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The Impact of the Diabetes Management Incentive on Diabetes-related Services, Hospitalizations, and Mortality Risk in Ontario

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A thesis submitted in partial fulfillment of the requirements for the Master of Science degree in Epidemiology and Biostatistics

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Abstract

Effective diabetes management provided in primary care has the potential to reduce hospitalizations and mortality. To improve diabetes management, a Diabetes Management Incentive (DMI) was introduced by the Ontario government for family physicians practicing in patient enrolment models. This thesis has three main objectives: 1) review the literature on the association between financial incentives for diabetes care and diabetes-related hospitalizations and mortality; 2) and 3) examine the impact of DMI on: diabetes-related services, diabetes-related hospitalizations, diabetes-related hospitalization costs, and mortality risk in Ontario. A review of the literature on the incentives revealed inconsistent findings. The impact of DMI was assessed using longitudinal administrative data from the ICES, and analyzed using multivariable difference-in-difference linear regression models. The results showed that DMI was associated with an increase in the provision of diabetes-related services, but had no effect on diabetes-related hospitalizations, hospitalization costs, and mortality risk.

Keywords

Diabetes management, financial incentives, pay-for-performance, primary care, hospitalization, cost, mortality risk, health administrative data, Ontario

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List of Abbreviations

2hPG:	2-hour plasma glucose
95% CI:	95% Confidence Interval
ACG:	Adjusted Clinical Group
ACSC:	Ambulatory Care Sensitive Condition
ADG:	Aggregated Diagnosis Group
β:	Beta coefficient
BC:	British Columbia
CAD:	Canadian dollars
CAPE:	Client Agency Program Enrolment
CIHI:	Canadian Institute for Health Information
CMG:	Canadian Medical Graduate
CPDB:	Corporate Provider Database
CPWC:	Cost Per Weighted Case
DA:	Dissemination Area
DAD:	Discharge Abstract Database
DID:	Difference-in-difference
DMA:	Diabetic Management Assessment
DMI:	Diabetes Management Incentive
FFS:	Fee-for-service

FP:	Family physician
FPG:	Fasting plasma glucose
HbA1C:	Glycated hemoglobin
HCQI:	Healthcare Quality Indicator
HR:	Hazard Ratio
ICD-9:	9th revision of the International Classification of Diseases
ICD-10:	10th revision of the International Classification of Diseases
IKN:	ICES key number
IMG:	International Medical Graduate
IPDB:	ICES Physician Database
IRR:	Incident Rate Ratio
LHIN:	Local Health Integration Network
LPM:	Linear Probability Model
MOHLTC:	Ministry of Health and Long-Term Care
MRS:	Mortality Risk Score
NT:	New Taiwan
ODD:	Ontario Diabetes Dataset
OECD:	Organisation for Economic Co-operation and Development
OGTT:	Oral glucose tolerance test
OHIP:	Ontario Health Insurance Plan

OLS:	Ordinary Least Squares
P4P:	Pay-for-Performance
P4Pa:	Pay-for-Participation
P4C:	Pay-for-Compliance
PCCF:	Postal Code Conversion File
PEM:	Patient Enrolment Model
PG:	Plasma glucose
Q1:	Quintile 1
Q5:	Quintile 5
QOF:	Quality and Outcomes Framework
RIW:	Resource Intensity Weight
RPDB:	Registered Persons Database
SDS:	Same Day Surgery
UK:	United Kingdom
US:	United States
USD:	United States dollar
WHO:	World Health Organization

Chapter 1

1 Introduction

1.1 Diabetes Mellitus

Diabetes mellitus, commonly referred to as diabetes, is a chronic disease that affects millions of people worldwide today.[1,2] The World Health Organization (WHO) defines diabetes as a disease in which the pancreas does not produce adequate amount of insulin in one's body, or when the body cannot effectively use the insulin produced.[3] Insulin is a hormone produced from the pancreas to regulate the body's blood sugar. The insulin helps transfer the extra sugar from the blood into cells of the body to be used for energy.[3,4] Diabetes is often characterized by chronic hyperglycemia or high blood sugar.[3,5] There are three common types of diabetes. Type 1 diabetes, commonly developed during childhood or adolescence, is when there is a deficiency of insulin produced in the body.[3,6] This occurs when the immune system mistakenly destroys the beta-cells that stores and releases insulin.[3,5] A risk factor for type 1 diabetes is having a family history of this disease; however, research on the exact risk factors of this type of diabetes is still ongoing.[7] Type 2 diabetes, the most common type, is when the body does not effectively use the insulin released or the body does not produce enough insulin.[3,5] Type 2 mostly develops later in life such as during adulthood and in the old age.[3,5,6] There are a number of risk factors for type 2 diabetes such as family history, age of 40 years and older, overweight, and members of certain racial/ethnic backgrounds (e.g. African American).[7–9] Lastly, gestational diabetes develops during pregnancy, and it is when the glucose levels are above normal, but lower than the threshold level for diabetes.[3,10]

Diabetes places a substantial burden worldwide, and the WHO estimated it to be the seventh leading cause of death in 2016.[3] Globally, the estimated number of adults with diabetes increased from 108 million in 1980 to 422 million in 2014.[11] Specifically in Canada, over the past decade the prevalence of diabetes had doubled.[10] Statistics Canada reported that in 2017, over 2.2 million Canadians aged 12 and older are living with

diabetes, of which 965,100 patients were from Ontario.[12] Based on 2013-2014 data, approximately 200,000 Canadians were newly diagnosed with diabetes.[13] Consequently, diabetes presents a significant economic burden on the healthcare system both in Canada and worldwide.[10] The estimated global cost of diabetes for the year 2015 was $1.31 trillion (United States dollar [USD]).[14] As for Canada, in 2010, the total cost of diabetes was estimated to be $12.2 billion (in 2005 Canadian dollars).[15] In 2018, Diabetes Canada reported the estimated direct cost of diabetes to the healthcare system was $3.6 billion.[16] The direct cost includes cost of direct and cardiovascular-related hospitalizations, general practitioners, specialists, and medications.[10,15]

Many individuals diagnosed with diabetes develop a number of diabetes-related short-term and/or long-term complications over time.[10] Diabetes-related short-term complications include diabetic ketoacidosis, hypoglycemia, and hyperosmolar hyperglycemic state.[17,18] Over the long-term, specific complications such as retinopathy associated with potential blindness, neuropathy with the risk of amputations and foot ulcers, and nephropathy with a risk of renal failure can be developed.[5,10] Diabetic patients are also at risk of cancer, psychiatric illnesses, cognitive decline, heart failure, cardiovascular, cerebrovascular, and peripheral vascular diseases.[5,10,19] Diabetes-related complications can lead to hospitalizations, premature death, and reduce an individual's life expectancy by 5 to 15 years.[10,20] In 2008-2009, one in ten deaths in Canadian adults aged 20 years and older were attributed to diabetes.[20,21]

