnosis are unaware of their diabetes.

We assess the validity of self-reported diabetes in our data by using HbA1c levels and the self-reports of diabetes related medicine use from wave three. We find that 90% of those self-reporting a diabetes diagnosis had an HbA1c $\geq$ 6.5% or did report taking diabetes medication, indicating relatively high specificity in our data as well.

We used this information to infer the "true" diabetes status for those with inconsistent reports. For those with two waves, we assumed that if a diabetes diagnosis had been reported in a prior wave they also had diabetes in the ensuing wave, even if then it was not reported. For people where we had data from all three waves, we used that additional information to make a decision on how to deal with inconsistencies using the rules outlined in Table 4.1

Table 4.1: Inconsistencies in diabetes self-report in MxFLS.

Inconsistency	Assumption	Number of observations replaced
Diabetes self report in 2002, 2005 but not in 2009	Has diabetes in 2009 as well	19
Diabetes self report in 2002, 2009 but not in 2005	Has diabetes in 2005 as well	63
Diabetes self report only in 2002, but not in 2005 and 2009	Has no diabetes in 2002 either	66
Diabetes self report only in 2005, but not in 2002 and 2009	Has no diabetes in 2005 either	52
Diabetes self report in 2002, but not in 2005. Not in survey in 2009	Has diabetes in 2005 as well	44
Diabetes self report in 2005, but not in 2009. Not in survey in 2002	Has diabetes in 2009 as well	23

This approach should add more consistency to the self-reported diabetes information by using all available information. We tested if this approach was supported by the HbA1c values provided in wave 3. Of those with inconsistencies in their diabetes elf-reports 95 were present in the biomarker sample (46 with two and 49 with one self-report of diabetes). We therefore Using a t-test we compared the mean HbA1c for the two groups and found a significantly ($p<0.001$) higher mean HbA1c (9.7%) for those with two self-reports compared to for those with only one self-report of diabetes (7.0%). Further, of those with one self-report, for only 30% the HbA1c$\geq$ 6.5% compared to 87% of those with two self-reports. Based on these results we are reassured that the way we have dealt with the inconsistencies in the data minimizes misclassification of people into diabetes or no-diabetes and has reduced some of the measurement error in the diabetes data. Unfortunately we cannot use a similar method for dealing with inconsistencies in the self-reported year of diabetes diagnosis, as it has only been reported once. Hence, the results from duration analysis should be interpreted with care.

A further, and no less important, source of measurement error is the omission of those with undiagnosed diabetes. In order to investigate how this may affect estimates of the labour market impact of diabetes we use information from a subsample of the 2009-2012 wave containing over 6000 respondents (everybody aged 45+ and a random subsample of

those aged 15–44 (Crimmins et al., 2015)) that have biometrically measured blood glucose values, allowing for the identification of those with undiagnosed diabetes. Throughout our analysis the samples we use are restricted to the working age population (15–64). To prevent pregnant women from biasing our results due to the increased diabetes risk during pregnancy and its effects on female employment status, we have dropped all observations of women reporting to be pregnant at the time of the survey (N=764). We further exclude everybody currently in school.

The detailed information in the MxFLS allows us to consider the following outcome variables of interest: employment[3], hourly wage and weekly working hours.[4] For the pooled data of all three waves (Table 4.2), diabetes was self-reported by 5% of men and 6% of women, respectively. This is consistent with other prevalence estimates of self-reported diabetes for this time period in Mexico.[5] About half of the respondents in the sample live in rural areas. Looking at our outcome variables, 86% of men report some form of employment compared to 37% of women. Interestingly, men do not report considerably higher hourly wages than women but work more hours per week. Also, men are working more often in agricultural jobs while women are more likely to be self-employed or in non-agricultural wage employment. Women also have lower educational attainment on average.

Turning to the biomarker subsample of the third wave (2009-2012), respondents are somewhat older on average than in the pooled sample, as it includes everybody above

[3]Employment status is defined as having worked or carried out an activity that helped with the household expenses the last week and working for at least four hours per week. This explicitly includes those employed informally, for instance people working in a family business. The number of working hours needed to be considered as working is lower than in Chapter 3. We took this decision because we wanted to assess the impact of diabetes on driving people out of work completely. Any effect on working hours should be captured in the respective working hours models. We also tested if changing the definition of being employed to having worked at least ten hours per week as in Chapter 3. This only led to marginal changes in the coefficients and standard errors, not affecting the interpretation of the results.

[4]Hourly wage was calculated by adding up the reported monthly income from the first and second job (if any) and dividing it by the average number of weeks per month. This gave us the average earnings per week which were then divided by the weekly working hours to arrive at an hourly wage estimate. Labor income was either reported as the total amount for the whole month or more detailed containing information on the monthly wage, income from piecework, tips, extra hours, meals, housing, transport, medical benefits and other earnings. Over 80% of respondents reported the total amount instead of a detailed amount. Respondents were also asked for their annual income and we used that information to arrive at an hourly wage if information for monthly labour income was missing. Finally, we adjusted the calculated wage for inflation from the year of the interview up to 2013 and took the log of those values. Due to a considerable number of missing or zero income reports the sample used for the wage estimation is smaller than the sample for working hours. Working hours were calculated summing up the self-reported working hours of the first and—if applicable—the second job.

[5]Barquera, Campos-Nonato, et al. (2013) show that the prevalence of diagnosed diabetes in Mexico was 7.5% in 2006, only somewhat above our results, which may be the result of the slightly different age groups considered.

Table 4.2: Descriptive statistics for panel and biomarker sample.

	Panel		Biomarker	
	Males	Females	Males	Females
Dependent variables				
Employed	0.86	0.37	0.86	0.34
	(0.34)	(0.48)	(0.35)	(0.47)
Hourly wage (Mexican Peso)	42.47	40.49	36.30	35.23
	(485.87)	(142.08)	(53.69)	(43.63)
Weekly working hours	46.82	38.99	46.00	38.15
	(16.79)	(18.90)	(16.89)	(19.65)
Agricultural worker	0.22	0.04	0.25	0.03
	(0.41)	(0.20)	(0.43)	(0.18)
Self-employed	0.19	0.28	0.21	0.32
	(0.39)	(0.45)	(0.41)	(0.47)
Non-agricultural worker or employee	0.59	0.68	0.53	0.64
	(0.49)	(0.47)	(0.50)	(0.48)
Diabetes variables				
Self-reported diabetes	0.05	0.06	0.09	0.12
	(0.22)	(0.24)	(0.29)	(0.32)
Diabetes duration if self-reported diabetes (years)	7.49	7.83	7.48	7.99
	(6.01)	(7.83)	(6.07)	(7.03)
Glycated hemoglobin (HbA1c)			6.46	6.58
			(1.89)	(2.02)
HbA1c $\geq 6.5\%$			0.26	0.28
			(0.44)	(0.45)
Undiagnosed diabetes			0.18	0.18
			(0.39)	(0.39)
Education and demographic variables				
Age	36.03	36.29	42.78	42.79
	(13.62)	(13.17)	(14.28)	(13.94)
Rural village of <2,500	0.44	0.43	0.50	0.46
	(0.50)	(0.50)	(0.50)	(0.50)
Married	0.54	0.54	0.60	0.56
	(0.50)	(0.50)	(0.49)	(0.50)
Number of children (age<6) in household	1.48	1.57	1.18	1.22
	(1.45)	(1.47)	(1.29)	(1.32)
Indigenous group	0.19	0.19	0.19	0.18
	(0.39)	(0.39)	(0.39)	(0.39)
Secondary	0.30	0.30	0.26	0.26
	(0.46)	(0.46)	(0.44)	(0.44)
High school	0.16	0.13	0.14	0.12
	(0.36)	(0.34)	(0.34)	(0.33)
Higher education	0.11	0.09	0.12	0.09
	(0.32)	(0.29)	(0.32)	(0.28)
Observations	21388	27341	2785	3623

Notes Mean values, standard deviations in parenthesis. Results for the other variables, i.e. the Mexican states, log hourly wage and wealth, are omitted to save space.

the age of 44 but only a random subsample of those aged 44 or below (Crimmins et al., 2015). Also, self-reported diabetes is higher than in the pooled sample[6]. Regarding the other control and outcome variables, the sample is fairly similar to the pooled sample. Remarkably, a relatively large share of people have an HbA1c indicative of diabetes, defined by the World Health Organization (WHO) as levels above or equal 6.5% (World Health Organization, 2011)[7]: 18% of males and females are unaware of their diabetes. This suggests that relying on self-reported diabetes as a measure for diabetes in Mexico might considerably understate the true extent of diabetes, potentially leading to biased estimates of its economic impact.

4.4 Estimation strategy

Strauss and Thomas (1998) provide a useful framework to think about the relationship between health and labour outcomes:

$$L = L(H, pc, w(H; S, A, B, I, \alpha, e_w), S, A, B, V, \xi) \tag{4.1}$$

where L is labour supply or labour market participation, pc is a vector of prices for consumer goods, w is the real wage; H is an array of measured health status ; S is education; A is a vector of demographic characteristics; B is the family background of the individual; I captures the local community infrastructure; α is an array of unobservables (e.g. ability), e_w represents the measurement error, V is non-labour income and ξ is the taste parameter.

The equation showcases the joint effect of health on both wages and labour supply or labour market participation. Health affects labour supply and participation directly by impacting the ability to work and indirectly by changing wages.

There are several ways diabetes may affect H. First of all, diabetes can deteriorate health if it remains untreated, with the adverse effects potentially increasing over time. Second, a diagnosis of diabetes and ensuing treatment may lead to better health compared to the undiagnosed state. However, compared to healthy people even those receiving treatment for their diabetes may still have worse health outcomes. Third, there is also evidence that the diagnosis itself may affect one's own health perception and could lead to worse self-perceived health (Thoolen et al., 2006). We therefore expect diabetes to

[6] As well as in the full sample of wave 3.

[7] In one of the first analyses of these new biomarker data, Frankenberg et al. (2015) show that the rates of elevated HbA1c levels in Mexico are very high when compared to HbA1c data from similar surveys in the USA and China.

adversely affect health and consequently labour market outcomes.

When estimating Eq. 4.1 empirically with observational data, unobserved heterogeneity may bias the results. As mentioned in section 4.1 unobserved factors captured in α such as early childhood investments, innate ability and risk preference could affect wages as well as the probability to develop diabetes. Further, changes in lifestyle due to changes in wages or employment status may also affect the probability to develop diabetes through changes in diet and physical activity. Finally, measurement error e_w may be an important issue due to the large undiagnosed population with diabetes, particularly if being diagnosed is related to employment or wages via better access to healthcare through employment benefits and higher income.

The following section describes our estimation strategy for the different parts of the data.

4.4.1 Panel data on self-reported diabetes

We investigate the relationship between self-reported diabetes and three labour market outcomes: employment, wages and labour supply, respectively, using a FE model. While using individual level FE does not allow to fully identify a causal relationship, this strategy does improve on the degree of causal inference, compared to a simple cross-sectional analysis.[8] In particular it does allow controlling for unobserved personal characteristics that could bias the estimates, without the drawbacks of an at least debatable IV strategy that has been widely applied in this literature. We have also estimated random effects models but do not present them here as the Hausman test suggested the use of the FE model throughout.[9]

We estimate the following model:

$$Y_{it} = \beta_0 + \beta_1 Diabetes_{it} + \beta_2 X_{it} + c_i + \gamma_t + u_{it}. \tag{4.2}$$

where Y_{it} is a binary variable taking a value of 1 if respondent i reports being in employment at time t and 0 otherwise, $Diabetes_{it}$ is a binary variable taking a value of 1 at time t if the respondent reports having ever received a diagnosis of diabetes[10], X_{it} is a vector of control variables, c_i represents an individual fixed effect, γ_t represents a year dummies, and u_{it} is the error term.

[8] Other forms of unobserved heterogeneity could also affect our estimates—for instance time-variant unobserved heterogeneity or omitted variables simultaneously driving labour outcomes and health.

[9] see the respective table for the results of the cluster robust Hausman test

[10] We are not able to distinguish between type 1 diabetes and type 2 diabetes using this data. Other studies that tried to assess the effect of type 1 diabetes on labour market outcomes have found no association (Minor, 2011; Minor and MacEwan, 2016). Including type 1 diabetes therefore likely attenuates any adverse relationship we may find.

For the relationship of self-reported diabetes with wages and working hours our empirical models are estimated conditional on having positive wages and being employed, respectively. In these models Y_{it} represents the log hourly wage of respondent i at time t or the weekly working hours over the last year.

The control variables in both FE specifications include dummy variables to capture the effects of the living environment, of living in a small, medium or large city with rural as the reference category, and state dummies. We also include a marital status dummy and the number of children residing in the household below the age of 6 to control for the impact of marriage and children on labour market outcomes and the effect of childbearing and related gestational diabetes on the probability of developing type 2 diabetes (Bellamy et al., 2009). To account for the effect of changes in household wealth on diabetes and employment probabilities, we use standard principal component analysis of multiple indicators of household assets and housing conditions to create an indicator for household wealth[11] (Filmer and Pritchett, 2001). Finally, a quadratic age term and calendar year dummies are included to capture the non-linear effect of age and any trends over time, respectively.

Before moving on, it bears emphasizing that despite our efforts to reduce any bias in our estimates, the estimated coefficients do not reflect true causal effects since time-variant unobserved heterogeneity may still bias the estimates. With respect to employment status, one potential issue would be that job loss affects lifestyle choices that increase the probability to develop diabetes, which could then in turn negatively affect labour market outcomes. So far, no strong adverse effects of job loss as a result of diabetes self-reports have been reported in the literature (Bergemann et al., 2011; Schaller and Stevens, 2015), but this has so far only been researched in a high-income country context. Another example relates to stress at work, which has been linked to the development of type 2 diabetes (Eriksson et al., 2013; Heraclides et al., 2012). However, while stress levels may change over time, a person's coping mechanisms to deal with stress are likely time-invariant (Schneiderman, Ironson, et al., 2005). While we cannot exclude the role of these time variant unobserved factors, it seems that the role of time-invariant variables, e.g. genetic predisposition and relatively stable personality traits, is predominant. The applied FE approach should then limit the bias resulting from these time-invariant confounding factors.

[11] Our composite wealth index consists of owning a vehicle, a second house, a washing machine, dryer, stove, refrigerator or furniture, any electric appliances, any domestic appliances, a bicycle or farm animals. It further accounts for the physical condition of the house, proxied by the floor material of the house, and the type of water access.

4.4.2 Self-reported diabetes duration

To explore the role of the duration of diabetes for labour outcomes, we estimate the following model using a self-reported measure of the years since diagnosis:

$$Y_{it} = \beta_0 + \beta_1 Dyears_{it} + \beta_2 X_{it} + c_i + u_{it}, \tag{4.3}$$

where $\beta_1 Dyears_{it}$ is a continuous variable indicating years since first diabetes diagnosis.

In an effort to capture possible non-linearities in the relationship of interest we then use a spline function that allows for the effect of an additional year with diabetes to vary over time.

$$Y_{it} = \delta_0 + g(Dyears_{it}) + \delta_2 X_{it} + c_i + u_{it}. \tag{4.4}$$

with $g(Dyears_{it}) = \sum_{n=1}^{N} \delta_n \cdot max\{Dyears_{it} - \eta_{n-1}\} I_{in}$ and $I_{in} = 1[\eta_{n-1} \leq Dyears_{it} < \eta_n]$, with η_n being the place of the n-th node for $n = 1, 2, \ldots, N$. We choose three nodes that—based on visual inspection (see Figures 4.1, 4.2 and 4.3 in Section 4.5.2)—best captured any possible non-linearity in the relationship between diabetes duration and labour outcomes. These are located at 4, 11 and 20 years after diagnosis. The first four years should capture any immediate effects of the diagnosis, the years five to eleven should capture any effects of adaptation to the disease. After 11 years it is conceivable that many of the debilitating complications of diabetes would appear that could deteriorate health and lead to adverse effects on labour market outcomes. The coefficient δ_n captures the effect of diabetes for the n-th interval. The effects are linear if $\delta_1 = \delta_2 =, \ldots, = \delta_n$.

Because the year of diagnosis was only reported in the third wave, duration of diabetes (or time since diagnosis) for the earlier waves was only calculated for those that had also been interviewed in the third wave, reducing the comparability of the results to those using the binary diabetes indicator.[12]

One caveat of using FE is that, when year dummies are included, any variable that varies by one unit in each time period, is not separately identified (Wooldridge, 2012). Because this is also the case for diabetes duration, in Eq. (4.3) and Eq. (4.4), identification of this variable relies on the presence of people without diabetes in the sample, for which diabetes duration does not increase at the same rate as time.[13] As a further robustness check, we also estimate two models that only use between-individuals variation, i.e. a linear probability model (LPM) that uses only data from the third wave, the only wave

[12] To obtain the time passed since diagnosis, the year of diagnosis was subtracted from the year of the interview.

[13] Consequently, those that reported a diagnosis in the year of the interview were counted as 'one year since diagnosis'. From this follows that if the respondent reported to having been diagnosed in the year before the interview he or she was counted as 'two years since diagnosis' and so on.

where year of diagnosis was originally reported, and a pooled LPM that used data from all three waves.[14]

4.4.3 Cross-section: biomarker and self-reported data

Self-reported diabetes only captures part of the diabetes population as many individuals remain undiagnosed; it may also contain cases of people who misreport having diabetes. Estimations based on self-reports may therefore suffer from selection bias in at least three ways:

1. Systematic overreporting of diabetes: people without diabetes may report a diabetes diagnosis, unintentionally—for instance due to misdiagnosis, either from a health professional or because of self-diagnosis, or intentionally—for instance with a view to justifying some other adverse event or status in their life (e.g. being unemployed).

2. Systematic underreporting of diabetes: people with diabetes may also underreport because they are concerned about negative stigma associated with the condition. Furthermore, diabetes often remains undiagnosed leaving people unaware of their condition.

3. Diagnosis is more likely for those who are more likely to have visited a doctor, for instance because they are more affected by the condition, wealthier, or hypochondriac.[15]

Overreporting may attenuate the effect of diabetes if those falsely reporting a diabetes diagnosis are in fact in good health; it may also lead to overestimation of the impact if some of those misreports reflect other factors that negatively affect labour outcomes (e.g. other illnesses or general ill health), or if they are used to justify other adverse events that may negatively affect labour outcomes. Similarly, underreporting may lead to overestimation if those with undiagnosed diabetes are generally healthier, hence more likely to have positive labour market outcomes than those with self-reported diabetes. However, if the undiagnosed and the diagnosed groups are similar in terms of health, then this would lead to an underestimation of the effect of diabetes.

The health information received at a diabetes diagnosis may also have an effect in itself. It may for instance affect an individual's psychology which in turn may influence economic

[14] Models excluding the calendar year dummies provide similar results.

[15] More formally, assume that the true model of the effect of diabetes on labour market outcomes is $y = X^*\beta + \epsilon$. Because we do not observe the true values of X^* we have to use self-reported measures that contain errors: $X = X^* + u$. Since u may be correlated with ϵ - in contrast to classic measurement error which is randomly distributed, we cannot sign the bias of β.

behaviour. Two studies found a diabetes diagnosis and subsequent treatment to increase the odds of psychological problems, including depression and anxiety (Paddison et al., 2011; Thoolen et al., 2006), while similar results have not been found for people with undiagnosed diabetes (Nouwen, Nefs, et al., 2011). Looking at behavioural change, health information has been shown to affect behaviour after the diagnosis of not only diabetes (Slade, 2012) but also of other chronic diseases (see Baird et al. (2014), Gong (2015), Thornton (2008), and Zhao, Konishi, et al. (2013)). However, little is known about the effects of health information on labour market outcomes. For diabetes, only Liu and Zhu (2014) investigate the effect of receiving a diabetes diagnosis on labour income in Chinese employees. This study finds a reduction in labour income which was attributed to the psychological effects of the diagnosis.[16]

The use of biomarker data allows to explore the relationship of measured diabetes with labour outcomes which can then be compared to the estimated effect of self-reported diabetes. The biomarker data also enables us to look at diabetes severity, as measured by HbA1c values. Since this data is only available for a subsample of one wave—the most recent one—our analysis here is limited to cross-sectional data no longer directly comparable to the panel-based results in this paper. Nonetheless, it allows for a first exploration of the relationships of measured diabetes and disease severity with labour market outcomes.

Our analysis of the biomarker sample consists of three steps. We first estimate Eq. 4.5 to assess the association of self reported diabetes with labour outcomes, as before, but this time for the biomarker sample only, using the following specification:

$$Y_i = \beta_0 + \beta_1 Dsr_i + \beta_2 X_i + c_i + u_i \tag{4.5}$$

We then estimate the relations between diabetes, as defined by our biomarker, and labour outcomes, via the following equation:

$$Y_i = \beta_0 + \beta_1 Dbio_i + \beta_2 X_i + c_i + u_i \tag{4.6}$$

Here $Dbio_i$ is equal to 1 if HbA1c $\geq 6.5\%$.

To find the effect of undiagnosed diabetes we include both variables at the same time and estimate:

$$Y_i = \beta_0 + \beta_1 Dsr_i + \beta_2 Dbio_i + \beta_3 X_i + v_i + u_i. \tag{4.7}$$

[16] In a very different context Dillon et al. (2014), using a randomized intervention, find that the news stemming from diagnosis of malaria affects productivity and income, but not labour supply among sugar cane cutters in Nigeria.

For the biomarker analysis we rely on within-household variation v_i for identification to account for unobserved community characteristics, such as the access to healthcare and the quality of healthcare in the community, poverty and unemployment levels in the community or the amount of public green space and recreational possibilities available. These factors potentially affect both the propensity to develop diabetes and to receive a diagnosis; they may also be related to labour market outcomes.[17]

4.5 Results

4.5.1 Incidence of self-reported diabetes

Table 4.3 presents the estimation results of the FE model using Eq. 4.2, which indicate significant and substantial reductions in the probability of employment for men and women with self-reported diabetes. The coefficients are similar for both sexes, showing a reduction in employment probabilities of over 5 percentage points. In relative terms—taking into account the lwoer employment rates for women compared to men—these percentage points reductions translate into a reduction of 14% for women and of 6% for men, suggesting a stronger impact of diabetes on female employment chances.

Table 4.3: Self-reported diabetes and labour market outcomes.

	Employment		Log hourly wages		Weekly working hours	
	(1) Males	(2) Females	(3) Males	(4) Females	(5) Males	(6) Females
Self-reported diabetes	−.054**	−.059**	0.054	0.081	−.524	−1.955
	(.025)	(.024)	(.067)	(.158)	(1.499)	(2.517)
Hausman test	255.260	388.822	1084.317	91.096	967.007	106.455
p-value	0.000	0.000	0.000	0.000	0.000	0.000
N	21388	27341	13828	7068	17616	9112

Notes Individual level fixed effects. Robust standard errors in parentheses. Reference category: dependent non-agricultural worker or employee. Other control variables: state dummies, urbanization dummies, education dummies, married dummy, number of children < 6, wealth, health insurance status, age squared and calender year dummies. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

The results in Columns 3–6 show no significant relationship between self-reported dia-

[17] We did not account for fixed household characteristics as the average number of observations per household was close to one, i.e. for most households only one member provided biomarker information in our subsample, significantly limiting the variation within households that would be needed for identification.

betes and wages or working hours. One may expect this relationship to differ by the type of work, as those with diabetes working in an agricultural job that requires strenuous, physical efforts may see their productivity more adversely affected than those engaged in more sedentary work. We therefore estimate a model including interaction terms between self-reported diabetes and agricultural employment and between self-reported diabetes and self-employment, respectively, using non-agricultural wage employment as the comparison group, and restricting our sample to those employed only.

Table 4.4: Effect of self-reported diabetes on wages and working hours, by type of work.

	Log hourly wage		Weekly working hours	
	(1) Males	(2) Females	(3) Males	(4) Females
Agricultural worker	$-.078^{*}$	$-.280$	-3.577^{***}	-4.473^{*}
	(.044)	(.186)	(.800)	(2.702)
Self-employed	0.028	$-.144^{*}$	-1.452^{**}	-4.713^{***}
	(.043)	(.087)	(.704)	(1.388)
Self-reported diabetes	0.105	0.064	0.617	$-.524$
	(.076)	(.169)	(1.606)	(2.252)
Self-reported diabetes x agricultural worker	$-.242$	$-.409$	-5.495^{*}	-3.535
	(.188)	(.373)	(2.833)	(22.300)
Self-reported diabetes x self-employed	$-.105$	0.125	0.306	-4.149
	(.192)	(.326)	(2.503)	(4.739)
Hausman test	280.491	912.537	4086.461	995.171
p-value	0.000	0.000	0.000	0.000
N	13828	7068	17616	9112

Notes Individual level fixed effects. Robust standard errors in parentheses. Reference category: non-agricultural worker or employee. Other control variables: state dummies, urbanization dummies, education dummies, married dummy, number of children < 6, wealth, health insurance status, age squared and calender year dummies. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

The results in Table 4.4 show that while male agricultural workers have lower wages in general, the relationship with diabetes does not depend on the type of work, as none of the interaction terms show up as significant. In the working hours regression one interaction term is significant, suggesting that those with self-reported diabetes working in agriculture supply 5 hours less relative to non-agricultural workers and employees. However, because we have more than two work types we cannot draw conclusions solely on the basis of the t-statistic. We therefore perform a Wald test for the overall significance of the interaction term which does not reject the null of no interaction effects ($p = .15$), indicating that the effect of diabetes on working hours does not vary significantly by type of work.

In summary, we find no evidence for an association between self-reported diabetes and

wages or working hours. This lack of effects may be explained by selection: potentially, only those with "mild" or asymptomatic diabetes are still in the same job continuing to earn similar wages. Only once complications become increasingly severe would they switch activity (or drop out of the labour market), without going through a notable phase of reduced productivity and labour supply.

To explore whether diabetes affects the selection into certain types of work we estimate FE models of the probability of being in non-agricultural wage employment, agricultural employment or self-employment using three dummy variables indicating the respective type of work as the left hand side variables. The results in Table 4.5 indicate a negative association with self-employment, though the estimates are quite imprecise. For women, those who self-report diabetes are less likely to work in agriculture and potentially self-employment. This may suggest that having diabetes drives people out of self-employment and agricultural jobs, for instance because these jobs are physically more demanding and possibly also because they provide less protection in terms of insurance and employment duration. We also estimated a pooled multinomial logit model augmented with the within-between approach (Bell and Jones, 2015), based on the work of Mundlak (1978), which allows interpreting the coefficients of all time-varying variables as within-effects by including individual means of all time-varying covariates[18]. The results indicate a very similar pattern both in size and significance (results available on request).[19]

Table 4.5: Relationship between self-reported diabetes and selection into types of work.

	Males			Females		
	(1) Non-agric.	(2) Agric.	(3) Self-employed	(4) Non-agric.	(5) Agric.	(6) Self-employed
Self-reported diabetes	−.006	−.008	−.043	−.001	−.022**	−.029
	(.029)	(.022)	(.026)	(.018)	(.009)	(.018)
Hausman test	2196.390	2005.383	1249.080	1126.933		86.400
p-value	0.000	0.000	0.000	0.000		0.000
N	20719	20719	20719	26577	26577	26577

Notes Individual level fixed effects. Robust standard errors in parentheses. Other control variables: state dummies, urbanization dummies, education dummies, married dummy, number of children < 6, wealth, health insurance status, age squared and calender year dummies. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

[18]Several other studies in economics have used this approach recently, e.g., Boll et al. (2016), Geishecker and Siedler (2011), and Wunder and Riphahn (2014)

[19]Using the same methods, we also investigated the impact of diabetes on changes in the type of work for those already employed, finding no evidence that diabetes leads to changes in the type of work. These results are also available on request.

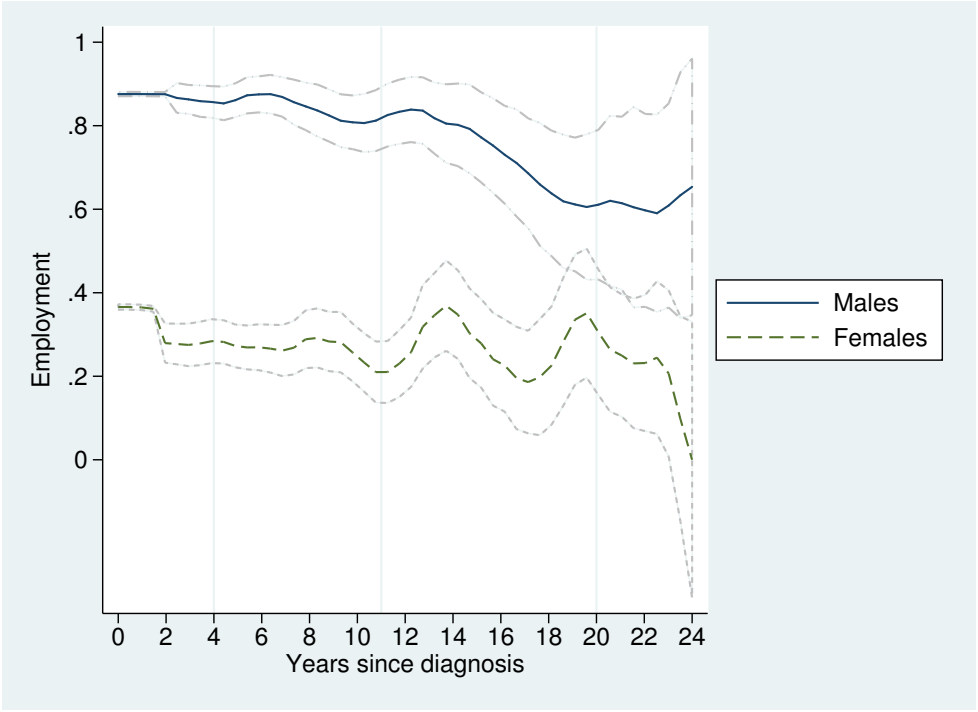
4.5.2 Duration of self-reported diabetes

Because diabetes is a chronic and generally life-long disease, we investigate how soon after the first diagnosis diabetes may affect labour market outcomes. Given that complications of diabetes develop over time, the effect may increase linearly as the years go by. Non-linear relationships are also plausible: health problems that have led to the diagnosis as well as psychological effects after the diagnosis may affect labour market outcomes immediately after having been diagnosed with diabetes. Similarly management of the disease may be successful only after some initial period. It is also possible that after some time complications start to appear, again reducing health and leading to reductions in labour supply and productivity.

To obtain an initial idea of the relationship between our outcome variables and diabetes duration we use a non-parametric kernel-weighted local polynomial regression. As Figure 4.1 shows, the relationship between diabetes duration and the probability of employment for men shows a more or less steady decline that becomes more pronounced as time progresses. For women, a first drop-off occurs right after diagnosis; thereafter no consistent pattern is observed.[20] A similar analysis for wages shows somewhat more erratic relationships, although there seems to be a long term negative trend for women but not for men (see figures 4.2 and 4.3). A similar negative trend can be observed for working hours for women, but not for men.

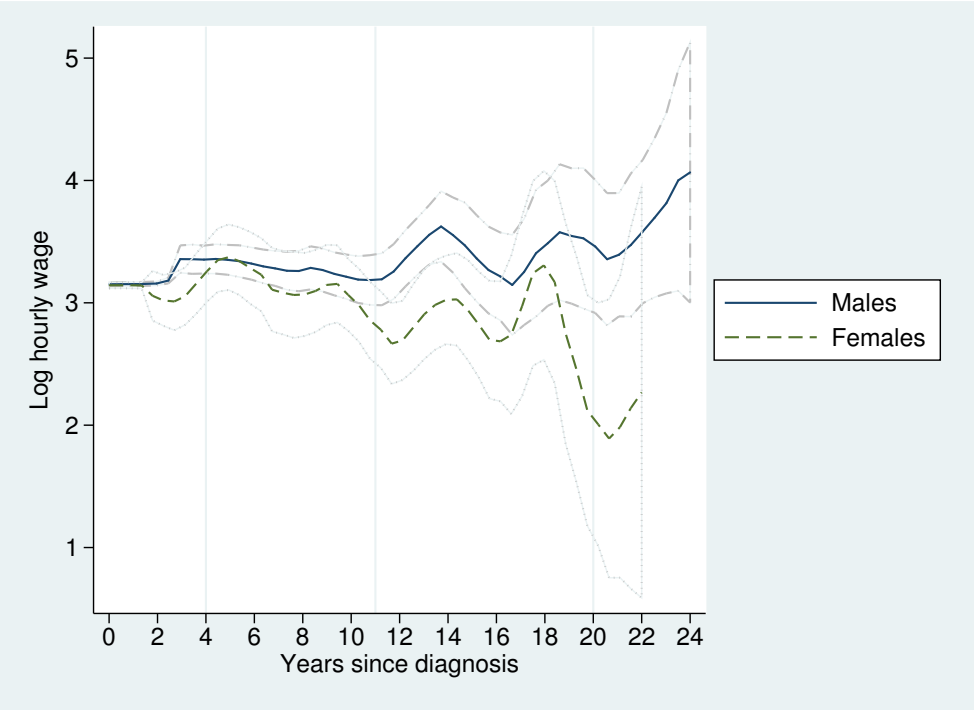
[20] Since long run estimations suffer from large standard errors—as the sample size is strongly reduced—this limits its interpretation and we therefore truncate the graphs at a disease duration of 24 years.

Figure 4.1: Kernel-weighted local polynomial regression of employment status on diabetes duration.



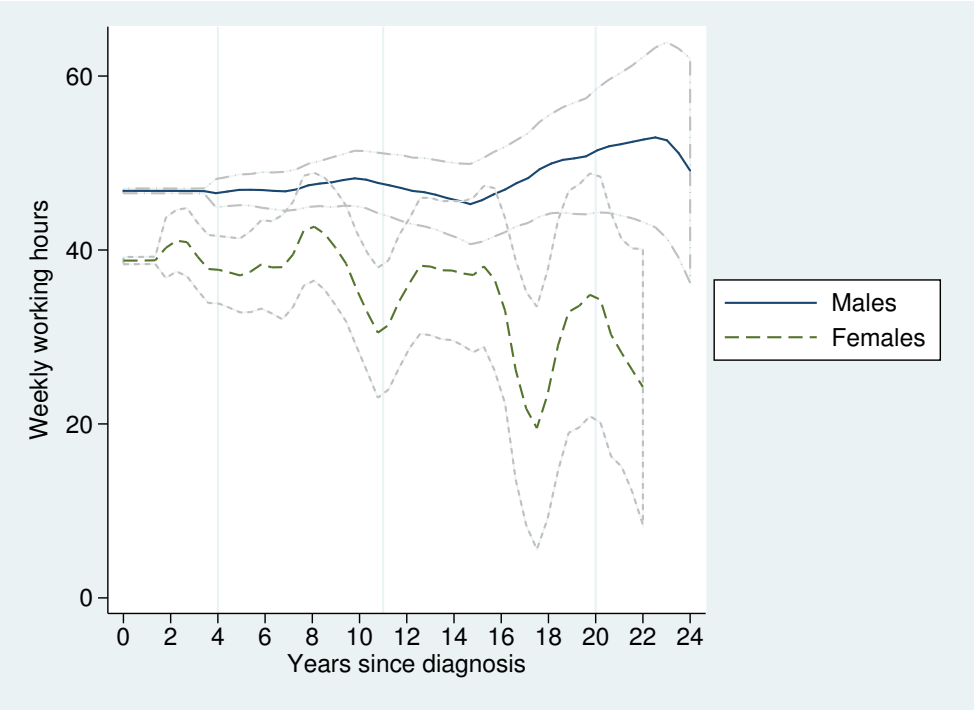
Notes The dotted lines around the main line show 95% confidence intervals.

Figure 4.2: Kernel-weighted local polynomial regression of log hourly wages on diabetes duration.



Notes The dotted lines around the main line show 95% confidence intervals.

Figure 4.3: Kernel-weighted local polynomial regression of working hours on diabetes duration.



Notes The dotted lines around the main line show 95% confidence intervals.

Table 4.6 presents the results of the linear and non-linear duration models (for which we created the following splines to capture the immediate, intermediate and long-term relationships:0–4, 5–11, 12–19 and 20+), starting with the results of the cross-sectional LPM, followed by the pooled LPM and then the FE model as specified in Eq. (4.3) and Eq. (4.4).

For employment probabilities the results indicate a yearly reduction in male employment probability throughout. For women the coefficient shows a reduction of up to almost 1 percentage points per year, though the association is not as strong in the FE model. The coefficients in the spline models provide some evidence for an immediate effect of diabetes, which then levels off for some time after which it becomes stronger again. Nonetheless, for males and particularly females, the coefficients are quite imprecisely measured.

Turning to wages, the FE model indicates a reduction in female wages of about 7% per year with diabetes. For men we find no consistent effect. The results of the non-linear specification indicate that there may be a reduction in wages 5–11 years after the initial diagnosis. We also find associations for women with more than 20 years of diabetes, but these estimates may be spurious due to the considerably reduced number of observations in this group.[21]. There appears to be no consistent relationship between working hours and time since being diagnosed with diabetes.

Overall these results suggest a fairly constant decrease in the probability of employment for both men and women and in earnings for women, which contrast with estimates for the USA (Minor, 2013), where no such linear relationship is observed. Minor (2013) finds a reduction in employment probabilities of 82 percentage points for females after 11 to 15 years and a reduction of 60 percentage points for males after 2-5 years, indicating very large employment penalties, in particular in comparison to our results for Mexico. However, our non-linear results are not directly comparable to these estimates as Minor used pooled cross-sectional data, constructed dummy variables instead of splines and used different duration groups.[22]

[21] There are only 9 and 3 observations for male and female wages with more than 20 years since diagnosis in wave 3, respectively, and similarly 17 and 7 in the pooled sample, respectively. For male and female working hours there are 12 and 7 observations with more than 20 years since diagnosis in wave 3, respectively, and 20 and 12 for the pooled sample, respectively.

[22] We estimated a comparable model to that of Minor (2013) using dummy variables and find a significant reduction in employment chances throughout, regardless of whether we use our duration groups to construct the dummies or the duration groups used by Minor (2013). For men, we find a significant reduction of about 6 to 12 percentage points, depending on the used specification, in the first 2 and 4 years after diagnosis, respectively. In the following years the effect size tends to increase somewhat. For women, we find less evidence for an immediate effect of diagnosis, but effects do emerge after about 2 years of living with the disease and also increase somewhat over time. These results are available on request.

Table 4.6: Relationship between self-reported years since diagnosis and labour market outcomes using continuous duration and duration splines.