Currently there is no cure to diabetes, however, appropriate management of the disease can reduce the incidence of diabetes-related complications while reducing mortality and morbidity.[22] For type 2 diabetes, lifestyle interventions such as modifying food intake and physical activity levels are crucial.[19] Diabetic patients generally receive a standardized diabetes education regarding the dietary intervention, and the significance of physical activity.[19] A patient's weight can be reduced through these interventions, thus improving glycemic control and reducing cardiovascular risk factors.[19] Patients unsuccessful with lifestyle modifications, or whom are predicted to be unsuccessful at diagnosis, are directed towards medications and insulin therapy.[19]

1.2 Diabetes and Hospitalizations

Diabetic patients are frequently admitted and readmitted to the hospital due to their acute and chronic complications.[18,23] In Canada, compared to individuals without diabetes, diabetic patients are more than three times as likely to be hospitalized with heart disease, over 12 times for end-stage renal disease, and over 20 times for non-traumatic lower limb amputations.[21] However, effective diabetes management at primary care can potentially reduce diabetes-related complications and hospitalizations.[24–26] Therefore, diabetes is listed as an ambulatory care sensitive condition (ACSC).[1,18,24,27–29] An ACSC is a health condition where accessibility to, and effective management at primary care can reduce hospitalizations.[1,18,24,27,28] For instance, certain conditions such as diabetic ketoacidosis, and hyperosmolar hyperglycemic state require immediate hospital admissions, however, with adequate primary care many of these hospitalizations can be prevented.[18]

1.3 Diabetes Diagnosis and Management

Based on the Diabetes Canada (previously known as Canadian Diabetes Association) Clinical Practice Guidelines from 2018, diabetes is diagnosed through venous samples and laboratory methods.[30] It is assessed using diagnostic tests that examine the following: fasting plasma glucose level (FPG), 2-hour plasma glucose levels (2hPG) from a 75g oral glucose tolerance test (OGTT), glycated hemoglobin (HbA1C) levels, or random plasma glucose (PG) levels. A patient is diagnosed with diabetes when they have a FPG $\geq$ 7.0 mmol/L, or 2hPG in a 75 g OGTT $\geq$ 11.1 mmol/L, or HbA1C in adults $\geq$ 6.5% or random PG $\geq$ 11.1 mmol/L.[30]

Diabetes Canada reports that approximately 80% of care for diabetic patients takes place at the primary care level, and that the diabetes care should be provided using a chronic care model. This model is used to provide care to patients with chronic diseases, and includes strategies to improve the quality of health services provided to patients and their health status.[30] The chronic care model consists of the following six elements: 1) delivery systems design - systematic changes are made to the primary care practices and health systems to improve patient care, 2) self-management support - focuses on the patient taking an active role in their care by self-monitoring and/or help make decisions, 3)

decision support - provide physicians with the best practice information to date to help make decisions, 4) clinical information systems – assists with organizing population and patient data to provide more efficient care (e.g. electronic medical records), 5) community - social and environmental factors such as food security that affects the patient's heath, and 6) health systems - providing support to diabetes care from a health care system perspective which includes services and strategies to help improve health outcomes.[30] Providing financial incentives to physicians to compensate for spending adequate time with diabetic patients for the effective disease management is also part of the health systems support.[30]

Diabetes management is a multifactorial approach which involves an interprofessional team of physicians and requires patients to be heavily involved in the care. Diabetes Canada has additionally noted some crucial tests that patients must take as part of the diabetes care. These tests include the HbA1C blood tests, nerve damage tests, monitoring blood pressure, urine tests, foot examinations, blood tests to check cholesterol and other fat levels, eye examinations, and reviewing blood glucose monitoring records from home.[31] Following Diabetes Canada's recommendations and having a FP who provides effective care can help manage diabetes.

1.4 Ontario's Primary Health Care and Reform

In Canada, primary care services are provided by FPs and general medical practitioners who diagnose and treat patient's illnesses and injuries.[32] Services provided at primary care includes prevention and treatment of diseases, providing referrals to other levels of care (e.g. specialist care), health promotion, primary mental health care, basic emergency services, and rehabilitation services.[32]

In the late 90s and early 2000's, the primary health care sector was confronted with a number of challenges internationally.[33,34] Some of the common challenges were maldistribution of physicians, gaps between the recommended care and those provided to patients, patient and provider dissatisfaction, and poor access to care.[33,35] In Ontario, the most populous province in Canada, primary care was historically delivered mostly by solo and small-group practices that were managed and owned by physicians.[35] Physicians

are paid by the Ontario Ministry of Health and Long-Term Care (MOHLTC).[35] Traditionally, FPs were paid by the fee-for-service (FFS) payment, where physicians billed every service provided to the patients.[36] Although FFS payments motivated physicians to provide services, there were some concerns such as physicians were more likely to provide shorter consultations, physicians tend to have a disincentive to prevent illnesses, services may be overprovided or prescriptions may be written when it was not necessary, and the increased costs to the healthcare sytem.[36,37]

In response to the challenges and to increase the emphasis on chronic disease prevention and management, policy-makers in Canada and other countries initiated primary care reform which included a number of changes such as implementing new models of reimbursement, new governance structure, various pay-for-performance (P4P) incentives, interdisciplinary teams and electronic health records.[33,35] The primary care reform in Ontario began in the early 2000s. During 2002 to 2007, a number of primary care organizational and funding models (Patient Enrolment Models; PEMs) were introduced, and each model had its unique characteristics to suit the physician and patient needs.[35] Physicians and patients were able to voluntarily enroll into these models. The newly developed models attracted many physicians as they were promised to obtain increased income, and improved infrastructures (e.g. electronic medical records in some practices). In addition, physicians enrolled to these models were reimbursed through blended payments such as capitation (fixed payment per patient per annum adjusted for age and gender), FFS, salary, and P4P incentives for preventive care and chronic disease management.[35]

1.5 Financial Incentives

Financial incentives, such as P4P, are provided to physicians, in addition to their existing base payments, as rewards for meeting specific outcomes or performance targets (e.g. improving preventive care provided to specific patients).[38,39] Financial incentives can influence FP's behaviour and motivate them to deliver a higher quality of care to their patients.[18] Financial incentives have been introduced in numerous countries such as the United Kingdom, Italy, Canada, Taiwan, United States, and Australia to improve disease management at primary care.[18,28,38,40,41]

On April 1, 2006, the MOHLTC introduced the Diabetes Management Incentive (DMI) in Ontario.[38] The DMI is a $60 annual payment per patient to FPs for documenting and providing ongoing care to diabetic patients in accordance with the Diabetes Canada's Clinical Practice Guidelines.[38,42] Physicians must document the Diabetes Canada's required elements that have been completed for the patient over the past 12 months. Documentation can be done using a flow sheet and must be stored in the patient's record.[38,42,43] The elements that must be recorded are: "a) lipids, cholesterol, HbA1C, blood pressure, weight and body mass index, and medication dosage; b) discussion and offer of preventive measures including vascular protection, influenza and pneumococcal vaccination; c) health promotion counselling and patient self-management support; d) record albumin to creatinine ratio; e) discussion and provide referral for dilated eye examination; and f) foot and neurologic examination".[44,45]

To claim the DMI, FPs are required to submit the Q040 fee code for their diabetic patient once per year.[38,42,43,46] As of October 1, 2015, FPs are only eligible to bill this incentive if they have submitted at least three K030 fee codes for their patient within the same 12-month period.[45,47] The K030 billing code, introduced on April 2002, is the Diabetic Management Assessment (DMA) fee code for providing diabetes-related services other than insulin therapy support to patients.[44,48] The K030 can be billed a maximum four times per patient over a 12-month period, and receive $39.20 each time it is billed.[45] There were a few changes in the value of the DMI and DMA since their introduction, therefore, a timeline mapping these changes are presented in Figure 1.1.[49]

When the DMI was first introduced, FPs enrolled in specific PEMs were eligible to bill the incentive for their enrolled patients. The specific PEMs include: Family Health Networks, Family Health Groups, Family Health Organizations, Comprehensive Care Models, Group Health Centre, St. Joseph's Health Centre, Primary Care Networks, Health Service Organizations, Rural and Northern Physician Group Agreement, and South Eastern Ontario Academic Medical Organization.[38,50] FPs practicing in the traditional FFS, and non-enrolled patients in the above PEMs were ineligible for DMI. However, as of April 1, 2009, all FPs were eligible to bill the DMI for all patients with diabetes.[38,43,46]

1.5.1 Gaps in the Literature Regarding the Impact of Financial Incentives for Diabetes Care

Financial incentives for diabetes care are implemented in many countries to improve the provision of services for diabetic patients and effective management of diabetes. It is important to understand the impact of these incentives on long-term patient outcomes such as hospitalizations and mortality. This will inform the effectiveness of these incentives in improving patient health. Furthermore, understanding the impact of these incentives on hospitalization costs is also vital, as hospitalization costs accounts for the largest portion of the estimated direct cost of diabetes.[10,51] A number of published papers have assessed the relationship between incentives for diabetes care and hospitalizations, hospitalization costs, or mortality. Thus, a literature review summarizing these findings is warranted in order to understand this relationship.

To date, there is a lack of studies that have focused on the impact of DMI in Ontario. One study in Ontario observed improvements in prescribing performance measures for diabetes care after physicians enrolled into either of the two new PEMs: Family Health Groups and Family Health Networks.[42] The authors briefly mention that some of the observed improvements may be due to the DMI.[42] Another study in Ontario which directly focused on the DMI found that, physicians participating in the Family Health Organization model were more responsive to the DMI compared to physicians in the Family Health Group model.[38] However, to date, it is unknown if the introduction of DMI is associated with increased diabetes-related services, and decreased diabetes-related hospitalizations, associated costs, and mortality risk in diabetic patients in Ontario. It is important to assess the above relationships, in order to inform health researchers and policy makers the effectiveness of this incentive.

1.6 Research Objectives

This thesis has three main objectives:

1. Perform a literature review on the relationship between financial incentives for diabetes care and diabetes-related hospitalizations, diabetes-related hospitalization costs, and mortality.

2. Examine the impact of DMI on diabetes-related services in patients diagnosed with diabetes in Ontario.
3. Examine the impact of DMI on diabetes-related hospitalizations, diabetes-related hospitalization costs, and mortality risk in patients diagnosed with diabetes in Ontario.

Objectives 2 and 3 are examined using longitudinal data spanning from April 1st, 2002 to March 31st, 2009. Data were accessed from several administrative databases housed at ICES. These two objectives will be examined by comparing diabetic patients enrolled to FPs practicing in PEMs eligible for DMI (DMI group) to patients affiliated to FPs practicing in the traditional FFS (comparison group).

1.7 Thesis Overview

Chapter 2 presents a literature review of the existing literature that assessed the relationship between financial incentives for diabetes care and diabetes-related hospitalizations, hospitalization costs, and mortality (Objective 1). Chapter 3 examines Objective 2 using four multivariable linear regression models with the difference-in-difference (DID) approach. Findings from these models are presented and discussed in this chapter. Chapter 4 examines Objective 3 using a similar methodological approach as Chapter 3, and the results are presented and discussed. Chapter 5 provides a summary of the main findings from the three studies. It also includes the areas where potential future research can be performed to gain further insights into the impact of DMI.

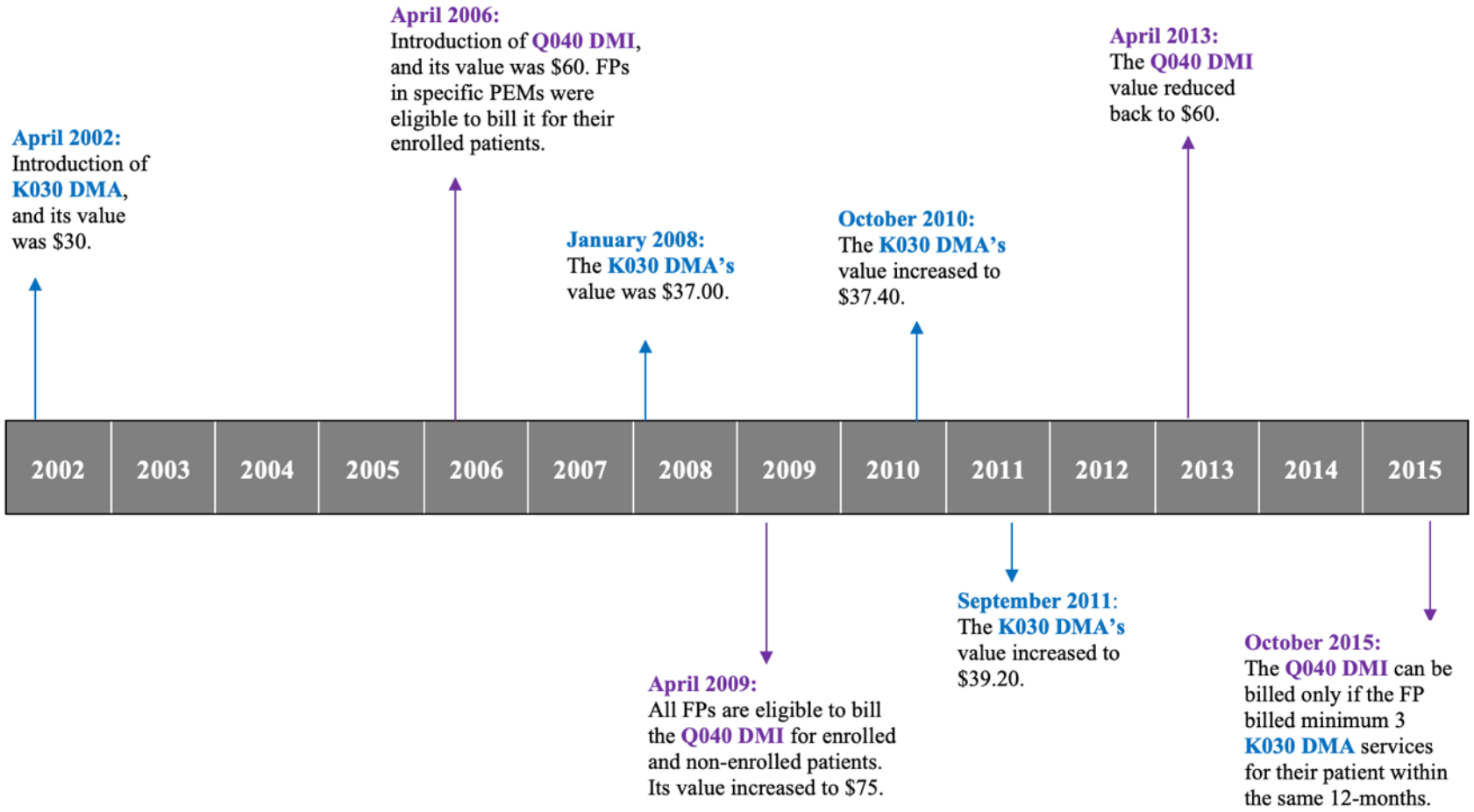

Figure 1.1: Timeline of the introduction of Q040 DMI and K030 DMA fee codes in Ontario