	Males			Females		
	(1) OLS (wave 3)	(2) Pooled OLS	(3) FE	(4) OLS (wave 3)	(5) Pooled OLS	(6) FE
			Employment probabilities			
Panel A:						
Diabetes duration (linear)	−.008***	−.007***	−.017***	−.005***	−.004***	−.009*
	(.002)	(.002)	(.006)	(.002)	(.001)	(.005)
Hausman test			153.024			200.073
p-value			0.000			0.000
Panel B:						
Diabetes duration (splines)						
0–4	−.007	−.007	−.026*	−.010	−.015**	−.017
	(.007)	(.006)	(.014)	(.007)	(.006)	(.016)
5–11	0.000	−.003	−.003	−.004	0.004	−.003
	(.009)	(.006)	(.009)	(.008)	(.006)	(.008)
12–20	−.030**	−.017*	−.029*	0.005	−.004	−.014
	(.012)	(.010)	(.016)	(.008)	(.006)	(.011)
> 20	0.011	0.007	−.046*	−.010*	−.003	−.015
	(.016)	(.014)	(.028)	(.006)	(.003)	(.018)
Hausman test			161.953			198.692
p-value			0.000			0.000
N	8217	16292	16292	10467	22407	22407
			Log hourly wage			
Panel A:						
Diabetes duration (linear)	0.001	0.010**	−.019	−.014*	−.009	−.073**
	(.006)	(.005)	(.018)	(.008)	(.008)	(.029)
Hausman test			838.213			93.232
p-value			0.000			0.000
Panel B:						
Diabetes duration (splines)						
0–4	0.034*	0.046***	0.033	0.027	0.030	0.015
	(.017)	(.016)	(.055)	(.031)	(.026)	(.138)
5–11	−.041*	−.037**	−.055*	−.039	−.034	−.101*
	(.021)	(.018)	(.033)	(.030)	(.024)	(.056)
12–20	0.015	0.044	0.062	−.032	−.071*	−.051
	(.033)	(.029)	(.056)	(.042)	(.039)	(.047)
> 20	0.053	0.014	−.111	−.007	0.041***	−.204***
	(.054)	(.040)	(.104)	(.028)	(.015)	(.053)
Hausman test			1037.290			96.266
p-value			0.000			0.000
N	5509	10767	10767	2874	5741	5741
			Weekly working hours			
Panel A:						
Diabetes duration (linear)	0.069	0.048	0.181	−.020	−.124	0.208
	(.124)	(.102)	(.330)	(.187)	(.127)	(.652)
Hausman test			704.904			107.709
p-value			0.000			0.000
Panel B:						
Diabetes duration (splines)						
0–4	−.033	−.233	0.709	0.739	0.470	2.014
	(.421)	(.325)	(.938)	(.645)	(.586)	(2.947)
5–11	0.269	0.338	−.218	−.410	−.479	−.508
	(.539)	(.399)	(.568)	(.728)	(.553)	(1.020)
12–20	0.209	0.137	0.698	−.164	−.051	−.402
	(.730)	(.538)	(.945)	(.995)	(.700)	(1.207)
> 20	−1.300	−.768	0.039	−.499	−.418	8.117***
	(.944)	(.930)	(2.184)	(.930)	(.305)	(1.612)

4.5.3 Cross-sectional biomarker analysis

In this section we gain additional insights from using the biomarker data collected in the third wave of the MxFLS. As noted in section 4.3, these data enable us to identify respondents with HbA1c levels equal to or above the internationally recognized diabetes threshold of 6.5%. This will allow the investigation of the direction of bias introduced when relying on self-reported diabetes only and when it is not possible to identify those unaware as well.

We first present a cross tabulation of self-reported diabetes and the results of the biomarker analysis (Table 4.7). The table indicates that 27% of the sample have HbA1c levels indicative of diabetes and 81% of those self-reporting a diabetes diagnosis also have HbA1c levels equal to or above the diabetes threshold. Overall, of the people with diabetes according to biomarker analysis, 32% self-report a diagnosis, while 68% do not.

Table 4.7: Number of observations with diabetes (HbA1c $\geq$ 6.5%) and self-reported diabetes.

	$HbA1c < 6.5\%$	HbA1c $\geq 6.5\%$	Total
No self-reported diabetes	4544	1181	5725
	79%	21%	100%
	97%	68%	89%
Self-reported diabetes	129	554	683
	19%	81%	100%
	3%	32%	11%
Total	4673	1735	6408
	73%	27%	100%
	100%	100%	100%

Notes The first row of each category presents absolute values, the second row row percentages and the third row column percentages.

To further investigate the relationship of self-reported and biomarker tested diabetes, we estimate the models presented in section 4.4.3. The results in columns 1 and 2 of Table 4.8 show that the earlier results are robust for the biomarker sample. The coefficients in column 3 and 4 indicate that the associations with employment probabilities are much weaker when using diabetes defined by the biomarker instead of self-reported diabetes.[23]

[23]We also created a dummy variable that additionally to measured diabetes accounted for those with a self-reported diabetes diagnosis but biomaker levels below the diabetes threshold. This allowed us to investigate the effect for the entire diabetes population. The coefficients and their statistical significance are only marginally different to those presented in columns 3 and 4 of Table 4.8, which is

In columns 5 and 6, obtained from estimating Eq. 4.7, the coefficient for the biomarker diabetes population $Dbio_i$ now reflects the effect of undiagnosed diabetes, as the regression includes a control for self-reported diabetes, revealing that undiagnosed diabetes is not associated with any of the labour outcomes. The coefficient for self-reported diabetes is marginally bigger in size for men and somewhat smaller for women compared to column 1 and 2, respectively. However, these differences are not statistically significant (p>0.1) using a Z-test, suggesting that not accounting for undiagnosed diabetes will likely leave the estimates of self-reported diabetes unbiased.

Table 4.8: Biomarker results

	Self-reported diabetes		HbA1c $\geq$ 6.5		HbA1c $\geq$ 6.5 and self-reported d.	
	(1) Males	(2) Females	(3) Males	(4) Females	(5) Males	(6) Females
Dependent variable: Employment						
Self-reported diabetes	−.051**	−.044*			−.053**	−.032
	(.026)	(.023)			(.026)	(.026)
HbA1c $\geq$ 6.5			−.012	−.031*	0.003	−.022
			(.016)	(.018)	(.017)	(.019)
N	2785	3623	2785	3623	2785	3623
Dependent variable: Log hourly wages						
Self-reported diabetes	−.010	−.040			−.006	−.010
	(.065)	(.113)			(.078)	(.119)
HbA1c $\geq$ 6.5			−.007	−.057	−.006	−.055
			(.044)	(.070)	(.049)	(.075)
N	1803	884	1803	884	1803	884
Dependent variable: Weekly working hours						
Self-reported diabetes	−.293	−.751			−.286	−1.566
	(1.305)	(2.178)			(1.419)	(2.351)
HbA1c $\geq$ 6.5			−.088	1.153	−.012	1.525
			(.844)	(1.462)	(.925)	(1.565)

Notes Community level fixed effects. Robust standard errors in parentheses. Other control variables: age, age squared, state dummies, urbanization dummies, education dummies, married dummy, number children < 6 and wealth. Calender year dummies are included as data collection for the third wave was stretched out over several years. The wage and working hour models additionally control for type of work (agricultural and self employed with non-agricultural wage employment as the base) and for health insurance status. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

As discussed earlier, differences in effects between self-reported diabetes and those undiagnosed are likely to stem from selection into the diagnosed population, for instance those in worse health or higher HbA1c levels are more likely to go to the doctor and be

why we do not present them here.

diagnosed as well as to lose their job because of their diabetes. To further explore this, we first estimate models additionally controlling for self-reported health status to capture differences in subjective individual health. Secondly, we investigate in how far differences in measured HbA1c, as a proxy for diabetes severity, may explain differences in employment effects of self-reported and undiagnosed diabetes. To this end we estimate Eq. 4.7 additionally controlling for HbA1c levels.

Table 4.9: Self-reported diabetes, biomarkers, diabetes severity and self-reported health and their association with labour market outcomes

	Employment		Log hourly wages		Weekly working hours	
	(1) Males	(2) Females	(3) Males	(4) Females	(5) Males	(6) Females
Panel A (self-reported health)						
Self-reported diabetes	−.036	−.023	0.002	0.060	0.123	−2.191
	(.026)	(.027)	(.079)	(.121)	(1.433)	(2.386)
Hba1c $\geq$ 6.5%	0.003	−.023	−.004	−.051	−.066	1.829
	(.017)	(.019)	(.049)	(.075)	(.926)	(1.569)
Self-reported health status						
good	0.023	0.057*	0.061	−.115	−1.131	3.521
	(.025)	(.034)	(.074)	(.124)	(1.376)	(2.499)
fair	−.007	0.006	0.025	−.157	−1.606	4.646*
	(.026)	(.034)	(.076)	(.128)	(1.424)	(2.607)
bad	−.127***	−.024	−.016	−.371*	−6.190**	6.918*
	(.043)	(.046)	(.135)	(.189)	(2.521)	(3.858)
very bad	−.165	0.117	−.331	0.316	−1.869	−17.400*
	(.110)	(.116)	(.300)	(.439)	(6.433)	(9.005)
N	2785	3621	1803	883	2302	1143
Panel B (HbA1c levels)						
Self-reported diabetes	−.056*	−.027	−.007	0.002	0.076	−1.440
	(.031)	(.025)	(.068)	(.114)	(1.362)	(2.382)
HbA1c $\geq$ 6.5%	−.005	−.005	−.010	−.019	1.032	1.887
	(.023)	(.026)	(.060)	(.099)	(1.279)	(2.490)
HbA1c	0.003	−.006	0.001	−.012	−.364	−.122
	(.005)	(.006)	(.013)	(.021)	(.279)	(.514)
N	2785	3623	1803	884	2302	1144

Notes Community level fixed effects. Robust standard errors in parentheses. Other control variables: age, age squared, state dummies, urbanization dummies, education dummies, married dummy, number children < 6 and wealth. Calender year dummies are included as data collection for the third wave was stretched out over several years. The wage and working hour models additionally control for type of work (agricultural and self employed with non-agricultural wage employment as the base) and for health insurance status. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

When additionally controlling for subjective health status, we find that for men and women the difference between self-reported diabetes and undiagnosed diabetes is reduced due to a smaller coefficient for self-reported diabetes (Table 4.9, Panel A). Especially for females, the point estimates for self-reported diabetes and undiagnosed diabetes are now virtually the same size, suggesting that differences can be almost exclusively explained by self-reported health. For men, factors not captured by self-reported health may still play a role. Additionally accounting for measures of overweight and obesity, self-reported hypertension, heart disease and depression does not further affect the interpretation of the diabetes coefficient (results available on request).

Turning to Panel B, we do not find an indication that differences in HbA1c levels are driving the different employment effects of diabetes for the aware and unaware. We therefore conclude that current diabetes severity is likely not associated with any labour outcome and does not explain the difference in effects between diagnosed and undiagnosed diabetes.

To the best of our knowledge only one study has previously used biomarkers to analyze the relationship with labour market outcomes in a comparable population. Brown, Perez, et al. (2011) use data for a Mexican American population in a broadly comparable way to this paper, though stopping short of investigating the labour market impact of undiagnosed diabetes. In concordance with our results this study also finds that once diabetes is diagnosed, current management plays a minor role in determining labour market outcomes. This is not surprising given that HbA1c levels only provide a picture of blood glucose levels over the last three months. They therefore may not be representative of blood glucose levels in the years before and after the diabetes diagnosis which ultimately determine how soon complications appear and how severe they will be.

4.6 Conclusion

Diabetes has become one of the most common chronic diseases in middle- and high-income countries, with the potential to severely impact the health and economic well-being of those directly (and possibly indirectly) affected. Yet there remains only limited 'hard' evidence on the economic consequences, especially for these countries. Moreover, what evidence does exist at best partially tackles the econometric challenges involved.

This paper improves on existing work by addressing several methodological challenges that arise due to the nature of the disease and types of data available, using rich longitudinal panel data from Mexico, a MIC for which the biomarker data used in this paper indicates that diabetes, including undiagnosed diabetes, has reached alarming levels.

Apart from providing unique evidence for a developing country, the paper makes methodological contributions for the estimation of labour market effects of diabetes. By estimating individual fixed effects the analysis provides an improved accounting for the endogeneity of self-reported diabetes, as this allows cancelling out the potential role of unobserved individual traits that may affect both labour market outcomes and propensity to self-report (or suffer from) diabetes. Using further information on the year of diagnosis enables us to investigate the potential heterogeneity in the effect of self-reported diabetes on labour market outcomes over time. Finally, taking advantage of biomarker data to identify the entire diabetes population, i.e. including those with undiagnosed diabetes, allows for an assessment of the potential bias in estimates relying on self-reported diabetes (which is still the most frequent measure in the previous literature).

The first part of our results confirms a considerable gap in employment probabilities for both men and women reporting a diabetes diagnosis, compared to those that do not report the condition. Especially women have to deal with a considerable relative reduction in their employment probabilities. We also find some evidence that diabetes is more likely to reduce the probability of employment in the agricultural and self-employment sector, characterized predominantly by informal arrangements, compared to the rest of the workforce. Those who remain employed do not suffer any wage or labour supply effects, possibly because they are still relatively healthy or are able to resort to a type of work that does not entail their diabetes status limiting their work-related performance. More research will be needed to confirm and further investigate this finding as well as its interpretation.

Regarding the heterogeneity in the effects of diabetes over time, our results indicate an adverse impact of self-reported diabetes on employment chances, with the impact growing in magnitude especially after the first 10 years post-diagnosis. This is plausible in that as time lived with diabetes evolves, complications associated with diabetes tend to become more frequent and more severe (Adler et al., 2003). Looking at wages as our labour market outcome, we uncover some adverse effects for females, indicating a sizeable reduction with time since diagnosis. Interestingly, theses reductions in wages appear more or less where no employment effects are found, suggesting that after the initial employment shock fo the diagnosis, reductions in productivity are more levelled, leading only to reductions in wages but not to job loss, at least until further more debilitating complications appear after additional years with the disease. These findings may bode ill for countries were diabetes has started appearing at an increasingly younger age, causing people to live with the disease for larger parts of their productive lifespan, possibly exacerbating the economic effects of reduced employment due to diabetes (Hu, 2011; Villalpando et al., 2010).

The second part of our results indicates that only relying on self-reported diabetes can lead to an overestimation of the relationship between diabetes and labour market outcomes. We find that a negative relationship only exists for those with self-reported, but not for those with undiagnosed diabetes. This perhaps surprising, notable difference, is at least mediated by the subjective health status being worse for those self-reporting compared to the undiagnosed. Current disease severity, as proxied by HbA1c levels, does not appear to play an important role in this context.

Our findings bear several implications. First, when interpreting labour market impact estimates relying on self-reported diabetes, one cannot assume that the results extend to those with undiagnosed diabetes. However, the strategy of simply merging self-reported and undiagnosed in one diabetes category may not be ideal, as doing so will fail to account for the heterogeneity between the groups in the amount of health information they possess, the time they have already been exposed to elevated blood glucose levels and consequently their subjective as well as true health status, leading to a potentially important loss of information. If, by contrast, both groups are separately accounted for in the model, thereby acknowledging their inherent differences, this allows us to gain information about the distribution of the economic burden across the two groups.

Further, the results of the biomarker analysis also reveal that the coefficient of self-reported diabetes is not strongly affected when accounting for biomarker diagnosed diabetes, suggesting that using self-reported diabetes still provides largely unbiased estimates. The latter estimates should then of course only be used to draw conclusions about the effect of self-reported diabetes, not of diabetes overall. In the case of Mexico, given that more than 7% of the Mexican population have been diagnosed with diabetes, the identified reduction in employment probabilities still amounts to a significant overall economic burden being associated with (diagnosed) diabetes.

Our results add further weight to the case for reducing the incidence and progression of diabetes. On top of the well-documented health benefits, it appears there are considerable potential gains to be had in terms of increasing the productive lifespan of people. This is of particular importance in LMICs, where parental health shocks, related job loss and increasing health expenditures can have repercussions across the entire household. Other family members, including children, may be forced to increase their labour supply and to reduce non-health expenditures in order to prevent deterioration of the household's economic situation. This can lead to forgone investments into child education, showcasing the potential for adverse long-term effects of health shocks due to diabetes (Bratti and Mendola, 2014). Moreover, the large proportion of undiagnosed people indicates that diagnosis—at least in Mexico—happens too late or not at all, thereby significantly reducing

the possibility to prevent complications via appropriate treatment and self-management, which has repercussions by increasing the risk of severe complications appearing early. Hence, much of the health and economic burden may be prevented by earlier diagnosis and, given the generally limited success in achieving good control in Mexico, better treatment of those already diagnosed with diabetes. Ultimately of course, there will be a need to invest in the prevention of diabetes cases in the first place. Taxation of sugar sweetened beverages may be one promising way forward (Colchero et al., 2016), though the long-term effects in terms of diabetes prevention remain to be demonstrated.

5 The effects of receiving a diabetes diagnosis on health behaviour and economic outcomes in China

Pre-amble

Chapters 3 and 4 provided evidence of the adverse impact of self-reported diabetes on employment probabilities in Mexico. However, if this is also the case in other middle-income countries (MICs) is unclear. The study in Chapter 5 intents to provide further evidence using rich panel data covering a period of rapid economic transition in China. It further intents to provide information about the current success of the Chinese healthcare system in bringing about behaviour change in those diagnosed. Studies have shown that smoking cessation and weight loss after a diagnosis can have beneficial effects on blood glucose control and the risk of complications.

This study again faces the problem of the potential endogeneity of diabetes. It uses an already established approach with the fixed effects (FE) estimator. However, it adds a further identification strategy by making use of marginal structural models (MSMs), a strategy widely applied in epidemiology to account for time-variant confounding, in particular selection into treatment on pre-treatment outcome variables. It is less known in economics but nicely complements the FE method. The aim of the study was to provide information on the success of current diabetes management in the Chinese healthcare system and to identify areas where improvements are needed to curb the burden of diabetes.

Abstract

A diabetes diagnosis entails important consequences for its recipients. They obtain health information but also face the challenge of having to manage the condition via lifestyle adjustments, with potential consequences for—among other things—their economic activity. We investigate the causal effect of a diabetes diagnosis on behavioural risk-factors as well as on employment chances, two potentially intertwined factors. We used longitudinal data from the China Health and Nutrition Survey (CHNS), covering the years 1997 to 2011. Two complementary statistical techniques—marginal structural models and fixed effects panel estimation—were used to estimate the causal effect of a diabetes diagnosis on a series of behavioural risk-factors and employment probabilities. Both models suggest female employment chances to decline significantly as a result of a diabetes diagnosis (over 11 percentage points), but no adverse effects for men. Chinese men appear to respond to a diagnosis by significantly reducing their body mass index (BMI), waist circumference and calorie consumption, in ways that are sustained over time. The effects on behavioural outcomes for women are smaller and less consistent. In light of the results it may be worthwhile for the Chinese healthcare system to focus efforts on addressing the needs of women with diabetes as it is them who have particular difficulties in improving their behavioural risk factors and who—perhaps as a consequence—pay the biggest price in terms of loss of employment chances. Future research is needed to unravel the mechanism behind these sex differences.

5.1 Introduction

While the risk factors for type 2 diabetes, post diagnosis blood glucose management and the resulting diabetes complications have received considerable research—including in the context of China (Batis, Mendez, et al., 2014; Chan, Zhang, et al., 2014; Ma et al., 2014; Pan, 2015; Yang, Zhao, et al., 2012; Zhao, Zhu, et al., 2012)—, the effects of a diabetes diagnosis itself on behavioural risk-factors for diabetes complications is less well known. This is despite research suggesting that behaviour changes after a diabetes diagnosis can have positive effects and reduce the risk of subsequent cardiovascular events(Long et al., 2014), may help in effectively managing blood glucose levels and achieving further treatment goals (Zhou, Ji, et al., 2016). Further, such changes in behaviours may also affect the economic impact of diabetes if they cause a delay in or even prevent the onset of complications. As Seuring, Serneels, et al. (2016) have shown for Mexico, a diabetes diagnosis can cause changes in labour market performance in a MIC. Therefore, we also investigate the impact of a diabetes diagnosis on employment probabilities.

One of the challenges faced by researchers investigating the effects of diabetes on both risk factors and economic outcomes, is establishing a causal relationship rather then associations. Firstly, unobserved variables may be biasing the estimates, in particular time-invariant causes such as poor early life conditions that could increase the probabilities to have diabetes and at the same time to be unemployed or to be smoking. Similarly, personal character trades are difficult to measure but could affect both diabetes and risk behaviours or employment outcomes. Further, it is conceivable that diabetes risk factors such as a high BMI or smoking are causally related to both employment chances and diabetes, and are at the same time affected by a diabetes diagnosis themselves. This makes it difficult to identify the causal pathway through which diabetes affects employment chances. So far studies exploring the economic impact of diabetes have often refrained from accounting for such risk factors due to the danger of over-adjusting, as standard regression techniques such as ordinary least squares (OLS) or FE are unable to account for the potentially bidirectional relationship. We therefore use MSMs, an estimation strategy that is able to account for time-dependent confounding across time (Robins et al., 2000) when estimating the impact of a treatment, here a diabetes diagnosis, on the outcome of interest. We further complement this strategy and test its robustness by alternatively estimating FEs models that—while unable to account for the potentially simultaneous relationships—are able to take into account any unobserved time-invariant confounding additionally to confounding due to observed variables.

More information about the effects of a diabetes diagnosis may be particularly important for low- and middle-income countries (LMICs) such as China, where diabetes prevalence has surged from 1% in the early 1980s to about 10% in recent years (Hu, 2011; NCD Risk Factor Collaboration, 2016). Confronting this diabetes epidemic puts a strain on healthcare systems (Seuring, Archangelidi, et al., 2015), increasing the need to find highly cost-effective prevention and treatment options in very resource constraint settings (Silink et al., 2010). However, to do this it is important to assess how successful people with diabetes currently are is in promoting positive health behaviours and preventing adverse economic outcomes.