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Chapter 2

2 The Relationship between Financial Incentives for Diabetes Care and Hospitalizations and Mortality: A Review of the Literature

2.1 Introduction

Diabetes mellitus in adults aged 18 and over is affecting millions of individuals worldwide today. In 2017, it was estimated that about 451 million individuals had diabetes between the ages 18 and 99 worldwide.[1] Diabetes can damage one's blood vessels, nerves, and organs if not managed appropriately.[2] In 2016, approximately 1.6 million deaths were caused by diabetes, and the World Health Organization (WHO) estimated diabetes to be the seventh leading cause of death that year.[3] Diabetes also places a substantial economic burden: the total healthcare expenditure for diabetes worldwide was estimated to reach 850 billion United States dollar (USD) for those aged 18 to 99 years in 2017.[1]

Individuals with diabetes often develop diabetes-related short-term complications such as diabetic ketoacidosis and hyperosmolar hyperglycemic state, and long-term complications such as kidney failure, non-traumatic limb amputation, and heart attack.[2] These complications can lead to diabetes-related hospitalizations and premature death.[2,4] In Canada, hospitalization costs is the leading source of direct health care costs for diabetes.[2] Appropriate treatment and management of diabetes at primary care can potentially reduce the risk of hospitalizations, and mortality.[5–7] At the primary care level, the family physician (FP) can: monitor the disease, order necessary tests, prescribe appropriate medications to prevent acute complications, refer the patient to appropriate specialists to deal with the diabetes-related complications, and offer advice regarding lifestyle modifications.[8,9] Therefore, diabetes is considered an ambulatory care sensitive condition (ACSC).[5,10–12] An ACSC is a condition in which hospitalizations for that condition can be avoided with adequate access to effective primary care.[5,9,10,13]

There are several ways effective diabetes management at the primary care setting can potentially reduce hospitalizations and associated hospital costs. First, better diabetes management at primary care settings can reduce the likelihood of being admitted to the hospital and/or emergency admissions.[8,9,14] Second, better disease management can potentially result in healthier patients. Therefore, if they do get admitted, then they are more likely to have fewer complications, and a shorter length of stay which can lower the hospital costs.[8] Third, in the event of a hospitalization, family practices that focus on better disease management will likely provide follow-up care following the hospital discharge.[8] Therefore, this may reduce the risk of readmissions and associated hospital costs. In a similar manner, primary care also plays an important role in reducing patient's risk of mortality from chronic conditions. This is often due to the interventions provided at the early stages of the disease.[7] With effective primary care, diseases can be diagnosed early, and risk factors can be identified and potentially modified in some instances.[15–17] Effective management of diabetes in primary care can reduce the risk of mortality in patients from causes such as stroke, ischemic heart disease, and chronic kidney disease.[15]

To improve chronic disease management at primary care and patient outcomes, many countries around the world introduced financial incentives such as the pay-for-performance (P4P) incentive schemes. These incentives reward FPs for the achievement of quality-of-care processes (e.g. periodic glycated hemoglobin [HbA1C] testing for diabetic patients, completing recommended laboratory tests, and etc.), and some for obtaining improved intermediate outcomes (e.g. cholesterol control in diabetic patients).[18,19] A number of studies that examined the relationship between P4P incentives for diabetes and diabetes-related services, or the quality of care provided to patients had observed a positive relationship.[14,19–21] However, some studies have also found the effect of these incentives to decline over time[20,22], or have no effect on the provision of diabetes-related services.[23,24]

It is also important to assess if these incentives led to improvements in patient outcomes (i.e. hospitalizations, mortality), and hospitalization costs for diabetes. Existing systematic reviews in this research area have mostly focused on the impact of P4P incentives for disease management on quality of care or on intermediate outcomes.[25–28] A

few reviews included papers that assessed the effect of these incentives on patient outcomes or costs[10,29–31], however, they either solely focused on one P4P scheme (the Quality and Outcomes Framework (QOF) from the United Kingdom (UK)), or assessed all types of P4P incentives. There was a lack of reviews that focused exclusively on P4P incentives for diabetes care and hospitalizations, hospitalization costs, and mortality. Therefore, the purpose of this literature review is to examine the impact of financial incentives for diabetes care on diabetes-related hospitalizations, diabetes-related hospitalization costs, and mortality. This review paper includes articles on hospitalization for ACSCs (includes both type 1 and type 2 diabetes) as part of the diabetes-related hospitalization and associated cost measures.

2.2 Methods

This literature review focuses on two issues: (i) the effect of financial incentives for diabetes care on diabetes-related hospitalizations and associated costs, and (ii) the effect of financial incentives for diabetes care on mortality. A literature search was performed to identify relevant published studies that examined (i), and (ii).

2.2.1 Search Strategy and Study Selection

A search strategy was used to identify related published studies on the relationship between financial incentives for diabetes care and (i) diabetes-related hospitalizations or diabetes-related hospitalization costs and (ii) mortality. Four research databases were used to conduct the search: MEDLINE using the Ovid interface, EMBASE, Scopus, and Web of Science. Specific keywords, and subject headings were used to identify a list of articles related to the research area of interest. First, the research topic was divided into four broad concepts, and then keywords and subject headings that addressed each concept were identified and used. The four broad concepts and a keyword used from each concept in the search are presented: avoidable hospitalizations (e.g. ‘avoidable hospital*’), diabetes management (e.g. ‘diabetes care’), primary care settings (e.g. ‘family physician*’), and financial incentive (e.g. ‘primary care incentive’, ‘pay-for-performance*’). The second part of the search (ii) which looked at mortality was performed using the same keywords except replacing the keywords that covered the

hospitalizations concept with the keywords for mortality (e.g. 'mortality*'). Following this, the keywords were combined together using AND/OR to enter a final search statement for parts (i) and (ii) separately into the database. An example of the search performed in the MEDLINE-Ovid database is presented in Appendix A2.1 (Table 2.1 for part (i) and Table 2.2 for part (ii)). Reference lists of studies based on the inclusion and exclusion criteria were subsequently searched to identify any additional articles. The final search was performed on November 2017.