So far, population-level research on the effects of health information on post-diagnosis behaviour change is scarce and has been limited to high-income countries (HICs). The sole study on the effects of recently diagnosed diabetes found positive behaviour changes shortly after diagnosis in a USA population. However, the effects were mostly short lived and tended to dissipate over time, particularly considering weight loss (Slade, 2012). Slade created an "at risk" control group without diabetes that intended to be similar to the treatment group with diabetes, apart from not having received a diagnosis. He used

information on diabetes biomarkers to estimate the propensity score of those without a diabetes diagnosis to be above a specific at risk threshold, so that everybody above a certain propensity score was used to form the control group. He then estimated dynamic population averaged as well as FE models for identification. While this allowed for the construction of a control group, the study was not able to account for the possibility of selection into treatment based on pre-treatment values of the dependent variables.

Another study investigated the effect of a hypertension diagnosis on nutritional behaviours in China using a regression-discontinuity design and biomarker information on blood pressure (Zhao, Konishi, et al., 2013). A crucial assumption in the study was that people above the hypertension threshold were indeed informed about that outcome while those just below the threshold were not. These two groups were then compared to isolate the particular effect of the additional health information on food consumption. The results indicated that a diagnosis leads to reductions in fat consumption of the rich at the consecutive wave. However, an important caveat of the study that the above assumption about who gets (not) informed about the outcome of the examination might not have been fully met. It remained somewhat unclear whether the participants received just the actual blood pressure measurement information and had to interpret these data themselves, or whether they were made explicitly aware of their hypertension (or also pre-hypertension) status (Zhao, Konishi, et al., 2013). Further, the results may have limited generalisability, since the measured treatment effect is a very local one, applying only to the population around the hypertension threshold. The effects might be different for people receiving their 'diagnosis' and having very severe hypertension already.

This study adds in several ways to the existing literature. First, it shows the impact of diabetes diagnosis on labour outcomes in China, not only over the short term, but for a period covering the entire decade of the 2000s, allowing for a more long term investigation of the effects. This both confirms and extends earlier evidence for other settings and using different methods. Second, it provides information on the effect of a diabetes diagnosis on health behaviours. Third, by considering the effects over time on both employment and health behaviour simultaneously, the results shed light on potential pathways through which the impact on employment may work. Fourth, the study provides a methodological innovation by using both MSM and FE estimation methods, offering insights not only on the robustness of MSM results, but also on the validity of some of its assumptions.

5.2 Methods

5.2.1 Study sample

The CHNS is an international collaborative project led by the Carolina Population Center at the University of North Carolina at Chapel Hill investigating nutrition and health behaviours in nine provinces of China (Zhang, Zhai, et al., 2014). We use data from 1997 onwards, which was the first time survey participants provided diabetes information. In total we use six waves (1997, 2000, 2004, 2006, 2009 and 2011) obtained from the longitudinal dataset released in 2015. The data provide extensive information on nutrition and health, including anthropometric measures of weight and height, reducing potential measurement issues. It further provides socioeconomic information, most importantly for this study about employment. The sample is limited to the adult population from age 18–64. The sample is not nationally representative and as such does not provide sampling weights (Popkin et al., 2010).

Overall, between 84% to 90% of the survey participants are followed up in the consecutive wave, with attrition being highest after 2006. Attrition in the CHNS due to mortality is around 1% (Popkin et al., 2010). Other reasons mentioned by Popkin et al. (2010) are loss in follow up due to migration, natural disasters and redevelopment of housing in the urban centres leading to relocations. We analysed if any of our variables of interest was significantly related to attrition and did only find lower calorie consumption to exhibit an association. Further, attrition was related to urbanization, level of education and being of younger age, suggesting that mostly younger, more urbanized participants tended to leave the survey.

5.2.2 Assessment of diabetes

We used self-reported information on a diabetes diagnosis to construct our diabetes indicator. We only relied on incident cases of self-reported diabetes, excluding individuals with self-reported diabetes at baseline. Given the chronic nature of diabetes, we assumed that after the initial diagnosis diabetes persisted for the rest of one's life. To construct a measure of diabetes duration for incidence cases we used self-reported information on the year of diagnosis. If we found that the year of diagnosis was reported to be before the last wave without a reported diagnosis, we used the midpoint between the last wave without diagnosis and the first wave with a diagnosis as the year of diagnosis.[1]

[1]The number of observations replaced at each wave was: 21 (2000), 44 (2004), 51 (2006), 78 (2009), 59 (2011). Overall it affected 43% of the year of diabetes diagnosis self-reports.

5.2.3 Assessment of outcomes

The economic outcomes we focus on is employment status, based on a self-reported measure of if the person was currently working. People who were not working because they were students were excluded. We did include those that were not working due to any other reason such as doing housework, being disabled or being retired. The behavioural outcomes we estimated were current smoking status, any alcohol consumption over the last year, BMI, waist circumference in centimetres and daily calorie consumption. Smoking status and alcohol consumption were self-reported, while BMI and waist circumference were based on anthropometric measurements, minimizing potential reporting errors. Waist circumference is reported in centimetres. Finally, daily calorie consumption is a constructed variable available in the CHNS, based on the average daily consumption of carbohydrates, protein and fat of every individual in the survey, measured on three consecutive days. Our economic outcomes was employment status, based on a self-reported measure of if the person was currently working. People who were not working because they were students were excluded. We did include those that were not working due to any other reason such as doing housework, being disabled or being retired.

5.2.4 Statistical analysis

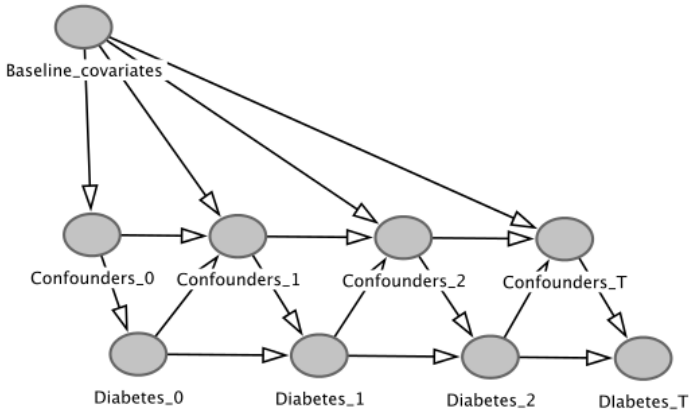
We use two statistical approaches to account for potential confounding: marginal structural models (MSMs) and fixed effects (FE).

Marginal structural models

MSMs apply inverse probability weights to adjust for confounding and selection bias as a result of time-varying confounders being affected by prior exposure (Robins et al., 2000). Under the assumption of the MSM(Robins et al., 2000)—the reported treatment is the treatment that has actually been received (consistency), there are no unmeasured confounders (exchangeability) and every person in the sample has a non-zero chance of receiving the treatment (positivity) (see Section 5.4 for a discussion of the validity of these assumptions in our case)—the causal DAG shown in Figure 5.1 displays the association between confounders and outcomes and a diabetes diagnosis.

In our context it seems possible that, for example, BMI could affect the probability of being diagnosed with diabetes which then itself may affect subsequent BMI levels, confounding the relationship between a diabetes diagnosis and BMI due to non-random selection. Similarly, employment history and current employment could affect the probability of a diabetes diagnosis through their impact on lifestyle and hence diabetes risk

Figure 5.1: Direct acyclic graph (DAG) representing the relations between confounders/outcomes and a diabetes diagnosis.



Notes The confounders not only include control variables but also pre-treatment values of our outcomes of interest to account for any predetermination of the treatment.

factors such as increases weight or smoking. For example, an increase in disposable income or a reduction in leisure time as a result of a new job and the subsequent effect on risk behaviours could confound the relationship between a diabetes diagnosis and employment status. MSM accounts for this by calculating weights based on the potential risk of a person being diagnosed at each time point.

To calculate these weights we first constructed unstabilized weights using baseline values of time-variant confounders, time-invariant confounders as well as time-variant confounders lagged by one period to predict the probability of developing diabetes at each wave. We used lagged time-variant confounders because current diabetes status as reported in the survey was determined at some point within the current and the previous wave that were determined before the current diabetes status, to prevent reverse causality. The used predictors were age and age squared to account for changes in risk with increasing age, an index of urbanization pre-constructed within the CHNS data, ranging from 1 to 120 as the level of urbanization increases (Zhang, Zhai, et al., 2014), to account for the impact of urbanization on diabetes risk (Attard et al., 2012). We also used secondary and university education, being married, having any medical insurance, being of Han ethnicity, living in a rural area, dummies for the different Chinese regions and the respective survey waves as predictors. Further we used inflation adjusted per-capita household income to adjust for effects of household wealth on diabetes. Finally, all outcome variables (employment status, alcohol consumption, smoking status, BMI, waist circumference and average

daily calorie consumption) were used as predictors.

Because unstabilized weights can be highly variable it is recommended to stabilize the weights (Cole and Hernan, 2008). Using the unstabilized weights as the denominator, stabilized weights were calculated by dividing the denominator by the predicted treatment propensity from a model using only time-invariant confounders and baseline information of the time-variant confounders as predictors. Because our analysis was stratified by males and females, we created weights separately for both groups.

The MSMs were estimated using OLS for the continuous and a logistic model for the binary outcomes. For the logistic model we calculated average marginal effects for greater comparability with the results of the FE models. All models were weighted by the stabilized weights constructed beforehand while adjusting for all baseline and time-invariant covariates used in the calculation of the stabilized weights, except for the respective outcome of interest. Robust standard errors to account for intra-class correlation of repeated outcome measurements in individuals were used throughout. In our primary analysis, we present the results of the MSM with untruncated stabilized weights, as these present unbiased estimates, albeit they likely are less efficient than truncated weights (Cole and Hernan, 2008). We checked the distributions of inverse probability weights for extreme values and that the mean weights were 1 (see Table 5.5).

Fixed effects

While the MSM can account for pre-treatment selection on observable and time-variant confounders, it assumes that there are no unobserved time-invariant confounders such as family background, cognitive abilities, and other personal characteristics. This is a strong assumption that may be violated. The individual level FE model can help remedy this problem as it is able to account for both observed time-variant and invariant variables as well as time-invariant unobserved variables. It does so by demeaning the confounding variables at each time point by the overall individual mean across all observed time points. It then uses solely the within-person variation for identification, thereby accounting for any time-invariant observed or unobserved as well as observed time-variant effects.

This comes at a price: due to the demeaning, time-invariant variables such as Han ethnicity, were dropped from the model and could not be estimated. Further, because the FE model is not able to account for any treatment effects on other time-variant confounders, only a more limited set of confounders could be included compared to the MSM. Otherwise our estimate of the effect of a diabetes diagnosis would likely be biased due to the inclusion of 'bad controls' (Angrist and Pischke, 2008). Bad controls are those that have been affected by the treatment itself—such as BMI or smoking status after a diabetes

diagnosis—and therefore likely capture part of the causal effect of diabetes on our outcome of interest, biasing the diabetes coefficient (Angrist and Pischke, 2008). The FE models thus only included controls for age, age squared, the level of urbanization, education, being married, having any medical insurance, living in a rural area, and dummies for the different Chinese regions and the respective survey waves. For the estimation of the effect of time since diagnosis, the linear age variable was dropped. In FE models, two or more variables that change at the same rate between waves cannot be separately identified. Here this was the case with age and time-dummies, as both variables increased by one each additional year (Wooldridge, 2012). To identify the effect of diabetes duration we had to rely on the presence of people without diabetes in the sample, for which diabetes duration did not increase at the same rate as time.

Because it is not possible to retrieve marginal effects from a logistic FE model, we used a FE linear probability model instead. It generally produces very similar estimates compared to non-linear models (Angrist and Pischke, 2008).

Multiple imputation

To deal with missing data, we used chained multiple imputation to impute the missing values in Stata 13 using the user written ICE command (Royston and White, 2009) and used the resulting data for all our estimated models. Overall, thirty imputed datasets were created. Imputation models included all variables used in the MSMs. We imputed missing data in the same wave for which some data were recorded; we did not impute completely missing waves. Further, we did not impute missing diabetes information and instead assumed that once a diabetes diagnosis was reported, the individual had diabetes in every ensuing wave, even when the observation was missing. If diabetes was never reported in any wave, we assumed that the individual never had diabetes. We then only imputed missing values for those observations that had a non-missing diabetes status. For the calculation of the marginal effects in the MSM logit models, Rubin's rules were applied using the user written Stata command mimrgns (Klein, 2014).

Numbers of observations

Because we used lagged variables to construct the stabilized weights for the MSMs, the number of observations used in the MSMs was lower than those used in the FE models, where we did not use lagged variables. The summary statistics shown in Table 5.1 are based on the observations used in the FE models.

Sensitivity analyses

We conducted three additional sensitivity analyses in order to test the robustness of our results to different assumptions and estimation strategies. First, we truncated weights at the 1^{st} and 99^{th} percentile to investigate the sensitivity of the MSMs to the most extreme weights. While untruncated weights provide unbiased estimates under the assumptions of the MSM, they may not be the most efficient and tend to have larger standard errors (Cole and Hernan, 2008). Second, we estimated all models using only covariate adjustment to investigate in how far this 'naive' approach diverts from the "causal" estimates of the FE and MSMs. Third, we estimated the FE and MSMs using the original non-imputed data to ascertain the extent to which multiple imputation affected the results.

5.3 Results

From the descriptive statistics, we can observe that people with diabetes in any wave were less likely to be employed. Looking at health behaviours, it were mainly men that smoked and reported alcohol consumption while very few women did so. The prevalence of smoking and drinking was lower for men with diabetes; they also consumed fewer calories compared to men without diabetes. Further, the ff diabetes group had both higher BMI and waist circumference levels. They were also older, lived in more urbanized areas, were more likely to have insurance and men were somewhat better educated while women were less educated compared to their counterparts without diabetes. Both men and women reported an average time since diagnosis of around 4 years. Looking at per capita household income, men and women with diabetes come from household with higher income levels than those without a diabetes diagnosis. Overall it appears that in China it is less educated women that report a diagnosis, while men with diabetes are better educated and tend not to be poorer than their counterparts without diabetes.

Table 5.1: Sample means for males and females, by diabetes status

	Males			Females		
	No diabetes	Diabetes	p-value (t-test)	No diabetes	Diabetes	p-value (t-test)
Employed	82%	68%	<0.001	67%	29%	<0.001
Smokes	58%	47%	<0.001	3%	4%	0.409
Any alcohol consumption	63%	53%	<0.001	9%	4%	<0.001
Daily Kcal eaten (3-day average)	2422	2166	<0.001	2068	1931	0.001
BMI	22.99	24.90	<0.001	23.10	25.80	<0.001
Waist circ. (cm)	82.02	88.81	<0.001	78.80	87.55	<0.001
Age	42.27	52.76	<0.001	43.24	55.32	<0.001
Han ethnicity	87%	89%	0.292	87%	93%	0.002
Rural area	69%	52%	<0.001	68%	51%	<0.001
Married	83%	93%	<0.001	88%	87%	0.392
Secondary education	65%	68%	0.439	50%	43%	0.007
University education	5%	11%	<0.001	4%	1%	0.017
Any health insurance	51%	82%	<0.001	50%	71%	<0.001
Urbanization Index	60.87	74.48	<0.001	61.77	68.68	<0.001
Per capita household income (Yuan (2011))	8617	16328	<0.001	8581	11101	<0.001
Years since diabetes diagnosis	–	4.5	–	–	4.65	–
Observations	23413	284	23697	23577	336	23913

Predicting the denominator for the stabilized weights we find that for men a higher baseline BMI increases the risk of a diabetes diagnosis. Further, increases in age, waist circumference as well as urbanization levels are associated with higher chances for men to be diagnosed with diabetes throughout the survey. Interestingly becoming employed may decrease the chances of being diagnosed with diabetes slightly, justifying the use of the MSM in our employment models as well (Table 5.2). Because these are not causal estimates, it may be that it is more likely for men with a lower risk of diabetes to be selected into employment. Interestingly, we do not find that higher household income levels are predictive of a diagnosis for men, despite what the descriptive statistics indicated. For women, higher age at baseline, increases in BMI and waist circumference as well as living in a non-rural environment predict a diabetes diagnosis. Further, especially living in certain provinces of the country appears to increase the likelihood to receive a diabetes diagnosis for men, but not for women.

The results of our regression analysis are presented in Table 5.3. Both the FE model and the MSM indicate that women with a diabetes diagnosis have reduced probabilities of being employed than their counterparts without diabetes, with a reduction of 11 percentage points in the FE model and 12 percentage points in the MSM. This translates into a relative reduction in employment probabilities between 16–17%. For men no such effect is observed, even though employment was significantly related to a diabetes diagnosis as shown in Table 5.2.

There is a more ambiguous picture for the effect of a diabetes diagnosis on behavioural outcomes. There is no consistent—and only marginally significant evidence in the MSM—that men reduced their smoking rate, however, a diabetes diagnosis led to a reduction in alcohol consumption as according to either model, though particularly so for the MSM. For waist circumference, BMI and calorie consumption, the FE and MSM both indicate reductions in BMI of close to 0.7, of about 2 cm in waist circumference and of up to 170 calories per day for men. Results for women look different, in that while the point estimates indicate a reduction in all outcomes, these tend to be smaller than those for men and only exhibit strong statistical significance in the FE model for BMI, waist circumference and alcohol consumption.

Exploring the effect of a diabetes diagnosis over time, we first estimated a specification using time since diagnosis as a continuous variable. The results of the FE model (Table 5.4) indicate a steady reduction of female employment probabilities of almost two percentage points per year and of male alcohol consumption, BMI, waist circumference and consumed calories. The MSM again supports the finding of the FE model, finding very similar effects in terms of size and statistical significance. For women, the MSM also support the finding

of a reduction in employment probabilities, with the point estimate being somewhat larger compared to the FE model. The evidence for changes in health behaviours is less consistent across models and outcomes, with the FE indicating a reduction in waist circumference but not in BMI and the MSM suggesting the opposite. The effect sizes for changes in health behaviours in women are about half the size to those found in men.

Table 5.2: Time variant and invariant predictors of a diabetes diagnosis (denominator of stabilized weights)

	Males		Females	
	(1) β	(2) SE	(3) β	(4) SE
Age (bl)	−.001	0.001	0.004**	0.002
Age squared (bl)	0.000	0.000	−.000*	0.000
Urbanization index (bl)	0.000	0.000	−.000	0.000
BMI (bl)	0.001**	0.001	0.001	0.001
Waist circumference (cm) (bl)	0.000	0.000	0.000	0.000
3-Day Ave: Energy (kcal) (bl)	−.000	0.000	−.000	0.000
Smoking (bl)	0.001	0.002	0.002	0.007
Any alcohol (bl)	0.000	0.002	0.000	0.003
Secondary educ. (bl)	−.002	0.004	0.002	0.004
University educ. (bl)	−.005	0.007	−	
Married (bl)	−.003	0.004	−.000	0.005
Any medical insurance (bl)	0.002	0.002	−.001	0.002
Employed (bl)	0.002	0.003	0.002	0.002
Han ethnicity	0.002	0.003	−.003	0.004
Rural	−.001	0.002	−.005***	0.002
Household expenditures (2011 Yuan) (bl)	−.000	0.000	0.000	0.000
Survey year				
2004	0.003	0.003	−.003	0.003
2006	0.001	0.003	−.004	0.003
2009	0.011***	0.004	−.001	0.004
2011	0.001	0.003	0.001	0.004
Age	0.004**	0.002	−.002	0.002
Age squared	−.000***	0.000	0.000	0.000
BMI	−.001	0.001	0.001*	0.001
Urbanization index	0.000	0.000	0.000	0.000
Waist circumference (cm)	0.000*	0.000	−.000	0.000
3-Day Ave: Energy (kcal)	−.000	0.000	0.000	0.000
Smoking	−.004*	0.002	−.001	7
Any alcohol	−.003	0.002	−.006	0.004
Secondary education	0.003	0.004	0.000	0.004
University education	0.003	0.007	−	
Married	0.000	0.005	−.002	0.004
Any medical insurance	0.002	0.002	−.000	0.002
Employed	−.004*	0.002	−.003	0.002
Household expenditures (2011 Yuan)	0.000**	0.000	−.000	0.000

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Results for province dummies omitted to preserve space.