Articles identified from the literature search were screened by title and abstract to identify relevant papers for the current review based on an inclusion and exclusion criteria (indicated below). Following this, the remaining articles were full-text reviewed for an in-depth screening. All articles were screened and reviewed independently by one reviewer. The inclusion criteria were: studies that focused on financial incentives that were provided to FPs or primary care physicians or general practitioners for diabetes management with an outcome measure for part (i) of diabetes-related hospitalizations, avoidable hospitalizations, hospitalizations for ACSCs, or hospitalization costs, and for (ii) mortality, mortality risk, mortality rate, or mortality score; and studies must be published in English language. Published reviews that met the above criteria were also included. Studies were excluded if they were: not related to the research topic (i.e. exposure measure of the study was not related to the financial incentives for diabetes care, and/or the outcome variable did not measure hospitalizations or hospitalization costs or mortality as indicated in the inclusion criteria), duplicate articles, and lastly relevant but not primary research articles or systematic reviews (e.g. editorials, commentaries).

Data were extracted from the final set of studies that were included in this review. The information abstracted were the author and year of publication, the exposure measure(s) or financial incentives assessed, the country or region of study, the outcome(s) measured, study design, study population, confounders controlled for (if any), statistical analysis techniques used, main study findings, and the strengths and/or limitations.

2.3 Results

2.3.1 Main Search Results

The literature search on the relationship between financial incentives for diabetes care and diabetes-related hospitalizations and hospitalization costs identified 430 articles. After screening the articles by title and abstract and removing duplicates, there were 19 relevant articles left, however, the full-text screening led to 16 articles. Following this, reference tracking was conducted on the remaining papers, and four additional articles were found. Finally, 20 articles were included for data extraction (Figure 2.1). From the 20 articles, 14 articles assessed the relationship between financial incentives for diabetes care and diabetes-related hospitalizations; five articles assessed the relationship of the incentives on both hospitalizations and associated costs; and one article looked at hospitalization costs. Details of the studies can be found in Appendix A2.2 (Table 2.3).

There were variations in the financial incentives for diabetes care that were studied in the literature. These incentives differed based on their design and context, however, a large number of studies focused on the P4P program implemented in the UK called the QOF which covered a number of chronic diseases including diabetes[18], and the Taiwan's P4P program that also covered diabetes.[14] Both P4P programs were implemented at a large-scale national-level, with the UK's QOF implemented in all practices in all four countries of the UK when it was first introduced. In addition, the studies were conducted in a number of countries that included Italy $(n = 3)$[11,13,32], Canada $(n = 1)$[9], Taiwan $(n = 7)$[14,20,22,33–36], UK $(n = 5)$[5,8,18,31,37], and United States (US) $(n = 3)$.[19,23,38] It is also worth to mention that these articles did not have the same outcome measure. Some of the hospitalization or hospitalization cost outcome measures were avoidable hospitalizations, hospitalizations for ACSCs, hospitalization for diabetic ACSCs, hospitalizations for diabetes-related complications, and hospitalization for all-causes. A few studies looked at emergency hospital admissions. However, all studies did include hospitalizations or emergency admissions that were due to diabetes.

The literature search on the relationship between financial incentives for diabetes care and mortality identified 421 articles. After the abstract-title screening and removing

duplicates, nine articles were left. Finally, the full-text screening led to only including seven articles, and no additional articles were included after reference tracking (Figure 2.2). The details of the articles included can be found in Appendix A2.2 (Table 2.4). The articles here either focused on the QOF P4P program or the Taiwan's P4P program for diabetes. Therefore, the studies were only conducted in the UK ($n = 5$)[15,31,39–41] and in Taiwan ($n = 2$).[33,42] There were variations to how mortality was measured with some measuring all-cause mortality, cause-specific mortality (includes diabetes), mortality reduction per 100,000 individuals or where one study[41] used a score to measure mortality reduction.

2.3.2 The Relationship between Financial Incentives for Diabetes Care and Diabetes-related Hospitalizations and Diabetes-related Hospitalization Costs

Diabetes-related hospitalizations. There were nineteen articles that evaluated the relationship between financial incentives for diabetes care and diabetes-related hospitalizations. These studies assessed this relationship using a variety of study designs, including comparing patients enrolled to a P4P program by their FPs who participated in the financial incentive scheme to a comparison patient group, and comparing the outcomes before and after the incentive was introduced. A number of studies found that P4P incentives for diabetes care led to a reduction in diabetes-related hospitalizations.[5,10,11,13,14,18–20,22,31–34,36,37] Four of those studies were performed in the UK assessing the QOF incentive scheme.[5,18,31,37] Dusheiko *et al*. (2011)[5] investigated cross-sectional and longitudinal associations between the quality of diabetes management and unplanned emergency hospital admissions due to short-term diabetes complications in England following the introduction of QOF. They found that the proportion of diabetic patients who achieved good glycemic control increased from 51.4% to 59.3% during the study period.[5] Cross-sectional findings revealed that a higher proportion of patients with good or moderate glycemic control was significantly associated with a decreased rate of unplanned emergency admissions for all short-term diabetic complications ($p < 0.01$), and for acute ($p < 0.01$) and nonspecific hyperglycemic complications ($p < 0.01$).[5] Similar findings were observed longitudinally. One limitation of this study was that, the

authors did not have data for certain quality measures prior to QOF; therefore, the authors were unable to assess the direct impact of QOF on emergency admissions.[5]

In Taiwan, six studies found P4P to be associated with reduced diabetes-related hospitalizations.[14,20,22,33,34,36] One cross-sectional study that compared patients with diabetes enrolled in the P4P program (intervention group) to those who were never enrolled to P4P (comparison group), found that the net effect of the P4P program was a decrease in admissions by 2.7 admissions per 100 enrolled patients per year ($p = 0.003$).[14] Cheng *et al*. (2012)[20] also had an intervention and comparison group, but instead used longitudinal data. They found that the net effect of the P4P program was fewer hospitalizations (Difference-in-difference (DID) Coefficient: -0.01). In addition, they observed the effect to be larger when comparing patients who were continuously enrolled in the program throughout the study period to their respective comparison group.[20] This study used propensity score matching to alleviate potential selection bias based on observables; however, unmeasured factors could have affected the study findings. In Hawaii, one study[19] found no significant difference in the all-cause hospitalization rates between diabetic patients who visited a P4P-participating physician and those who visited a non-P4P-participating physician during one year.[19] In contrast, patients who saw a P4P-participating physician for three consecutive years were significantly less likely to be hospitalized compared to their non-participating counterparts (Incident Rate Ratio [IRR]: 0.75; 95% confidence interval [CI]: 0.61 to 0.93; $p < 0.01$).[19]

In the Emilia Romagna region of Italy, there were three forms of incentive mechanisms implemented to improve care for patients with chronic diseases: P4P program, Pay-for-Participation (P4Pa), and Pay-for-Compliance (P4C). In the P4P program, FPs are paid based on their achievement of specific targets; in the P4Pa FPs are paid based on the number of patients with specific chronic conditions under their care; and in the P4C scheme, FPs are paid based on the number of collaborative activities they participated in (e.g. attended diabetes audit meetings).[11,13] In addition to these incentives, there was also a lower-powered incentive scheme introduced in 2003 in the same region named the Diabetes Management Program. FPs can receive the associated incentives that came with enrolling into this program if they complete the required activities. FPs were

compensated for delivering care to diabetic patients, and for coordinating with the local Healthcare Districts and secondary care facilities.[32] Three articles[11,13,32] and one review paper[10] found some of the financial incentives in Italy to have a statistically significant negative effect on diabetes-related hospitalizations. A study by Fiorentini *et al*. (2011)[11] revealed that only P4P (Coefficient (logit scale): -0.02; $p \leq 0.05$) and P4C (Coefficient (logit scale): -0.04; $p \leq 0.10$) programs influenced the probability of inappropriate hospitalizations (defined as hospitalizations for 27 medical diagnostic-related groups that were identified by the Emilia-Romagna region as at risk of inappropriateness in primary care).[11] In contrast, P4Pa had a significant effect only when the authors separately analysed the impact of this incentive on admissions due to acute diabetes complications (comas) in a subpopulation of type 2 diabetic patients. The authors rationalized that P4Pa was linked with management of specific chronic conditions (e.g. diabetes), therefore, the program's effects will likely be loosely measured in the general population.

In contrast, a few studies found financial incentives to have no effect on diabetes-related hospitalizations[9,13,23,37,38], while one study found an increase in emergency visits.[35] One study that observed a non-significant finding was a study from Italy.[13] This study found that from the two forms of incentives (P4Pa and P4C), P4C received by FPs for diabetes care did not have a significant effect on the probability of hyperglycemic emergency admissions for diabetic patients (Coefficient (logit scale) = -0.04).[13] Similarly, two studies from the US also observed financial incentives to have no effect on hospitalizations.[23,38] In contrast, one study that assessed the diabetic P4P program in Taiwan found that, emergency visits due to diabetic hypoglycemia was significantly higher after P4P implementation in patients enrolled into P4P compared to before.[35]

Two of the studies that were included in this review used an ecological study design to assess the impact of the incentives on diabetes-related hospitalizations.[9,37] One of the studies was by Bottle *et al*. (2008)[37] from England. The authors found that in patients aged 59 years and younger, there was a statistically non-significant association between quality of care scores for diabetes care from the QOF P4P scheme (total points awarded to family practices based on their achievement on specific indicators that are part of the QOF [e.g. points given based on proportion of diabetic patients with blood pressure ≤

145/85 mmHg]) and hospital admissions for diabetes.[37] However, they found a negative association between the QOF quality of care scores for diabetes care and hospital admissions in patients 60 years and older. An important note is that this study did not directly assess the impact of QOF on hospital admissions for diabetes, but assessed quality of primary care using QOF data on hospital admissions. The other study was conducted in Canada, which examined whether the policy changes at primary care in 2003 improved the rate of diabetes-related hospitalizations in two provinces of Canada: British Columbia (BC) and Alberta.[9] Financial incentives for diabetes management were introduced to FPs in BC only in 2003. Findings from the study revealed that the post-2003 period had no effect on the hospitalization rate in both provinces.[9]

Diabetes-related hospitalization costs. Six studies evaluated the relationship between financial incentives for diabetes care and diabetes-related hospitalization costs. Three of these studies were conducted in Taiwan,[14,20,36] of which two were longitudinal[20,36] and one was cross-sectional.[14] All three studies found that the P4P program was associated with lower hospitalization costs in diabetic patients. A longitudinal study by Cheng *et al*. (2012)[20], however, found that lower expenses for diabetes-related hospitalizations was evident only when patients who continuously stayed in the P4P program throughout the study period were compared to their respective comparison group of patients who were never enrolled. Over time, the net difference increased from -3,106 New Taiwan (NT) dollars in 2006 (approximately -$111 Canadian dollars [CAD] in 2006) to -5,099 NT dollars in 2009 (approximately -$167 CAD in 2009) per patient ($p < 0.001$).[20] The remaining three studies were conducted in the UK.[5,8,18] Two of the studies that examined the impact on hospital costs were performed after the QOF was introduced in the UK in 2004.[5,18] One study that used QOF data reported that on average in 2006/07, a family practice that had 5% more patients with moderate glycemic control over poor glycemic control would have reduced the hospital costs for short-term diabetes complications by an estimated £771 ($1,204 CAD).[5] The other study found that during the 2010/11 financial year, the estimated reduction in admissions for incentivized ACSCs due to the QOF introduction was 8%.[18] This was equivalent to a reduction of 53,000 emergency admissions in England, thus resulting an estimated annual cost saving of £92.5m ($147 m CAD).[18] It is important to note that the findings on hospitalization costs from the two

studies were estimated reduction in costs rather than an analysis on the impact of P4P on hospitalization costs. In contrast, the third UK study investigated the relationship between the quality of disease management at primary care for ten chronic diseases (e.g. diabetes) using QOF data and hospital costs, and found a statistically significant reduction in hospital costs only for stroke care.[8]

2.3.3 The Relationship between Financial Incentives for Diabetes Care and Mortality

Seven studies investigated the relationship between financial incentives for diabetes care and mortality. The findings from these studies were inconsistent as three studies reported a reduction in mortality[33,39,42] while four studies found no effect.[15,31,40,41] Two of the three studies that reported a reduction in mortality were from Taiwan.[33,42] For example, Lin *et al.* (2016)[33] found that the risk of all-cause mortality was lower in type 2 diabetic patients in the full P4P participation group compared to their control group (Hazard Ratio [HR]: 0.41; 95% CI: 0.74 to 0.84); also in the partial participation group compared to their corresponding control group (HR: 0.77; 95% CI: 0.74 to 0.81).[33] The full P4P participation group were patients with a full enrollment to the program and had complete annual evaluation records that included a management plan, examinations, biochemical tests, and the patient's medical history. The partial participation group had at least one physician's claim data in the program, and either did not have complete annual evaluation records or the physician's claims were discontinued during the study's follow-up period.[33] Although patient and physician characteristics were controlled for in this study, other unmeasured factors such as patient's education could have affected this association. In the UK, one study found that based on the 2004 QOF contract, as the primary care performance (for chronic diseases including diabetes) improved from pre-contract (2003) to achievement of target levels for full incentive payment, additional 11 lives were estimated to be saved per 100,000 population per annum (lower-upper estimates: 7-16).[39] However, between 2005 and 2006, the additional mortality reduction dropped to zero.[39] Additionally, the authors found that if all eligible patients were treated over and above the set target levels for full incentive payment, then for the 2004 QOF contract an additional 56 lives (lower-upper estimates: 29-81) per 100,000 population per

annum would have been saved.[39] Disease areas with the largest estimated mortality reductions were heart disease, diabetes, and primary hypertension.[39] A major limitation in this study was that it was difficult to state that the improvement in performance seen in FPs was solely due to the QOF.[39]