Table 5.3: Analysis of the effect of a diabetes diagnosis on employment status and behavioural outcomes using fixed effects and marginal structural models

	(1) Employment	(2) Smoking	(3) Any alcohol	(4) BMI	(5) Waist (cm)	(6) Calories (kcal)
			Marginal structural model			
Male sample						
Diabetes	0.018	−.026	−.087***	−.727***	−2.215***	−171.754***
	(.030)	(.032)	(.034)	(.187)	(.590)	(65.287)
Female sample						
Diabetes	−.110***	−.027**	−.023	−.668**	−1.177*	−62.971
	(.035)	(.013)	(.018)	(.264)	(.622)	(55.960)
			Fixed effects			
Male sample						
Diabetes	−.008	−.054*	−.132***	−.785***	−1.686***	−125.161*
	(.027)	(.030)	(.034)	(.188)	(.591)	(66.311)
Female sample						
Diabetes	−.122***	−.017*	−.076***	−.458*	−.559	−60.878*
	(.030)	(.009)	(.023)	(.251)	(.633)	(34.744)

Notes Standard errors in parentheses. Other control variables: age (only MSM), age squared, region, urban, education, han, marital status, urbanization index, time dummies, health insurance status, household expenditures. Fixed effects: N=23697 (male sample), N=23913 (female sample); MSM: N=13231 (male sample), N=14630 (female sample).
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$)

Table 5.4: Analysis of the effect of time since diabetes diagnosis on employment status and behavioural outcomes using fixed effects and marginal structural models

	Odds ratios			Beta coefficients		
	(1) Employment	(2) Smoking	(3) Any alcohol	(4) BMI	(5) Waist (cm)	(6) Calories (kcal)
			Marginal structural model			
Male sample						
Time since diagnosis	−.000	−.004	−.014**	−.155***	−.542***	−25.595**
	(.008)	(.007)	(.007)	(.036)	(.111)	(10.297)
Female sample						
Time since diagnosis	−.018**	−.005**	−.002	−.087	−.260**	−11.696
	(.007)	(.002)	(.003)	(.053)	(.122)	(8.946)
			Fixed effects			
Male sample						
Time since diagnosis	−.006	−.011*	−.021***	−.151***	−.417***	−28.974***
	(.005)	(.006)	(.006)	(.037)	(.103)	(10.199)
Female sample						
Time since diagnosis	−.025***	−.003*	−.015***	−.117**	−.166	−10.991*
	(.006)	(.001)	(.006)	(.047)	(.124)	(6.338)

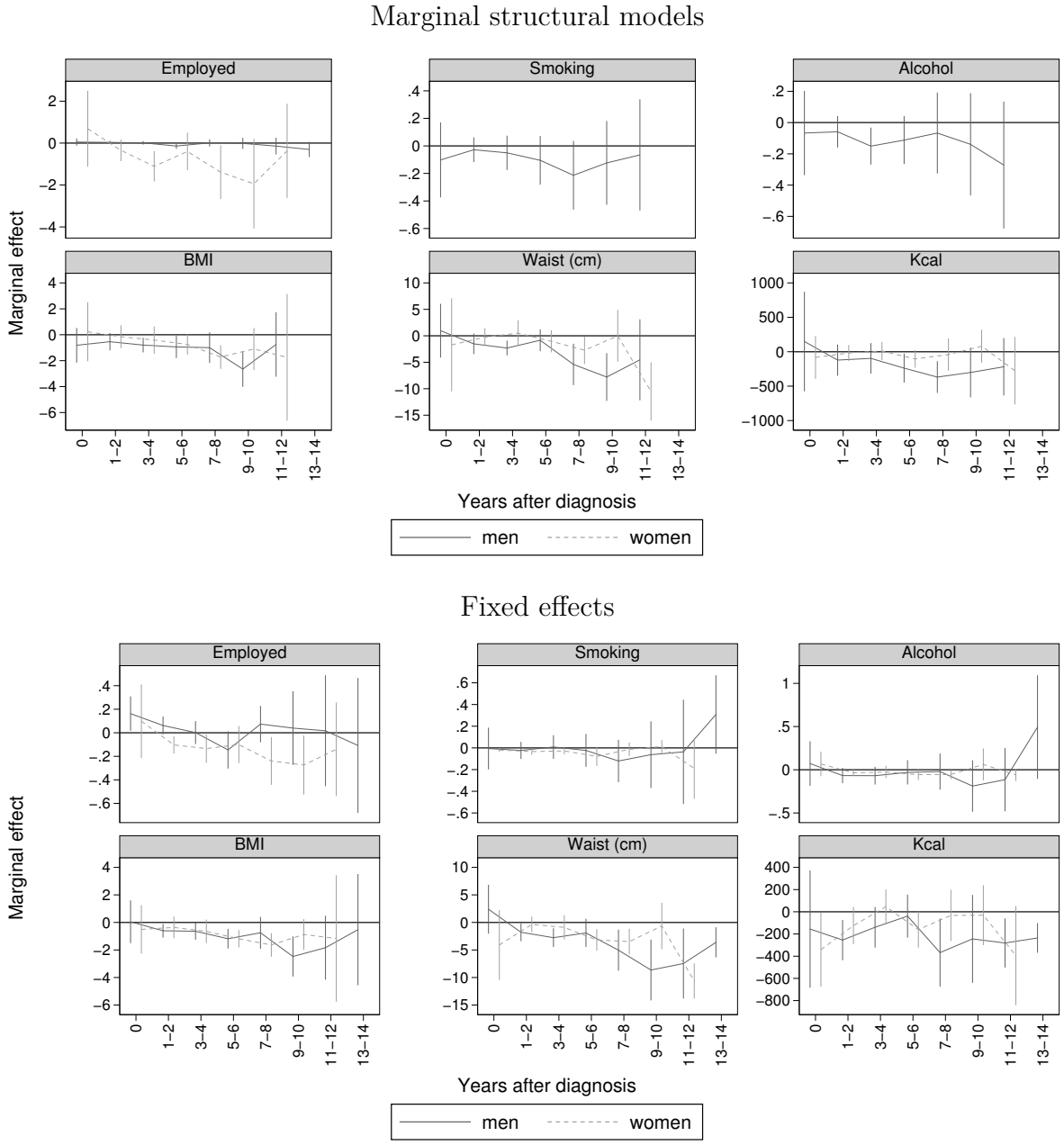
Notes Standard errors in parentheses. Other control variables: age (only MSM), age squared, region, urban, education, han, marital status, urbanization index, time dummies, health insurance status, household expenditures. Fixed effects: N=23697 (male sample), N=23913 (female sample); MSM: N=13231 (male sample), N=14630 (female sample).

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$)

In a second step we estimated a specification using year dummies to capture the potential non-linearity in the relationship between time since diagnosis and our outcomes. The results for both estimation methods are visualized in Figure 5.2 and presented in Tables 5.7 and 5.6 for the FE and MSM, respectively. Despite the smaller sample size in each group and hence lower precision, the FE model still indicates a reduction in BMI and waist circumference for men, especially in the first 8 to 10 years after diagnosis. A similar effect is found for females, especially for years 3 to 8 after diagnosis. Interestingly, female employment already decrease rapidly in the 1 to 2 year after diagnosis and it does not appear that females are able to increase their chances later on. Using the MSM, all point estimates suggest similar effects, but due to the lower sample size, we were not able to estimate the effects for females on smoking and alcohol consumption.

We conducted three sensitivity analyses. First, we truncated weights at the 1^{st} and 99^{th} percentile to investigate the sensitivity of the MSMs to the most extreme weights. The found effects are very similar to those using the untruncated weights (Table 5.8 and 5.9), suggesting no important loss in efficiency and supporting the decision to use untruncated weights. Second, we estimated all models using only covariate adjustment to investigate in how far this 'naive' approach diverts from the "causal" estimates of the FE and MSMs. The results show that the bias is particularly strong for BMI and waist circumference, where the naive regression indicates a positive association with a diabetes diagnosis (Tables 5.10 and 5.11). For the other outcomes, the results are close to or at least point into the same direction as the FE and MSMs. This suggests that for these outcomes the risk of introducing bias while using a naive regression method may be lower. Third, we estimated the FE and MSMs using the original non-imputed data. The results are broadly similar (Tables 5.12, 5.13, 5.15 and 5.14), in particular for the FE model, still indicating a reduction in female employment chances and male alcohol consumption, BMI and waist circumference. The coefficients of the MSM still point into the same direction as those using the imputed data, but the estimated effects are smaller in size and confidence intervals relatively large.

Figure 5.2: Analysis of the effect of time since diabetes diagnosis on employment status and behavioural outcomes using marginal structural models and fixed effects (duration groups)



5.4 Disussion

Our results suggest that receiving a diabetes diagnosis in China led to a lasting reduction in male BMI and waist circumference as well as in risk behaviours such as alcohol and calorie consumption. For females, our primary results did not find as strong indications for behaviour change. However, we found a reduction in female employment probabilities, suggesting that women stopped working as a result of the diagnosis. Medical evidence suggest that sustained reductions in weight and body fat can lead to increasing insulin sensitivity, better blood glucose levels and consequently a reduced risk for diabetes related complications (Long et al., 2014; Zhou, Ji, et al., 2016). Given our results, it appears that women in China may not have been as successful at making behaviour changes to reduce their risk.

Having both, the FE models and MSM models indicating very similar results suggests that both performed relatively well and were able to reduce confounding, in particular due to selection into a diabetes diagnosis as a result of high baseline BMI and waist circumference levels. As the regression results using a naive approach have shown, not accounting for this will lead to results suggesting an increase of BMI and waist circumference after diagnosis.

5.4.1 Limitations

While we used two estimation methods to reduce the influence of selection bias due to unobserved confounding, one limitation of the used approaches is their inability to account for all forms of selection simultaneously. Therefore a causal interpretation is only possible under restrictive assumptions, namely no unobserved time-variant confounding for the FE model and positivity, exchangeability and consistency for the MSM. The assumption of positivity is likely to hold, given that every person should have at least a small chance of receiving a diabetes diagnosis. This is also supported by the relatively small range of stabilized weights and no zero-weights. Exchangeability, or no unmeasured confounding, is not testable and could potentially be violated if not all time-invariant or time-variant confounders are accounted for. This has potentially been the case which is why we also estimated a FE model. Consistency would have been violated if a diabetes diagnosis had been reported but the person had actually not been diagnosed with diabetes. This is likely only violated in very rare cases of misreporting, given that specificity of diabetes self-report is very high in China (Yuan et al., 2015). Because we were interested in the effect of a diabetes diagnosis, unobserved diabetes did not violate the consistency assumption.

A limitation of the FE model is the possibility of time-variant confounding causing se-

lection into a diabetes diagnosis based on changes in pre-treatment values of our outcomes of interest. Further, the FE model is unable to account for the effect of confounders that are causally related with diabetes such as BMI or waist circumference but may also have an effect on the outcome themselves. This may lead to an over- or underestimation of the effect of diabetes if the diabetes variable captures parts of the effect of very high BMI levels. This may be the reason for some of the, albeit small, differences in point estimates between the FE model and MSM. On the other hand this difference may also be due to the inability of the MSM to account for unobserved characteristics.

5.4.2 Potential mechanisms

The constant reduction in male BMI and waist circumference we have found has also been observed in a cohort of Danish patients (De Fine Olivarius et al., 2015), where weight increased the years preceding diagnosis, while after diagnosis weight decreased. The exact reasons for this decrease were unknown but attributed to motivation changes as a result of the diagnosis, concluding that time around the diagnosis may represent a window of opportunity to obtain long lasting weight change. Nonetheless, reductions in weight may also be the result of treatment initiation with metformin or other diabetes drugs that have been shown to lead to weight reductions (Yang and Weng, 2014). Importantly, the reduction in BMI in our study was accompanied by a reduction in waist circumference. Given that in China diabetes incidence has been especially attributed to a high accumulation of visceral fat and central obesity (Ma et al., 2014), reductions in waist circumference therefore may have a particular positive effect on diabetes control and the prevention of comorbidities. This also allows for the interpretation that the changes in BMI are due to reductions in fat and not lean body mass(Klein et al., 2007).

For women, however, we did not find similar strong evidence for reductions in BMI and waist circumference. The relatively smaller effects for women could indicate a lower ability to change behaviours supportive of weight loss. A potential mechanisms may be their lower educational attainment, which has been indicated as a factor in preventing better glucose control (Luo et al., 2015). Lower income levels for females may also negatively affect the ability to receive adequate treatment following a diagnosis, limiting their ability to change health behaviours (Luo et al., 2015). We found that women with diabetes tended to live in households with substantially lower expenditure levels, suggesting that lower financial resources may actually be a reason for their higher risk to be unemployed and to not be able to achieve substantial behaviour change. Further, there are likely biological factors that lead to worse health outcomes for women compared to men. There is some evidence that, due to different ways of fat storage between men and women,

men are more likely to cross the diabetes threshold at an earlier point in time and at a comparatively healthier metabolic state then women (Peters, Huxley, Sattar, et al., 2015; Peters, Huxley, and Woodward, 2014a,b). Women are more likely to have spend more time in a pre-diabetes stadium (Bertram and Vos, 2010), and the diabetes threshold is only crossed once the metabolic state of women has significantly deteriorated, leading to a greater risk of cardiovascular disease and stroke (Peters, Huxley, Sattar, et al., 2015). Supporting this, a study for China found a greater prevalence of diabetes comorbidities in Chinese women than men (Liu, Fu, et al., 2010). In this light it may not be surprising that we find more conclusive evidence of worsening employment probabilities for women than for men. If women are less likely to receive proper treatment and to change their health behaviours and at the same time have a greater risk for complications then men, the long term effects of diabetes on their health are likely more severe than for men and consequently affect their employment status.

Compared to the only other study that used population level observational data to investigate the effect of a diabetes diagnosis on health behaviours in the USA by Slade (2012), our results paint a somewhat different picture. While Slade finds a more lasting effect on smoking cessation and alcohol consumption, but not on overweight or obesity, our results indicate lasting effects on male alcohol consumption but not on smoking, and we find evidence for a sustained reduction in male body weight. Nonetheless, one has to keep in mind that we used continuous weight indicators in BMI and waist circumference, Slade investigated the effect on the probability of being obese or overweight, making a direct comparison difficult. Importantly—and in concordance with our findings—he finds that simple covariate adjustment leads to estimates, indicating an increase in obesity and overweight and underlining the importance of accounting for unobserved heterogeneity and treatment selection. I ALSO DID RUN REGRESSIONS USING OBESITY AND OVERWEIGHT INDICATORS SUGGESTING THAT MEN AFTER A DIAGNOSIS HAVE A LOWER PROBABILITY OF BEING OBESE. NO EFFECT ON OVERWEIGHT. WOULD IT BE WORTHWHILE TO INCLUDE IN THE RESULTS AS WELL? HAVE NOT DONE IT NOW BECAUSE OF SMALL MISTAKE IN CALCULATING THE WEIGHTS FOR THESE OUTCOMES, SO I HAVE TO REESTIMATE THE OBESITY MODELS WHICH TAKES SOME TIME. I HAVE ADDED RESULTS FOR THE FE MODELS FOR NOW THAT SHOW ESPECIALLY ,POTENTIALLY, LASTING EFFECTS FOR MEN TO DROP OUT OF THE OBESITY CATEGORY. THIS IS THE CHINESE OBESITY AND OVERWEIGHT THRESHOLDS OF A BMI OF 28 AND 24 RESPECTIVELY. SEE END OF APPENDIX FOR THE RESULTS

The found adverse effect of ff diabetes on employment is in line with other studies on

the labour market impact of diabetes and in particular with a study from Mexico that, using FE estimates for a similar time period, found significant reductions for both males and females of about 5 percentage points (Seuring, Serneels, et al., 2016), with the relative impact being much stronger for women due to their lower overall employment rates.

5.5 Conclusion

Our results indicate changes in male health behaviours after a diabetes diagnosis in China. These findings are robust to the application of two distinct econometric techniques. Further, women likely had to bear a larger diabetes burden also affecting their economic well-being, as evidenced by their reduction in employment probabilities. Potentially, one of the causes of these adverse economic effects is the lower ability of women to successfully change their behaviour as a result of the diagnosis. Further research should try to unravel the mechanisms behind these differential outcomes for men and women. Overall, given the large prevalence of undiagnosed diabetes, our results indicate that an early diagnosis can lead to early behaviour change that may lead to more positive health outcomes for people with diabetes over time. It appears, however, that more emphasis on the adequate treatment options for women may be needed to reduce their burden of diabetes.

Stabilized weights

Table 5.5: Summary of stabilized weights

	Mean	Min	Max
Untruncated (men)	1.001343	.1740716	5.780513
Untruncated (women)	1.000773	.1661002	8.754402
Truncated 1 and 99 percentile (men)	.9997768	.8906016	1.107517
Truncated 1 and 99 percentile (women)	.9988097	.8323757	1.119154

5.5.1 Duration groups results

Table 5.6: Analysis of the effect of time since diabetes diagnosis on employment status and behavioural outcomes using marginal structural models (duration groups)

	(1) Employment	(2) Smoking	(3) Any alcohol	(4) BMI	(5) Waist (cm)	(6) Calories (kcal)
Male sample						
0	0.049	−.102	−.067	−.811	0.968	148.433
	(.087)	(.139)	(.138)	(.682)	(2.587)	(369.013)
1-2	0.034	−.028	−.059	−.535	−1.517	−121.424
	(.038)	(.046)	(.051)	(.340)	(.996)	(115.615)
3-4	0.012	−.050	−.150**	−.795***	−2.312***	−96.393
	(.042)	(.063)	(.060)	(.288)	(.712)	(113.071)
5-6	−.139**	−.105	−.112	−.937**	−.843	−237.957**
	(.068)	(.090)	(.078)	(.438)	(1.050)	(107.745)
7-8	0.010	−.213*	−.067	−.995*	−5.401***	−368.463***
	(.087)	(.127)	(.132)	(.602)	(1.991)	(117.513)
9-10	−.014	−.124	−.139	−2.648***	−7.791***	−300.917
	(.136)	(.155)	(.167)	(.699)	(2.294)	(184.269)
11-12	−.142	−.065	−.272	−.751	−4.542	−218.570
	(.203)	(.205)	(.206)	(1.262)	(3.896)	(212.524)
13-14	−.304					
	(.186)					
Female sample						
0	0.110			0.233	−1.713	−82.792
	(.132)			(1.158)	(4.483)	(158.560)
1-2	−.063			−.153	−.238	−17.870
	(.049)			(.450)	(.850)	(59.249)
3-4	−.210***			−.409	0.506	11.054
	(.071)			(.537)	(1.229)	(67.419)
5-6	−.074			−.743*	−1.038	−104.696
	(.087)			(.396)	(1.063)	(64.981)
7-8	−.262**			−1.721***	−2.724**	−41.099
	(.122)			(.464)	(1.315)	(119.484)
9-10	−.355**			−1.095	−.012	80.030
	(.172)			(.827)	(2.495)	(122.037)
11-12	−.072			−1.739	−10.515***	−275.508
	(.213)			(2.489)	(2.806)	(250.141)

Notes Other control variables: age, age squared, region, urban, education, han, marital status, urbanization index, time dummies, health insurance status, household expenditures. N=13195 (male sample), N=14549 (female sample).
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$)

Table 5.7: Analysis of the effect of time since diabetes diagnosis on employment status and behavioural outcomes using fixed effects (duration groups)

	Odds ratios			Beta coefficients		
	(1) Employment	(2) Smoking	(3) Any alcohol	(4) BMI	(5) Waist (cm)	(6) Calories (kcal)
Male sample						
0	0.163**	−.006	0.072	0.049	2.397	−155.323
	(.075)	(.098)	(.132)	(.792)	(2.258)	(268.552)
1-2	0.062	−.023	−.067	−.605**	−1.782**	−254.427***
	(.039)	(.040)	(.045)	(.252)	(.825)	(92.421)
3-4	0.002	0.008	−.068	−.639**	−2.768***	−139.397
	(.050)	(.055)	(.052)	(.314)	(.870)	(93.516)
5-6	−.145*	−.023	−.030	−1.183***	−1.901	−39.053
	(.081)	(.077)	(.071)	(.362)	(1.304)	(98.730)
7-8	0.074	−.121	−.021	−.751	−5.037***	−367.421**
	(.079)	(.100)	(.106)	(.588)	(1.896)	(156.656)
9-10	0.040	−.062	−.188	−2.472***	−8.642***	−244.372
	(.159)	(.157)	(.152)	(.741)	(2.812)	(201.960)
11-12	0.017	−.037	−.114	−1.835	−7.465**	−281.008**
	(.240)	(.245)	(.187)	(1.181)	(3.238)	(112.461)
13-14	−.108	0.308*	0.494	−.524	−3.615***	−235.985***
	(.293)	(.184)	(.306)	(2.059)	(1.383)	(67.961)
Female sample						
0	0.098	−.019**	0.067	−.505	−4.090	−340.952**
	(.159)	(.008)	(.072)	(.896)	(3.235)	(169.411)
1-2	−.103***	−.034**	−.036*	−.364	−.355	−124.847
	(.037)	(.015)	(.020)	(.404)	(.717)	(85.402)
3-4	−.134**	−.028*	−.025	−.648	−.896	45.970
	(.062)	(.016)	(.036)	(.435)	(1.120)	(79.063)
5-6	−.100	−.079*	−.056*	−1.184***	−3.176***	−160.445*
	(.080)	(.045)	(.033)	(.323)	(.990)	(83.164)
7-8	−.240**	−.013	−.054**	−1.637***	−3.482***	−32.865
	(.103)	(.032)	(.026)	(.433)	(1.182)	(117.750)
9-10	−.274**	0.012	0.062	−.876	−.639	−30.676
	(.128)	(.031)	(.094)	(.568)	(2.147)	(137.658)
11-12	−.140	−.189	−.059	−1.163	−10.633***	−393.884*
	(.202)	(.143)	(.036)	(2.344)	(1.618)	(227.502)

Notes Other control variables: age squared, region, urban, education, han, marital status, urbanization index, time dummies, health insurance status, household expenditures. N=13195 (male sample), N=14549 (female sample).

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$)

Robustness checks

MSMs using truncated weights

Table 5.8: Analysis of the effect of a diabetes diagnosis on employment status and behavioural outcomes using marginal structural models with truncated stabilized weights at 1st and 99th percentile

	(1) Employment	(2) Smoking	(3) Any alcohol	(4) BMI	(5) Waist (cm)	(6) Calories (kcal)
			Diabetes			
Male sample						
Diabetes	−.026	−.053*	−.132***	−.707***	−1.426**	−200.750***
	(.025)	(.031)	(.034)	(.188)	(.560)	(54.156)
Female sample						
Diabetes	−.138***	−.017*	−.076***	−.243	0.058	−61.998*
	(.029)	(.009)	(.023)	(.252)	(.640)	(35.849)
			Years since diagnosis			
Male sample						
Time since diagnosis	−.009*	−.011*	−.021***	−.145***	−.377***	−34.287***
	(.005)	(.006)	(.006)	(.037)	(.102)	(9.612)
Female sample						
Time since diagnosis	−.027***	−.003*	−.015***	−.093**	−.086	−10.750*
	(.007)	(.001)	(.006)	(.047)	(.128)	(6.455)

Notes Standard errors in parentheses. Other control variables: age squared, region, urban, education, han, marital status, urbanization index, time dummies, health insurance status, household expenditures. N=13231 (male sample), N=14630 (female sample).

Table 5.9: Effect of time since diabetes diagnosis on employment status and behavioural outcomes using MSM with truncated stabilized weights (1st and 99th pct; imputed)

	(1) Employment	(2) Smoking	(3) Any alcohol	(4) BMI	(5) Waist (cm)	(6) Calories (kcal)
Male sample						
0	0.075	−.102	−.067	−.345	2.302	−86.368
	(.077)	(.139)	(.138)	(.839)	(2.872)	(247.229)
1-2	0.012	−.028	−.059	−.375	−.812	−224.716**
	(.036)	(.046)	(.051)	(.297)	(.957)	(95.028)
3-4	−.018	−.050	−.150**	−.723**	−1.965***	−167.769*
	(.042)	(.063)	(.060)	(.305)	(.735)	(86.996)
5-6	−.139**	−.105	−.112	−1.034***	−.891	−203.814**
	(.066)	(.090)	(.078)	(.392)	(1.096)	(102.051)
7-8	0.018	−.213*	−.067	−.944*	−4.935***	−347.441***
	(.084)	(.127)	(.132)	(.563)	(1.846)	(125.660)
9-10	−.033	−.124	−.139	−2.627***	−6.998***	−232.656
	(.122)	(.155)	(.167)	(.689)	(2.453)	(177.019)
11-12	−.151	−.065	−.272	−.889	−4.363	−212.318
	(.202)	(.205)	(.206)	(1.123)	(3.500)	(189.967)
13-14	−.305*					
	(.185)					
Female sample						
0	0.112			0.685	−.060	−104.652
	(.128)			(1.289)	(4.993)	(158.546)
1-2	−.104**			0.205	0.698	−18.334
	(.047)			(.452)	(.834)	(64.456)
3-4	−.208***			−.299	0.889	6.982
	(.068)			(.520)	(1.191)	(65.213)
5-6	−.138*			−.569	−.793	−122.064*
	(.082)			(.364)	(1.087)	(64.349)
7-8	−.249**			−1.662***	−2.125	−5.039
	(.121)			(.502)	(1.315)	(120.139)
9-10	−.373**			−1.019	0.409	72.475
	(.169)			(.829)	(2.523)	(132.027)
11-12	−.087			−1.858	−10.814***	−251.975
	(.214)			(2.510)	(2.749)	(234.610)

Notes Standard errors in parentheses. Other control variables: age squared, region, urban, education, Han, marital status, urbanization index, time dummies, health insurance status, household expenditures. N=13195 (male sample), N=14549 (female sample).

Only covariate adjustment

Table 5.10: Analysis of the effect of a diabetes diagnosis on employment status and behavioural outcomes only using covariate adjustment

	(1) Employment	(2) Smoking	(3) Any alcohol	(4) BMI	(5) Waist (cm)	(6) Calories (kcal)
			Diabetes			
Male sample						
Diabetes	0.006	−.074**	−.119***	0.925***	2.964***	−165.647***
	(.023)	(.036)	(.033)	(.289)	(.817)	(50.101)
Female sample						
Diabetes	−.100***	−.007	−.072***	1.805***	4.619***	−33.807
	(.029)	(.011)	(.023)	(.354)	(.877)	(33.783)
			Years since diagnosis			
Male sample						
Time since diagnosis	−.002	−.052*	−.017**	0.107*	0.318**	−27.700***
	(.005)	(.031)	(.007)	(.058)	(.161)	(9.297)
Female sample						
Time since diagnosis	−.019***	−.030	−.014**	0.245***	0.645***	−4.186
	(.007)	(.079)	(.006)	(.067)	(.178)	(6.113)

Notes Standard errors in parentheses. Other control variables: Age, age squared, region, urban, education, han, marital status, urbanization index, time dummies, health insurance status, household expenditures. N=23697 (male sample), N=23913 (female sample).

Table 5.11: Analysis of the effect of time since diabetes diagnosis on employment status and behavioural outcomes using covariate adjustment (duration groups) (imputed)

	(1) Employment	(2) Smoking	(3) Any alcohol	(4) BMI	(5) Waist (cm)	(6) Calories (kcal)
Male sample						
0	0.067	−.095	−.045	1.763**	7.505***	−7.725
	(.060)	(.136)	(.136)	(.737)	(2.581)	(222.633)
1-2	0.027	−.087*	−.104**	1.247***	3.518***	−214.457***
	(.027)	(.049)	(.047)	(.294)	(.944)	(78.407)
3-4	0.002	−.019	−.146**	1.406***	3.208***	−127.663
	(.039)	(.060)	(.058)	(.435)	(1.131)	(86.377)
5-6	−.078	−.114	−.132	0.857	4.054***	−146.275
	(.058)	(.084)	(.084)	(.619)	(1.425)	(101.505)
7-8	0.075	−.291**	0.001	0.308	−.579	−326.239**
	(.053)	(.126)	(.129)	(.532)	(2.014)	(129.013)
9-10	0.082	−.025	−.037	−.603	−1.740	−144.106
	(.083)	(.138)	(.149)	(.959)	(2.495)	(171.510)
11-12	−.151		−.175	−1.601	−6.070	−140.067
	(.230)		(.220)	(1.094)	(4.376)	(195.607)
13-14	−.246			0.265	−1.131	−34.363
	(.152)			(2.421)	(4.340)	(176.819)
Female sample						
0	0.083	0.025	0.030	3.742***	8.177*	−83.493
	(.115)	(.067)	(.107)	(.995)	(4.255)	(139.371)
1-2	−.101**	−.014	−.056***	2.096***	5.256***	−23.578
	(.044)	(.009)	(.018)	(.455)	(.943)	(59.415)
3-4	−.132**	−.018	−.059**	1.833***	5.405***	57.985
	(.066)	(.012)	(.023)	(.544)	(1.432)	(63.186)
5-6	−.071	−.014	−.059*	1.416***	3.092**	−77.020
	(.079)	(.015)	(.032)	(.485)	(1.519)	(64.878)
7-8	−.132	0.013		0.536	2.251	69.285
	(.125)	(.030)		(.851)	(1.878)	(116.795)
9-10	−.223	0.012		1.453	5.297*	151.466
	(.194)	(.030)		(1.357)	(2.988)	(127.461)
11-12	0.007			−.352	−7.653***	−162.492
	(.230)			(1.479)	(2.436)	(213.782)

Notes Standard errors in parentheses. Other control variables: age, age squared, region, urban, education, han, marital status, urbanization index, time dummies, health insurance status, household expenditures. N=23661 (male sample), N=23830 (female sample).

Results using non-imputed data

Table 5.12: Analysis of the effect of a diabetes diagnosis on employment status and behavioural outcomes using fixed effects and marginal structural models (no imputation)

	(1) Employment	(2) Smoking	(3) Any alcohol	(4) BMI	(5) Waist (cm)	(6) Calories (kcal)
			Marginal structural model			
Male sample						
Diabetes	0.050	−.042	−.112**	−.641***	−1.224	−152.149
	(.046)	(.041)	(.049)	(.220)	(.803)	(123.921)
Female sample						
Diabetes	−.081*	−.028*	−.075	−.583	−.935	−50.350
	(.049)	(.015)	(.045)	(.393)	(.866)	(56.914)
			Fixed effects			
Male sample						
Diabetes	0.028	−.000	−.063*	−.868***	−2.448***	−152.027**
	(.030)	(.033)	(.034)	(.170)	(.517)	(68.421)
Female sample						
Diabetes	−.107***	−.024**	−.022	−.638**	−1.049*	−81.554*
	(.034)	(.012)	(.019)	(.288)	(.636)	(48.970)

Notes Standard errors in parentheses. Other control variables: age (only MSM), age squared, region, urban, education, han, marital status, urbanization index, time dummies, health insurance status, household expenditures. FE: N=21444 (male sample), N=23128 (female sample), MSM: N=10039 (male sample), N=11489 (female sample).

Table 5.13: Analysis of the effect of time since diabetes diagnosis on employment status and behavioural outcomes using fixed effects and marginal structural models (non-imputed)

	(1) Employment	(2) Smoking	(3) Any alcohol	(4) BMI	(5) Waist (cm)	(6) Calories (kcal)
			Marginal structural model			
Male sample						
Time since diagnosis	0.027	−.020	−.024	−.221**	−.705**	−80.594**
	(.018)	(.016)	(.017)	(.087)	(.295)	(39.681)
Female sample						
Time since diagnosis	−.030	−.009	−.039	−.413*	−.598	−14.552
	(.022)	(.006)	(.025)	(.216)	(.376)	(24.269)
			Fixed effects			
Male sample						
Time since diagnosis	−.003	0.005	−.003	−.164***	−.581***	−22.700
	(.008)	(.007)	(.007)	(.044)	(.121)	(12.487)
Female sample						
Time since diagnosis	−.026**	−.006*	−.005	−.163**	−.325*	−16.888
	(.009)	(.002)	(.004)	(.060)	(.148)	(10.337)

Notes Standard errors in parentheses. Other control variables: age (only MSM) age squared, region, urban, education, han, marital status, urbanization index, time dummies, health insurance status, household expenditures. FE: N=22066 (male sample), N=23051 (female sample), MSM: N=10028 (male sample), N=11465 (female sample).

Table 5.14: Analysis of the effect of time since diabetes diagnosis on employment status and behavioural outcomes using marginal structural models (duration groups) (non-imputed)

	(1) Employment	(2) Smoking	(3) Any alcohol	(4) BMI	(5) Waist (cm)	(6) Calories (kcal)
Male sample						
0	0.107	0.051	−.149	−1.004*	1.113	314.866
	(.080)	(.150)	(.175)	(.562)	(1.103)	(409.370)
1-2	0.038	−.050	−.050	−.609**	−1.727*	−146.884
	(.047)	(.052)	(.057)	(.284)	(.973)	(148.251)
3-4	0.000	−.038	−.095	−1.028**	−3.164	−695.698***
	(.)	(.159)	(.117)	(.460)	(2.066)	(190.065)
Female sample						
0	0.134	0.000	0.000	−.102	−1.362	−111.379
	(.179)	(.)	(.)	(1.544)	(6.099)	(207.839)
1-2	−.079	−.019**	−.052*	−.484	−.581	−32.105
	(.069)	(.008)	(.029)	(.487)	(1.006)	(67.670)
3-4	0.000	0.000	0.000	−5.590*	−8.485***	1.258
	(.)	(.)	(.)	(3.286)	(1.792)	(258.264)

Notes Due to Standard errors in parentheses. Other control variables: Age, age squared, region, urban, education, han, marital status, urbanization index, time dummies, health insurance status, household expenditures. N=10028 (male sample), N=11465 (female sample).

Table 5.15: Analysis of the effect of time since diabetes diagnosis on employment status and behavioural outcomes using fixed effects (duration groups) (non-imputed)

	(1) Employment	(2) Smoking	(3) Any alcohol	(4) BMI	(5) Waist (cm)	(6) Calories (kcal)
Male sample						
0	0.132	−.014	0.125	−.009	1.439	−268.692
	(.072)	(.085)	(.136)	(.702)	(1.879)	(215.527)
1-2	0.065	−.013	−.053	−.849***	−2.391***	−244.075**
	(.039)	(.041)	(.045)	(.212)	(.663)	(91.888)
3-4	0.009	0.058	−.035	−.720*	−2.642**	−105.039
	(.048)	(.054)	(.053)	(.334)	(.824)	(100.459)
5-6	−.127	0.029	−.006	−1.168***	−1.733	−14.828
	(.080)	(.079)	(.078)	(.351)	(1.204)	(104.926)
7-8	0.118	−.089	0.030	−.617	−4.227*	−319.563
	(.081)	(.090)	(.087)	(.537)	(1.871)	(166.278)
9-10	0.018	0.030	−.115	−2.199***	−9.351***	−189.090
	(.154)	(.132)	(.145)	(.659)	(2.503)	(224.518)
11-12	−.032	0.097	0.058	−2.060	−9.185**	−162.422
	(.250)	(.200)	(.097)	(1.074)	(2.868)	(94.541)
13-14	−.116	0.341*	0.599	−.527	−3.481***	−146.776*
	(.312)	(.153)	(.311)	(1.959)	(.864)	(68.253)
Female sample						
0	0.117	−.019*	0.066	−.811	−4.079	−372.137*
	(.154)	(.008)	(.072)	(.912)	(3.403)	(171.871)
1-2	−.091*	−.032*	−.037	−.324	−.383	−133.764*
	(.037)	(.014)	(.021)	(.417)	(.681)	(61.475)
3-4	−.144*	−.024	−.025	−.857	−1.051	26.559
	(.061)	(.014)	(.039)	(.458)	(1.184)	(85.752)
5-6	−.118	−.080	−.062*	−1.243***	−2.531**	−190.484*
	(.080)	(.046)	(.031)	(.348)	(.958)	(94.117)
7-8	−.255*	0.004	−.050	−1.823***	−3.976**	−47.473
	(.102)	(.020)	(.026)	(.454)	(1.217)	(133.625)
9-10	−.249*	0.016	0.064	−1.121	−.803	−89.938
	(.125)	(.033)	(.102)	(.653)	(2.277)	(136.611)
11-12	−.197	−.224	−.069	−.878	−10.898***	−563.138*
	(.170)	(.172)	(.041)	(2.888)	(1.724)	(240.085)

Notes Standard errors in parentheses. Other control variables: age squared, region, urban, education, han, marital status, urbanization index, time dummies, health insurance status, household expenditures. N=22066 (male sample), N=23051 (female sample).

Overweight and obesity results (only FE so far)

Table 5.16: Analysis of the effect of a diabetes diagnosis on overweight and obesity using FE models

	Males		Females	
	(1) Overweight	(2) Obese	(3) Overweight	(4) Obese
Diabetes	−.029	−.052**	−.085**	−.044
	(.035)	(.025)	(.037)	(.028)

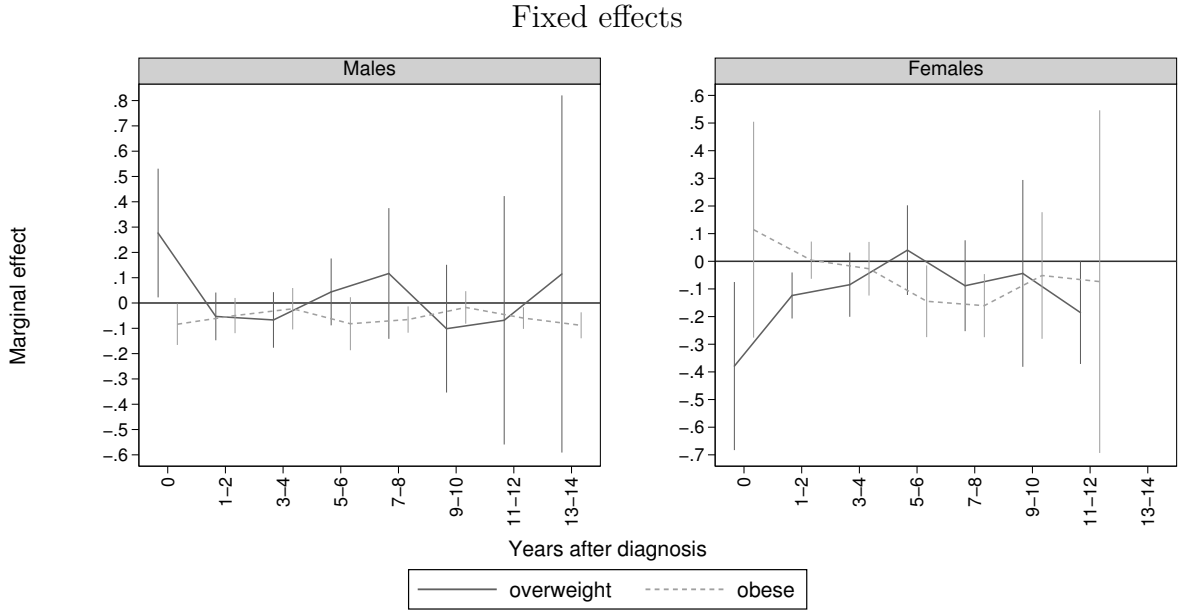
Notes Standard errors in parentheses. Other control variables: Age squared, region, urban, education, han, marital status, urbanization index, time dummies, health insurance status, household expenditures. N=19897 (male sample), N=21592 (female sample).

Table 5.17: Analysis of the effect of time since diagnosis on overweight and obesity using FE models

	Males		Females	
	(1) Overweight	(2) Obese	(3) Overweight	(4) Obese
Diabetes	−.009	−.008**	−.009	−.012**
	(.008)	(.004)	(.007)	(.006)

Notes Standard errors in parentheses. Other control variables: Age squared, region, urban, education, han, marital status, urbanization index, time dummies, health insurance status, household expenditures. N=23697 (male sample), N=23913 (female sample).