Several studies found that financial incentives have no effect on mortality based on the evaluation of QOF in the UK.[15,31,40,41] One study found that there was a weak correlation between the clinical QOF point score and the Public Health Impact score.[41] In the QOF, family practises were awarded points based on the proportion of patients who achieved specific targets for the QOF clinical indicators. These points are later converted into payments.[18] The clinical QOF point scores measured the family practice's level of achievement for those clinical indicators.[41] The Public Health Impact score measured the estimated mortality reduction per 100,000 registered patients per annum.[41] The authors concluded that the financial awards from the QOF are not directly aligned with mortality reduction for preventable chronic diseases in family practices.[41] Likewise, a systematic review that examined if the QOF improved care and outcomes for patients with long-term conditions found no clear effect on mortality.[31]

Two other studies that found no effect differed from the above studies as an ecological study design was used to assess the relationship. Ryan *et al.* (2016)[15] used country-level data comparing UK to other high-income countries, and found QOF was not significantly associated with age, and sex-adjusted population mortality for chronic diseases covered by the QOF including diabetes (-3.68 per 100,000 population; 95% CI: -8.16 to 0.80).[15] The second study, Kontopantelis *et al*. (2015)[40], used data collected at the lowest available geographic level named the "lower layer super output area", found no statistically significant relationship between primary care practice's performance on QOF indicators, and all-cause or cause-specific mortality rates for six chronic conditions including diabetes after controlling for area and population-level characteristics.[40] In other words, the primary care performance incentivized by the QOF scheme did not seem to reduce mortality in the population. Overall, specific limitations in some of these studies such as the use of an ecological study design and/or presence of unmeasured confounders may have led to the contradictory findings.

2.4 Discussion and Conclusions

The purpose of this review was to identify relevant literature and understand the relationship between financial incentives for diabetes care and diabetes-related hospitalizations, diabetes-related hospitalization costs, and mortality. This literature review identified 20 articles on the association between financial incentives for diabetes care and diabetes-related hospitalizations or hospitalization costs, and seven articles on the relationship between financial incentives for diabetes care and mortality. Studies identified were from several countries including Canada, UK, US, Italy, and Taiwan. To date, the literature assessing the effectiveness of these incentives in reducing diabetes-related hospitalizations have produced conflicting results. The majority of the papers found that the incentives were associated with reduced diabetes-related hospitalizations, however, a few articles observed no effect, while one found an increase in diabetes-related emergency visits. The potential reason behind the increase in the diabetes-related emergency visits in this study could be due to, the Taiwan P4P program's aim to have the patient's HbA1C < 7%, and this intensive glycemic control plan can increase the risk of emergency visits for hypoglycemia.[35] As for the effects of financial incentives for diabetes care on hospitalization costs and mortality, mixed findings were also documented.

There are a couple of potential explanations as to why such discrepancies were found in the literature. First, the differences could be due to the institutional context and design of the financial incentives. This review included studies that evaluated a number of diverse incentives, with the QOF being the largest P4P program.[30,31] The QOF, introduced in April 2004, pays up to 25% of the FP's income, and their payment under QOF was linked to their performance on more than 100 clinical and organisational quality indicators including for diabetes.[18] The diabetes-related indicators that are included in this scheme covers process of care measures (e.g. record of foot examination) and intermediate outcomes (e.g. control of HbA1C levels, cholesterol, blood pressure).[5,43] For the clinical indicators, family practices earned points based on their level of achievement for each clinical indicator, and then these points are converted to payments for each family practice after adjusting for list size and disease prevalence.[18] During the first year, the

incentives for an indicator ranged from £75 (approximately $179 CAD in 2004) to £4,200 ($10,014 CAD in 2004) for an average practice. By the second year the incentives increased by 68%.[18] In contrast, smaller incentives were introduced in some areas such as in BC in 2003 where FPs received $75 (increased to $125 later) per year per patient for providing disease management for diabetes patients and following British Columbia's Clinical Practice Guidelines.[44,45] Therefore, these differences may have affected the patient outcomes and hospitalization costs differently. Second, the differences in the study design or setting may also contribute to the different conclusions. Some studies included in this review were cross-sectional; thus, it is difficult to infer a temporal relationship between financial incentives for diabetes care and the outcomes. Some of these cross-sectional studies found the incentives to have an association with the outcomes, while in some longitudinal studies such associations disappeared. Differences in the setting of the study also plays a role as the health care systems, policy initiatives already introduced, and policy or system changes that simultaneously occurred in the country during the study conduction differs in each setting and can affect the results. Additionally, some of the studies adopted an ecological perspective such as Kontopantelis *et al*. (2015)[40] and Laberge & Pefoya (2016)[9]. Findings from these ecological studies may not be applicable to individual-level outcomes. Lastly, the discrepancies in the literature may have also been due to the specific limitations found in some of the individual studies included in this review such as unmeasured confounding, selection bias, and smaller sample size.

Although some of the individual studies had its own limitations (e.g. unmeasured confounding); several of the included studies still had their own strengths such as assessing the relationships using longitudinal data, having before-and-after comparisons, or having a valid comparison group. A number of studies that assessed Taiwan's P4P program for diabetes did have all three strengths. However, selection bias was an issue, since in Taiwan, FPs voluntarily participated in the P4P program and patients enrolled to the program were selected by their physicians.[14,20,34] To alleviate this bias, some studies used propensity score matching to make the intervention and comparison groups comparable in terms of the observable characteristics. Other studies outside of Taiwan such as the one by Harrison *et al*. (2014)[18] in England compared the outcomes before and

after the financial incentives were introduced to assess if the incentives resulted any changes. Harrison *et al.* (2014)[18] also adjusted for the underlying trends in the admission rates to get a conservative estimate of the QOF's impact.

Similar to this literature review, existing systematic reviews regarding P4P incentives in general have also observed conflicting findings.[29,30,46] For instance, Mendelson *et al*. (2017)[30] reported that a number of studies found positive outcomes associated with P4P, but inconsistent findings were also present, and it was difficult to confidently indicate that the changes in the outcomes were solely due to P4P. Gillam *et al.* (2012)[29] also indicated the presence of conflicting findings in the literature, and reported that some modest reductions in hospital admissions and mortality were found. In contrast, one systematic review which focused on the QOF found that the P4P program did slow down the increase in emergency admissions, however, there was no effect on mortality.[31] Another systematic review, Gibson *et al*. (2013)[10], which included one paper on financial incentives for diabetes care, also found that the incentives was associated with fewer diabetes-related hospitalizations.[10] Although the current review observed inconsistent findings similar to previous systematic reviews, the findings from this review provides knowledge on the relationship between P4P incentives for diabetes care and patient outcomes and hospitalization costs exclusively. This differs from existing reviews which either focused on the QOF P4P scheme alone, or had reviewed all types of P4P incentives together (e.g. including cancer screening, smoking cessation).