Figure 5.3: Analysis of the effect of time since diabetes diagnosis on overweight and obesity using fixed effects (duration groups)



6 Discussion and conclusions

6.1 Chapter overview

As discussed in Chapter 1, diabetes has reached epidemic proportions in middle-income countries (MICs) and is a major contributing factor to disabling poor health and early mortality. The economic impact of diabetes on individuals and healthcare systems has, however, received relatively little attention. Further, little is known about how successful healthcare systems currently are in encouraging behaviour change in those diagnosed in order to prevent the disabling complications of diabetes. This is despite the fact, that until now efforts to halt the increase in disease prevalence have been of little success. Consequently, the goal of this thesis was assessing the economic burden of diabetes in MICs. This should help to better understand the importance of primary and secondary prevention of diabetes and identify those populations must susceptible to the adverse economic effects of diabetes.

To meet these aims, four separate studies were conducted around the following questions:

1. What is the current evidence on the economic costs of type 2 diabetes?
2. What is the causal effect of self-reported diabetes on labour market outcomes in a MIC?
3. In how far can the results gained from self-reported diabetes data be used to characterize the entire diabetes population?
4. What is the effect of health information provided by a diabetes diagnosis in terms of affecting health behaviours in a MIC?

This concluding chapter has four parts. Firstly, it summarises the principal findings. Secondly, it contextualises the findings within the wider literature and provides implications for policies. Thirdly it reflects on the methods. Finally, there are suggestions for future research and concluding comments.

6.2 Summary of principal findings

Chapter 2 set out to provide an overview of and critically assess existing studies on the economic costs of type 2 diabetes globally. This not only included so called cost-of-illness (COI) studies but also studies on labour market outcomes. Systematic review methods were used and the evidence was synthesized narratively. 86 COI studies and 23 labour market studies were identified. Of those, 24 came from low- and middle-income countries (LMICs), with 23 being COI studies.

For COI studies, the review found a large range of estimated costs, with the largest per-capita costs being generated in the USA while costs were generally lower in LMICs. However, it also found that the direct economic burden caused by the treatment of type 2 diabetes is much higher in poorer countries when taking into account the lower income levels, in particular for the poorest parts of the population. Treatment costs were paid almost entirely out-of-pocket by the poor due to a lack of health insurance coverage, consuming considerable parts of the annual income. The review also found considerable differences in the used methodologies and the study quality. This made it difficult to directly compare the studies. While in many high-income countries (HICs) studies an incremental costing approach was used and data sources were representative for a distinct population, studies in developing countries often had to rely on non-representative, relatively small convenience samples, often lacking a control group. Many studies also lacked explicit mentioning of the used study perspective or the included costing components.

For labour market impact studies, most found adverse effects of self-reported diabetes on employment probabilities, wages or working days. Studies were concentrated on a few HIC, in particular the USA. More recent studies took into account potential biases due to the endogeneity of diabetes, mainly using an instrumental variable (IV) strategy with the family history of diabetes as an instrument. However, the direction of bias was ambiguous across different studies and countries.

The review also identified methodological and thematic areas so far only sparingly covered. So did no COI studies take into account the possibility of biased estimates as a result of endogeneity of diabetes. Consequently, there is a lack of evidence in the literature about the potential bias in the cost estimates of diabetes COI studies. Further, few studies used an incidence approach to investigate lifetime costs of people with diabetes, providing better information about the dynamics of cost increases after a diabetes diagnosis.

Despite these identified limitations of the COI literature, the review was able to provided a picture of the healthcare costs of diabetes in almost every continent. This was not the case for labour market studies, where almost no evidence was found for LMICs. Arguably, given the less advanced healthcare systems, later diagnosis but earlier onset of diabetes, the larger informal labour market and overall different labour market structure in developing countries, the impact of diabetes could be very different compared to HICs. Also in terms of methodology, studies had not taken advantage of panel data techniques to achieve a causal interpretation of their estimates. Especially studies on the effect on employment probabilities had relied on the same—at least debatable—identification strategy using IVs. Therefore, a study using a different identification strategy was warranted.

Importantly, no study investigating the impact of unobserved diabetes on labour market outcomes was identified by the review. Hence, an important part of the diabetes population had been mostly neglected. This left open the question in how far results for self-reported diabetes were applicable to the unaware population.

Based on the findings of the review, the three research studies that followed addressed parts of the identified gaps, in particular focusing on labour market outcomes. The aim of Chapter 3 was to provide first evidence for the impact of diabetes on employment probabilities in a developing country, where diabetes had become a public health concern. Because little was known about the equity impacts of diabetes, a further goal was to investigate the heterogeneity of effects across formal and informal employment and for the "rich" and "poor". Due to the unavailability of an alternative identification strategy, the study applied the already established IV approach using parental diabetes. However, using further familial background information on parental education, it improved upon earlier studies by controlling for a potential confounding pathway that could have invalidated the used instrument. It further used two methods to implement the IV approach. The preferred estimates came from a bivariate probit model that had been shown to be better suited for our specific data, in comparison to a standard linear IV model. We nonetheless also provided the results of the latter approach.

Chapter 3 found evidence for an adverse effect of diabetes on employment chances, reducing them by about 10 percentage points for men and 5 percentage points for women. Further, diabetes was not found to be endogenous, suggesting the use of a simple probit model. The subgroup analysis showed that the adverse employment effects occurred mainly to those above age 44, while younger people seemed less affected. Also, being poorer increase the exposure to negative employment effects of diabetes. The same was the case for those in the informal compared to those in the formal labour market. Across all models, the point estimates were bigger for males than for females.

While these results provided good evidence for an adverse effect of diabetes on employment chances in a developing country, several questions identified in Chapter 2 still remained. Further, the robustness of the findings of Chapter 3 had to be tested using more extensive and recent data and a different identification strategy. Chapter 4 addressed these issues taking advantage of a recent extension to the data used in Chapter 3. The data now spanned three waves and eight years, which allowed for the use of a longitudinal individual fixed effects model to estimate the relationship of self-reported diabetes with employment. Additionally, the investigated labour market outcomes were extended to wages and working hours. Further, it was now possible to investigate the relationship of diabetes duration with labour outcomes, in order to understand when diabetes tended to

cause adverse labour market outcomes. Importantly, the additional wave also provided information on diabetes biomarkers to investigate the effects of diabetes for the entire diabetes population as well as those unaware of diabetes separately.

The analysis carried out in Chapter 4 confirmed the adverse relationship of self-reported diabetes with employment, finding a five percentage point reduction for males and females alike. Given the relatively low female employment rate, this translated into a 14% decrease in employment probabilities women compared to 6% for men. Compared to the cross-sectional results of Chapter 3, the estimated effects of the fixed effects (FE) model are about half the size for men, but are similar and of stronger statistical significance for women. This is likely due to the additional data used in Chapter 4, but could also partly be the result of the different estimation technique. For wages and working hours no adverse effects of self-reported diabetes were found.

Further analysis showed that the most adverse effects were concentrated among self-employed and independent agricultural workers, potentially due to lower job security and access to healthcare in these often informal jobs. Further, Chapter 4 revealed that the adverse effect of diabetes on employment appeared shortly after diagnosis, then levelled off for some time until it appeared again. This pattern was observed for both males and females, albeit only statistically significant for the former. Interestingly it was found that when the employment effects levelled off, wages started to fall, again for both genders. This suggested that during this period reductions in productivity mainly reduced wages, protecting against job loss.

Finally, the results of the biomarker analysis presented in Chapter 4 showed that relying on self-reported diabetes information can lead to measurement bias in the coefficient of diabetes. Using the biomarker data to identify people with diabetes, compared to self-reported diabetes smaller effects especially on employment probabilities were found. This was caused by the non-existent associations between undiagnosed diabetes and employment chances. It was further found, that part of the difference in effects between self-reported and undiagnosed diabetes could be explained by differences in subjective health status, with those self-reporting diabetes also reporting a worse health status. Interestingly, differences in glycated hemoglobin (HbA1c) levels did not drive the stronger effects for those self-reporting.

Chapters 3 and 4 produced evidence of the adverse effect of self-reported diabetes on labour market outcomes in Mexico. Chapter 5 continued the investigation of the impact of self-reported diabetes on employment probabilities, but this time on China. It further investigated how a diabetes diagnosis affected diabetes relevant health behaviours in a developing country. Because the relationships may be biased due to unobservables and

selection, the study used two different econometric strategies in marginal structural models (MSMs) and FE. Each controlled for a different source of confounding, improving the robustness of the identified effects. The used dataset consisted of six waves of the China Health and Nutrition Survey (CHNS), covering a period from 1997 to 2011.

The results provided further evidence of a deterioration of employment probabilities after a diabetes diagnosis, though this time only for women. They experienced a reduction in employment chances between 11 to 12 percentage points. For men, the FE and MSM showed insignificant relationships. These reductions for women were similar to those found in Mexico (16–17% in China and 14% in Mexico) when the different female employment rates are taken into account. The results for health behaviours also suggested different effects for men and women. For health behaviours, all results indicated that men were able to reduce alcohol consumption, body mass index (BMI) levels, waist circumference and their daily calorie consumption. These reductions also translated into lower probabilities of being obese, potentially leading to important reductions in a variety of risk factors (Wilding, 2014). For women, no strong evidence for similar reductions was found. A similar picture remained when investigating the effects over time using linear and non-linear specifications. They suggested maintained reductions in female employment probabilities over time. Men were able to reduce their BMI and waist circumference consistently in the years following diagnosis.

These results point to very different effects of a diabetes diagnosis for men and women. On the one hand women were unable to reduce their risk factors, but men were. On the other hand, women also had to bear the main adverse economic effects.

6.3 The context of the findings and their implications

The findings of this thesis indicate an important global economic burden of diabetes and have added first evidence on the effect of self-reported diabetes on labour market outcomes in MICs. The thesis also showed that diabetes—at least in the case of labour market outcomes—did not similarly affect the unaware diabetes population as it did those aware. Additionally it showed, that a diabetes diagnosis can elicit positive changes in health behaviours. Further, several potential equity issues are brought ot light, were the burden of diabetes appears to be distributed unequally, disproportionally affecting the poor, those in the informal labour market and women.

These findings may lead to several implications to reduce the economic burden of diabetes in MICs.

Inequities in the economic burden of diabetes

An important implication of this thesis are the found economic inequities in the burden of diabetes. In Chapter 2 the review found a high out-of-pocket (OOP) burden in LMICs, especially for those with no insurance coverage. Chapter 3 showed that the adverse employment effects were concentrated among those in the informal labour market and with fewer resources. This was further supported by findings from Chapter 4 that indicated a greater reduction in employment probabilities to work in the agricultural or self-employed sector, while for those working in a non-independent wage job—that often entails greater contractual job security and better access to health insurance—diabetes did not appear to elicit negative effects. Chapter 5 found bigger adverse employment effects and less positive behavioural changes in women compared to men after they had received a diabetes diagnosis. These gender inequities are also supported by the results for Mexico, in particular by Chapter 4, where, taking into account the lower overall employment rates for women in Mexico, the relative reduction in employment chances was much greater for females than for males.

There may be several potential strategies how to reduce these inequalities and improve access to care. Several of these will be presented here with a focus on the identified populations in this thesis.

The identification of people with diabetes

Adverse labour market outcomes were only observed for the self-reporting diabetes population, suggesting that the adverse impact manifested only after some time of living with the disease and mainly after diagnosis. This is not surprising given the gradual increase in blood glucose as diabetes progresses and with this a relatively slow deterioration of health (Bertram and Vos, 2010). A first important step to reduce the economic burden of diabetes could therefore be the earlier diagnosis of diabetes. The large undiagnosed population found in Mexico in Chapter 4 as well as for other LMICs in a recent study by Beagley et al. (2014), suggests that in LMICs many people with diabetes remain undiagnosed for an extended period of time. Even though earlier detection would increase healthcare demands and costs in the short term, such effects may be set off by increases in productivity and productive life years in the working age population with diabetes, as well as lower inpatient expenditures due to reduced rates of severe, cost-intensive complications such as dialysis (Engelgau and Gregg, 2012). Evidence on the cost-effectiveness of a population-based diabetes screening program provided a recent study from Brazil, where over 22 million people over the age of 40 were screened for diabetes, being the first

evaluating an actual real-life population-based diabetes screening program in a developing country (Toscano et al., 2015). It was unclear if the program could be considered good value for the healthcare system, as the cost-effectiveness of the findings depended strongly on the used assumptions about how effective treatment would be in preventing coronary heart disease and stroke. Given the results from this thesis, cost-effectiveness may be greater from a societal perspective if an earlier diagnosis would prevent or decrease losses in productivity and productive lifespan. Of course, early diagnosis may only be reasonable if the healthcare system is sufficiently developed to allow all diagnosed cases access to appropriate treatment options (Engelgau and Gregg, 2012; Toscano et al., 2015).

Apart from worse health in the population aware of its diabetes, another policy relevant reason for the difference in the observed effects could be the psychological effect of a diabetes diagnosis. Reductions in productivity may be the result of increasing anxiety and depression as a result of becoming aware of the disease and its potential consequences. Further, difficulties in adapting to the treatment regime may cause additional stress. As discussed in Cahpter 4, there is some evidence that becoming aware of the disease leads to reductions in labour income likely due to its psychological effects (Liu and Zhu, 2014). If this is confirmed by other studies, then strategies to provide better guidance and support at diagnosis and thereafter to reduce the psychological burden of the disease could be worthwhile.

Diabetes treatment in resource constraint settings

The adverse labour market effects found for those with self-reported diabetes and the increase in effect size over time after diagnosis, suggest that people aware of the disease are not able to prevent these adverse economic outcomes from happening. This may have several reasons. The diagnosis could happen too late to prevent first complications from having developed and it becomes increasingly difficult to prevent further complications. Another reason could be the sub-optimal treatment of the disease, in particular in the most adversely affected—likely socioeconomically disadvantaged—groups identified in this thesis. Therefore, an important step to improve outcomes would be the provision of better quality in diabetes treatment. The existing evidence on treatment models applicable in very resource constrained settings has recently been reviewed by Esterson et al. (2014). While the evidence is still limited, the study provided information on interventions that have had some success in improving diabetes treatment for the poor. Further, it identified common characteristics of these successful interventions: collaboration, education, standardization of guidelines and algorithms, technological innovations, and resource optimization. The authors recommended that initiatives to provide care to underserved

populations should be build on collaborations between academic institutions, hospitals, the private sector and other organizations such as local governments. This should help to achieve goals that would otherwise be difficult to reach for one stakeholder alone. Further, programs should aim at providing appropriate education to doctors to increase their ability to successfully treat people with diabetes. For very remote communities Esterson et al. (2014) suggested the use of peer-support programs, so that few well educated community members or nurses could help their peers with the challenges of diabetes management. Further, a need for standardized guidelines and treatment algorithms was identified as a means for healthcare professionals to improve and maintain their standards of care. Given that mobile phones have already reached even very remote areas and are common in the developing world, interventions based on existent technologies could also improve care and diabetes outcomes. They could facilitate communication between doctors and their patients as well as tracking and controlling diabetes management and outcome measures. Finally, resource optimization to use available and constrained resources more effectively, e.g., by transferring certain responsibilities from doctors to nurses or from healthcare professionals to peers could be an option in very resource constrained settings (Esterson et al., 2014). Together, the presented strategies could help in reaching and treating poorer parts of the population.

Further, in MICs, the provision of universal health care has been advocated for as a means to reduce health inequities by providing everyone with the ability to access healthcare (Marmot et al., 2008). So could this enable those in the informal economy to access affordable treatments, narrowing inequities. Mexico has been one of the countries where the goal of universal health care has been almost accomplished through the introduction of "Seguro Popular", which provides those without prior health insurance coverage with social security and access to diabetes treatment options (Knaul et al., 2012; Rivera-Hernandez et al., 2016). However, evidence on the impact of diabetes treatment and outcomes has shown that the availability of this program has only led to very modest improvements, only finding a positive effect on the use of pharmacological therapy. No effects were found on the monitoring of blood glucose or adherence to exercise plans by people with diabetes (Rivera-Hernandez et al., 2016). A likely reason for this brought up by the authors was that many clinics were not prepared to provide specialized diabetes care and medications, suggesting that barriers to accessing appropriate diabetes care and education still existed. Hence, while public health care provision for those previously uninsured can reduce inequities, such programs need to ensure that their efforts are not sabotaged by the low quality of the offered services.

Diabetes prevention in resource constrained settings

Apart from improving the quality of care for people with diabetes with few resources, the prevention of diabetes may also reduce the observed inequities and the individual economic burden of diabetes. Given the inequities found in this thesis, such efforts may be particularly worthwhile if they focus on those disproportionally affected by the adverse economic effects of diabetes.

One option are population level interventions. There is already some real life evidence of such interventions with the goal of reducing obesity in developing countries. In Mexico, a 10% tax on purchases of sugar-sweetened beverages and "junk food" has been introduced in 2014. First results suggested a reduction in purchases of these goods after the introduction of the tax, with a steeper decline for those with lower income levels (Batis, Rivera, et al., 2016; Colchero et al., 2016). If these changes in consumption actually lead to a healthier diet and are large enough to cause reductions in obesity and diabetes prevalence has not been evaluated yet and remains to be seen. Other efforts to prevent diabetes in LMICs include increasing the awareness of diabetes and how to prevent it via population level campaigns, and increasing the accessibility of sport courses and fitness equipment to increase physical activity Cefalu et al. (2016).

Another option is the identification of at risk groups and providing them with interventions to increase physical activity and dietary changes. These have shown promising results across the globe, including in developing countries such as India and China, where interventions have caused long term reductions in the risk of developing diabetes (Cefalu et al., 2016). The evidence for pharmacological interventions mainly using metformin also indicates a reduction in the risk of diabetes. However, Cefalu et al. (2016) mention the potentially large heterogeneity in the benefit of pharmacological interventions across ethnicities. More research to this respect will be needed to find out if successful pharmacological interventions in one ethnicity can be translated to other ethnicities. Further, all these interventions were tested in randomized controlled trials, and translation into real-world settings has been less successful, even in high-income countries (Wareham and Herman, 2016). There are also questions about the cost-effectiveness of these interventions if scaled to a population level and the problem of finding sufficiently educated personal to implement lifestyle interventions at the local level. Cefalu et al. (2016) argue that preventive metformin treatment in individuals with a high risk of progressing to diabetes may be the best approach in countries with few economic resources. Low-cost generic versions of metformin exist, are considered essential diabetes medications in almost all LMICs (Bazargani et al., 2014), are effective in preventing or delaying the onset of diabetes, and are save (Rojas and Gomes, 2013). They therefore may present a relatively

cost-effective intervention that could be applied using existent healthcare infrastructure and pharmacies. It could be especially effective in MICs, where the healthcare system infrastructure is much more developed than in low-income countries (LICs).

The identification of high-risk individuals that could be targeted with the mentioned interventions may pose an additional hurdle to successfully preventing diabetes. Population level screening could be a way to identify people at risk. Screening could also be carried out at the workplace or the community and existing medical records could be used to identify people at an increased risk. Further, there may be possibilities to promote risk self-assessments using online resources through advertising and social media (Cefalu et al., 2016). However, scientific evidence of the cost-effectiveness and feasibility of screening for high-risk individuals in LMICs is non-existent, and if it where to happen may overwhelm health care systems. It also carries the risk of further widening health inequities if the lower income populations were less likely to attend screening efforts (Wareham and Herman, 2016).

The need to account for gender differences

Finally, and one of the main results of this thesis, is the need to specifically address women with diabetes. Gender differences in disease burden of diabetes have only come to the forefront recently (Peters, Huxley, Sattar, et al., 2015), but may hold one of the keys to reducing the economic burden of diabetes. The reduction in inequalities by the strategies discussed above may already lead to a reduction in the observed gender differences. If women have fewer economic resources then men, are more likely to work in the informal labour market and less likely to be insured (Galli and Kucera, 2008) and therefore are more adversely affected by diabetes, then interventions targeting the poor and uninsured should specifically help women. However, it appears that biological differences between men and women may make it necessary to specifically target women. Diabetes likely affects them to a greater extend (Bertram and Vos, 2010; Peters, Huxley, Sattar, et al., 2015; Peters, Huxley, and Woodward, 2014a,b) and this could be driving the observed differences in the economic effects. Efforts to reduce the burden for females would include increasing awareness among doctors about the higher risks for women to develop diabetes complications, as well as screening for cardiovascular risk factors in women at or before a diabetes diagnosis. This would present an opportunity to prevent a further escalation of the cardiovascular risk profile (Peters, Huxley, Sattar, et al., 2015). For women, weight reduction thereby seems to be the single most important step to reduce the risk of diabetes and ensuing complications (Peters, Huxley, Sattar, et al., 2015). As this thesis has shown, women in China were not able to achieve weight reduction to the extend men did and

therefore may need to be treated differently. Strategies will need to be developed that can foster this in LMICs.

Overall it seems that for LMICs, population level interventions to prevent diabetes are currently the best option to halt the escalation of the economic impact of diabetes and to reduce inequities. The results of this thesis suggest that it should be a priority to design interventions that address the existent inequities by preventing diabetes in those populations that experience the worse economic consequences. Further, targeting those with little access to healthcare in screening programs for both undiagnosed diabetes and those at high-risk for diabetes, and then following up with offers for preventive pharmacological treatment and potentially also lifestyle interventions could be of value. Further, strategies to improve treatment of diabetes will need to take into account the specific circumstances of the respective target group and should be developed in cooperative efforts to make them work.

6.4 Reflections on the methods used in the thesis

Apart from Chapter 2, the thesis used exclusively quantitative methods in an attempt to establish causal relationships between diabetes and the outcomes of interest. The goal of using econometrics in this thesis was to investigate the relationship of diabetes with labour market outcomes and health behaviours in the absence of experimental data. Given the good quality of available data and the dearth of previous quantitative research on the economics of diabetes in MIC, using econometric methods seemed to be the most appropriate way to answer the posed research questions and to provide evidence for different geographical regions.

One of the challenges was the choice of the most appropriate method to establish a causal relationship. The main concern was that unobserved variables, measurement error as well as reverse causality may introduce bias into the estimates. A variety of methods were used that each had advantages and disadvantages in terms of the underlying assumptions and the ability to account for potential sources of bias. Their choice was mainly guided by the available data and the best way of achieving a causal interpretation under the given circumstances. Nonetheless, regardless of the method used, results consistently showed an adverse relationship of self-reported diabetes with employment probabilities, suggesting a relatively robust and likely causal effect.

6.5 Strengths and limitations

The strengths and limitations of each study and the methodological approach used have been evaluated within each chapter. Additionally, the thesis overall has strengths and limitations.

A strength of this thesis is the provision of a a comprehensive overview and assessment of the state of economic research on the impact of diabetes. It provides other researchers guidance by identifying areas for future research and suggestions on which methods to use. Further, the thesis itself fills some of the identified gaps by investigating the impact of diabetes on labour market outcomes in MICs. A strength of these analyses is the use of rigorous econometric approaches taking advantage of available and previously under-explored household data, allowing to investigate a variety of topics. The used methods also improved on previous approaches, providing more robust evidence and extended the range of methods used in the exploration to methods predominantly known in epidemiology. A further strength is the provision of evidence on the potential of diabetes to widen the economic inequities in developing countries, identifying the groups that were disproportionally affected by the disease. Further, it has also advanced the understanding of diabetes as a multifaceted condition by exploring effects over time and for those with observed and unobserved diabetes. Finally, it provides evidence from different data sources and contexts and also investigates the value of health information and its ability to influence health behaviours.

The thesis has several limitations. Whilst the intention was to provide evidence on the economics of diabetes in MICs, the thesis mostly investigates the economic impact of diabetes. While this provided important information for researchers and policy makers, the thesis did not investigate how to curb this economic diabetes burden. Information about the best and most costs-effective interventions that could be applied in MICs to lower the burden of diabetes is urgently needed as information about who is affected most will not suffice to effectively reduce the burden. Research on how to implement interventions feasible in non-HIC settings is therefore of paramount importance and has not been provided in this thesis.

This leads to the next limitation. The thesis does not investigate in how far healthcare systems in MICs need to change in order to better provide care. Because they often lack financial resources, do not efficiently use the available resources, are designed to treat acute infectious diseases rather then affecting the outcomes of long-lasting non-acute non-communicable diseases (NCDs), and often provide unequal access to their health services due to financial constraints of those seeking care, research into how to strengthen these

systems is urgently needed (Guzmán et al., 2010; Mills, 2014).

A further limitation is the geographical concentration of the thesis in its empirical investigation. While Mexico and China are among the ten countries with most people with diabetes in the world, there are other large and small MICs currently facing similar challenges (NCD Risk Factor Collaboration, 2016). It cannot be assumed that the evidence provided in this thesis is representative of other MICs. It therefore will be important to investigate the economic burden and potential solutions in other countries, given their own specific context in terms of culture, the political system, economic development and equity and equality issues.

Finally, while the thesis intended to provide a picture of the potential inequities in the economic impact of diabetes for socioeconomic subgroups, it did not investigate in detail why these inequities exist and could only speculate on the reasons. A better understanding of the underlying reasons will be integral for designing adequate strategies to address these inequities. Further, whilst the thesis has touched upon the potential reasons for the differences in employment effects between those self-reporting diabetes and those unaware, it has not provided an in depth analysis of this phenomenon. A better identification of the underlying reasons will be needed to design interventions that can prevent the adverse economic effects of diabetes.

6.6 Suggestions for future research

This thesis has shown the global economic impact of diabetes and its adverse effect on labour market outcomes in Mexico and China. It identified the poor, those in the informal economy and women as being most adversely affected by the disease. It further found that, at least in China, it is men that appear to profit most from a diabetes diagnosis in terms of positively changing their health behaviours. Finally, it provided some indication that while self-reported diabetes is related to adverse labour market effects, undiagnosed diabetes is not. Without a greater understanding of the underlying reasons for the found differences, it will be difficult to design policies that can help prevent the burden of diabetes in MIC and reduce inequalities.

Several reasons for the observed gender differences in the impact of diabetes have been discussed in this thesis, including biological reasons that increase the risk of complications in women Arnetz et al. (2014), Catalan et al. (2015), Engelmann et al. (2016), Peters, Huxley, Sattar, et al. (2015), Peters, Huxley, and Woodward (2014a), Policardo et al. (2014), Roche and Wang (2013), and Seghieri et al. (2015) and may also impair the ability of women to lose weight (Penno et al., 2013), as well as differences in the access to

appropriate healthcare (Penno et al., 2013). One strategy to further investigate the reasons would be the use of biomarker data in combination with information on healthcare utilization as well as socioeconomic outcomes. This could then be used to investigate potential heterogeneities in the relationship between diabetes and overall metabolic health with labour market outcomes. Further, information on healthcare usage could be used to investigate if differences in healthcare access mediate the economic impact of diabetes. A potentially rich source of information provide two Chinese household surveys, the China Health and Nutrition Survey (CHNS) and the The China Health and Retirement Longitudinal Study (CHARLS). Both contain an extensive list of measured biomarkers and socioeconomic variables that could help to investigate differences in metabolic risk between men and women. This information may also be used to further investigate differences in metabolic risk between people aware and unaware of their diabetes.

Researchers should also try to confirm the results regarding the found inequities, using different data and countries. If these relationships can be confirmed, the underlying drivers of these inequities need to be explored to design adequate policies. This could be done by identifying countries where these inequities may not have been found, to isolate the causal determinants. Further, strategies implemented currently or in the future in MICs that aim to reduce these inequities, such as the implementation of universal health insurance schemes need to be evaluated in how far they are actually achieving this goal in terms of diabetes. The same is true for population level interventions such as taxes on foods or nutrients, as these theoretically should reduce consumption in particular for those with lower levels of income (Mytton et al., 2012). This could then lead to a reduction in diabetes incidence in these groups. However, depending on the price elasticities of the taxed products as well as substitution effects with equally untaxed products, such taxes may only reduce the disposable income. It could thereby reduce food purchases of healthy products or could cause a shift in consumption towards other equally unhealthy untaxed products (Mytton et al., 2012).

Third, the diabetes population in all countries, but especially in LMICs is only partially observed. In other words many people with diabetes are not aware that they have the disease. This thesis has provided an investigation of the differences between those aware and unaware. It, however, still remains unclear to what extend different factors such as health information and actual health status are causing the observed heterogeneity in the economic impact. Because increasingly household surveys are providing biomarker data in combination with socioeconomic information, they should be used together with quasi-experimental econometric techniques to investigate this topic. A regression-discontinuity design may be used in a similar vain as in Zhao, Konishi, et al. (2013), who use cut-off

values for hypertension to identify those newly diagnosed and the subsequent effect of this diagnosis on health behaviours. A similar approach could be used to explore the effects of a diabetes diagnosis and the entailed health information on labour market outcomes, health behaviours and other economic outcomes. Importantly, researches should assess the heterogeneity of effects across income groups, rural versus urban, education levels and between males and females. This would provide important information for designing interventions to reduce the physiological and economic burden of diabetes while preventing a widening of inequities.

Fourth and finally, there is a need to explore further economic downstream effects of the economic impact of diabetes. If diabetes causes reductions in employment and potentially also income, it is likely that these will cause not only problems for the individual directly affected, but for the entire household as well. In MICs, where social security is less extensive and comprehensive, adverse health shocks due to diabetes could have consequences for the children, spouses or other family members living in affected households (Alam and Mahal, 2014). The loss in labour income due to diabetes needs to be compensated either by increasing the labour supply of other household members or by reducing expenditures for other consumption goods. Both could affect children directly, for example by reducing the time for or quality of education when tuition fees cannot be paid anymore and also by having to substitute time for education with labour time. Similarly spouses may be forced to increase their labour supply, reducing the time they can care for their children. These effects have remained unexplored for diabetes but given the scale of the diabetes epidemic may not be trivial.

6.7 Concluding remarks

Diabetes presents a major challenge for MICs, but evidence on its economics has been scarce. This thesis has found that diabetes has an adverse economic impact on individuals and puts a burden on healthcare systems. Because evidence on the impact of diabetes on labour market outcomes was lacking in developing countries, the thesis had a special focus on this topic. Thereby it not only provided evidence of the adverse impact of diabetes on employment, but also improved upon previously used econometric methods by using novel strategies to identify a causal relationship. The thesis also identified potential inequities in the impact of diabetes, pointing to larger adverse effects for the poor, those in the informal labour market and women. But the thesis did not only focus on the economic impact of diabetes, but also investigated the effects of a diabetes diagnosis on health behaviours, unravelling evidence for differences in the ability to change health behaviours between

men and women.

These findings suggest that there is a need to reduce the economic impact of diabetes in MICs. Considering the increasingly earlier onset of diabetes and the ongoing increase in incidence in many countries, the non-trivial adverse economic effects could otherwise hinder economic development and present a substantial poverty risk. Strategies to combat the adverse diabetes effects need to be tailored to the available resources within countries, target the most affected groups to narrow inequities, also having in mind potential gender differences. Finally, there is a large undiagnosed diabetes population in MICs that is likely to experience severe diabetes complications if identified very late. Hence, ways to diagnose this population earlier in order to prevent further deterioration of health may go a long way in preventing and delaying the most catastrophic economic and health outcomes.

In conclusion, it is hoped that this thesis, and the publications born out of it, contribute to the knowledge on the economics of diabetes and help to identify cost-effective strategies to lower the health and economic consequences of diabetes. It has demonstrated the economic burden currently caused by diabetes, in particular in Mexico and China, and has identified groups that are particularly vulnerable to the negative consequences of the disease and should be at the centre of efforts to prevent the burden of diabetes.

Appendix

Table 6.1: Household surveys from low- and middle-income countries including diabetes information as of 2014

Name	Country	Cross-section / Panel	Waves	Years	Population	Sample size	Nationally Representative	Ongoing	Data available	Interesting content	URL
DHS	Armenia	Cross-section		2010	women and men 15-49	6700 households	yes	no	yes	diabetes questions, health expenditures	http://www.measuredhs.com/what-we-do/survey/survey-display-354.cfm
DHS	Bangladesh	Cross-section		2011	women 12-49 and men 15-54	17141 households	yes	no	yes		http://www.measuredhs.com/what-we-do/survey/survey-display-349.cfm
DHS	Benin	Cross-section		2011-2012	women 12-49 and men 15-64	17422 households	yes	yes	not yet	diabetes questions	http://www.measuredhs.com/what-we-do/survey/survey-display-420.cfm

Table 6.1: Household surveys from low- and middle-income countries including diabetes information as of 2014

Name	Country	Cross-section / Panel	Waves	Years	Population	Sample size	Nationally Representative	Ongoing	Data available	Interesting content	URL
LSMS	Bosnia and Herzegovina	Cross-section		2004	both sexes	2969 household	yes	no	yes	Diabetes question, healthcare expenditures, employment, earnings	http://go.worldbank.org/OLMHSTUX40
LSMS	Bulgaria	Cross-section		2001, 2003, 2007	both sexes	4300 households	yes	no	yes	diabetes questions, since when diagnosed, health expenditures, earnings	http://econ.worldbank.org/

Table 6.1: Household surveys from low- and middle-income countries including diabetes information as of 2014

Name	Country	Cross-section / Panel	Waves	Years	Population	Sample size	Nationally Representative	Ongoing	Data available	Interesting content	URL
Cebu Longitudinal Health and Nutrition Survey	Philippines	Panel	5	1991-2005	Filipino women who gave birth between May 1, 1983, and April 30, 1984	2800 women and 2260 children	no	yes	yes	diabetes, health, nutrition and economic data for mothers available at least since 1991, for children blood samples taken in 2005 and were asked for chronic illnesses	http://www.cpc.unc.edu/projects/cebu/datasets
CHNS	China	Panel	Every 2 years since 1989	1989-2011	both sexes, all ages	Around 16000 people	yes	yes (next wave 2013)	yes	Diabetes question, biomarkers	http://www.cpc.unc.edu/projects/china

Table 6.1: Household surveys from low- and middle-income countries including diabetes information as of 2014

Name	Country	Cross-section / Panel	Waves	Years	Population	Sample size	Nationally Representative	Ongoing	Data available	Interesting content	URL
DHS	Dominican Republic	Cross-section		2007	Women 15-49 and men 15-59	32000 households	yes	no	yes	Diabetes question, (earnings, employment, health expenditures, wealth)	http://www.measuredhs.com/what-we-do/survey/survey-display-291.cfm
DHS	Egypt	Cross-section		2008	Females 15-49 and males 15-59	18968 households	yes	no	yes	Diabetes question, socioeconomic information (earnings, employment, health expenditures, wealth)	http://www.measuredhs.com/what-we-do/survey/survey-display-294.cfm

Table 6.1: Household surveys from low- and middle-income countries including diabetes information as of 2014

Name	Country	Cross-section / Panel	Waves	Years	Population	Sample size	Nationally Representative	Ongoing	Data available	Interesting content	URL
DHS	India	Cross-section		2005	women 15-49 and men 15-54	109041 households	yes	no	yes	diabetes question and history, earnings, employment, wealth	http://www.measuredhs.com/what-we-do/survey/survey-display-264.cfm
Indonesian Family Life Survey	Indonesia	Panel	4	1993, 1997, 2000, 2007	both sexes, all ages	30000 people	almost	no	yes	diabetes question only in last wave	http://www.rand.org/labor/FLS/IFLS.html

Table 6.1: Household surveys from low- and middle-income countries including diabetes information as of 2014

Name	Country	Cross-section / Panel	Waves	Years	Population	Sample size	Nationally Representative	Ongoing	Data available	Interesting content	URL
LSMS	Iraq	Cross-section		2007	both sexes, all ages	18144 households	yes	no	yes	diabetes questions, comorbidities,health expenditures, earnings, employment, wealth	http://go.worldbank.org/HATUQJIMF0
DHS	Lesotho	Cross-section		2009	Women 15-49 and men 15-59	9391 households	yes	no	yes	diabetes questions, earnings, income, wealth	http://www.measuredhs.com/what-we-do/survey/survey-display-317.cfm

Table 6.1: Household surveys from low- and middle-income countries including diabetes information as of 2014

Name	Country	Cross-section / Panel	Waves	Years	Population	Sample size	Nationally Representative	Ongoing	Data available	Interesting content	URL
LSMS	Malawi	From 2013 on partly panel structure		2004, 2010	both sexes	12271 households in 2010	yes	yes	yes	diabetes questions, health expenditures, employment, income	http://go.worldbank.org/RMEFTSE800
MxFLS	Mexico	Panel	2	2002, 2005	both sexes, all ages	35000	yes	no	yes	diabetes question, labour outcomes, parental diabetes	http://www.ennvih-mxfls.org/es/ennvih.php?seccion=1&subseccion=1&session=76719964140

Table 6.1: Household surveys from low- and middle-income countries including diabetes information as of 2014

Name	Country	Cross-section / Panel	Waves	Years	Population	Sample size	Nationally Representative	Ongoing	Data available	Interesting content	URL
Enquete nationale sur les niveaux de vie des menages	Morocco	Cross-section		2007	?	7200 households	yes	no	no information found	Diabetes question	http://www.hcp.ma/Enquete-nationale-sua96.html
LSMS	Nepal	Cross-section/Panel	3	1996, 2003, 2010	both sexes	6000 households, Panel 1200	yes	no	yes	diabetes questions, since when diagnosed, health expenditures, earnings, employment	http://go.worldbank.org/LLAVNKC6E0

Table 6.1: Household surveys from low- and middle-income countries including diabetes information as of 2014

Name	Country	Cross-section / Panel	Waves	Years	Population	Sample size	Nationally Representative	Ongoing	Data available	Interesting content	URL
DHS	Peru	Cross-section		2011	only females, 15-49	26182 households	yes	no	yes	diabetes questions, income, health expenditures, employment, wealth	http://www.measuredhs.com/what-we-do/survey/survey-display-433.cfm
DHS	Senegal	Cross-section		2011	Women 15-49 and men 15-59	7902 households	yes	no	yes	diabetes questions, income, health expenditures, employment, wealth	http://www.measuredhs.com/what-we-do/survey/survey-display-365.cfm

Table 6.1: Household surveys from low- and middle-income countries including diabetes information as of 2014

Name	Country	Cross-section / Panel	Waves	Years	Population	Sample size	Nationally Representative	Ongoing	Data available	Interesting content	URL
LSMS	Serbia and Montenegro	Panel	2	2002, 2003	both sexes	19725 persons (2002), 8027 persons (2003)	yes	no	yes	Diabetes question, healthcare expenditures, employment	http://microdata.worldbank.org/index.php/catalog/80
South African National Income Dynamics Study (NIDS)	South Africa	Cross-section	2	2008, 2011	both sexes	7300 households	yes	yes	yes	Diabetes question, taking medication and since when diabetes, income, health expenditures, labour outcomes	http://www.nids.uct.ac.za/home/

Table 6.1: Household surveys from low- and middle-income countries including diabetes information as of 2014

Name	Country	Cross-section / Panel	Waves	Years	Population	Sample size	Nationally Representative	Ongoing	Data available	Interesting content	URL
LSMS	Tajikistan	Cross-section		2007	both sexes	4860 households	yes	no	yes	diabetes questions, labour outcomes, health expenditures	http://go.worldbank.org/6TUMCB3K30
LSMS	Tanzania	Panel	2	1994, 2004	both sexes	900 households	no	no	yes	diabetes questions, income, employment, health expenditures	http://go.worldbank.org/9F9RHLXM20

Table 6.1: Household surveys from low- and middle-income countries including diabetes information as of 2014

Name	Country	Cross-section / Panel	Waves	Years	Population	Sample size	Nationally Representative	Ongoing	Data available	Interesting content	URL
WHO World Health Survey	Worldwide	Cross-section		2002	both sexes		yes	no	not directly	Diabetes question	http://www.who.int/healthinfo/survey/instruments/en/index.html
Russia Longitudinal Monitoring Survey (RLMS)	Russia	Panel	15	1994-2011	both sexes	4000-6000 households	yes	yes	yes	diabetes question, time of diagnosis, health expenditures, labour outcomes	http://www.cpc.unc.edu/projects/rlms-hse

LSMS Living Standards Measurement Surveys **DHS** Demographic and Health Survey

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