As for the policy implications, the effect of financial incentives for diabetes care on patient outcomes and hospitalization costs is unclear in the existing literature. There is no strong evidence that consistently shows these incentives to improve patient outcomes (hospitalizations and mortality) and diabetes-related hospitalization costs. The diverse designs of the incentives and the setting of the studies play a large role for this. It can also be that physician financial incentives alone cannot produce the desired improvements, and combining these incentives with other methods may promote better long-term health to patients. In addition, some of these incentives may be unintentionally disadvantageous to certain patients. For instance, in Taiwan, patients with more comorbidities or severe conditions were less likely to be enrolled into the P4P program.[47,48] Therefore, this group

of patients may be less likely to receive adequate diabetes care or management compared to other patients, as the FPs may not focus on them as much as those in the P4P program. Similarly, in the UK, there is exception reporting within the QOF. Exception reporting is when certain patients are excluded for specific or all incentivized targets from the QOF, if the physician judges it to be inappropriate for the patient based on a set criteria agreed for exception reporting.[39,49,50] Practices will not be penalized financially for missing targets for these patients, as they will not be included when calculating the proportion of patients who achieved the target level for the specific QOF indicator.[39,49,50] However, it has been reported that exception reporting is increasingly found in patients with multiple chronic health problems, individuals with mental illnesses, and those living in deprived areas.[49–51] Since these patients are being missed from the P4P incentives, it is possible that the true effect of these incentives in improving patient outcomes and costs are ambiguous.

There are some strengths of this literature review. First, to the best of our knowledge, this is the first literature review that assessed the impact of financial incentives for diabetes care on diabetes-related hospitalizations, hospitalization costs, and mortality. Existing systematic reviews had either focused only on the QOF, or summarized findings from P4P incentives in general rather than diabetes specific. Second, studies conducted in a wide range of countries were included in this review to be more informed on the use and impact of these incentives around the world.

This literature review also had a couple of limitations. The main limitation of this review was that the evidence mostly came from observational studies; no randomized trials were available to be included in this review. Therefore, it is difficult to infer if the outcomes observed were due to the P4P incentives or not. Furthermore, the evidence was affected by the limitations found in the specific individual studies included in this review, and the heterogeneity in the study population, study design, study setting, nature of financial incentives examined, and the outcomes measured. Although, it was advantageous to include studies from a diverse range of countries, findings from such studies cannot be easily generalized to the Canadian context. Moreover, some of the studies included from the UK did not directly measure the impact of the P4P scheme on diabetes-related

hospitalizations, hospitalization costs, and mortality. These studies used QOF data to evaluate quality of diabetes management in primary care on patient outcomes or hospitalization costs, and were conducted after the QOF scheme was introduced. However, these studies did provide some knowledge on the effect of the QOF's indicators and/or scores on patient outcomes and hospitalization costs. Another limitation was that the articles were screened and reviewed by one reviewer, and this may have impacted the selection and assessment of the studies in this review. Lastly, findings from this review may not be informative to policy makers due to the lack of consistency of financial incentives linked to improved patient health outcomes.

Based on the available evidence from observational studies and systematic reviews, the relationship between financial incentives for diabetes care and diabetes-related hospitalizations, diabetes-related hospitalization costs, and mortality is unclear. Existing literature on this topic has produced conflicting findings. In addition, there is a lack of literature on the impact of financial incentives for diabetes care on hospitalizations costs and mortality, with most of the existing studies performed in the UK and Taiwan. Therefore, future research should assess the above relationship in other countries over the long-term to potentially get a better understanding of the impact of these incentives. Moreover, it is also important to determine ways to revise the existing incentives so that improvements in the patient outcomes can be observed in the future.

2.5 Figures

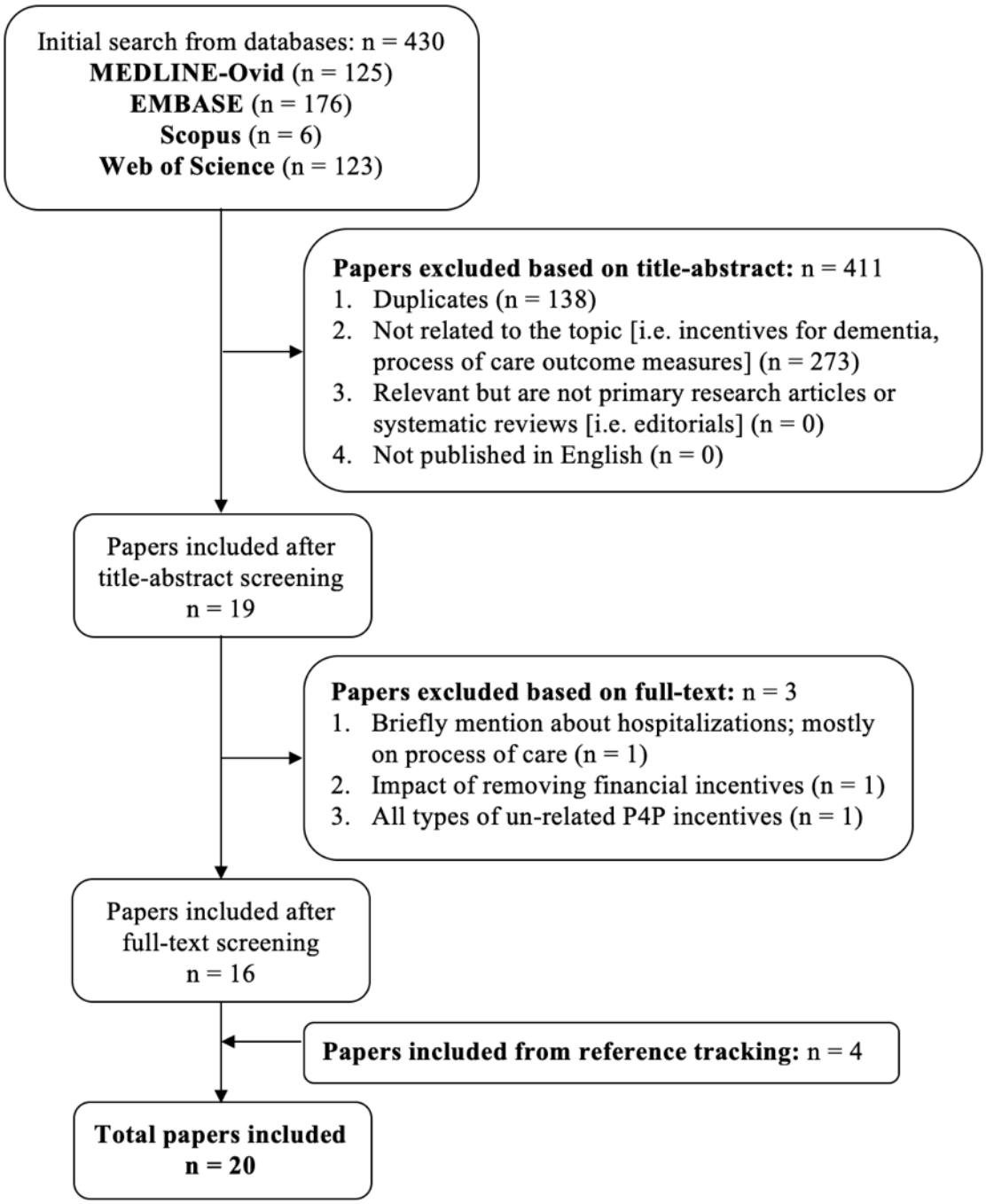

Figure 2.1: The literature search screening for the relationship between financial incentives for diabetes care and diabetes-related hospitalizations and hospitalization costs

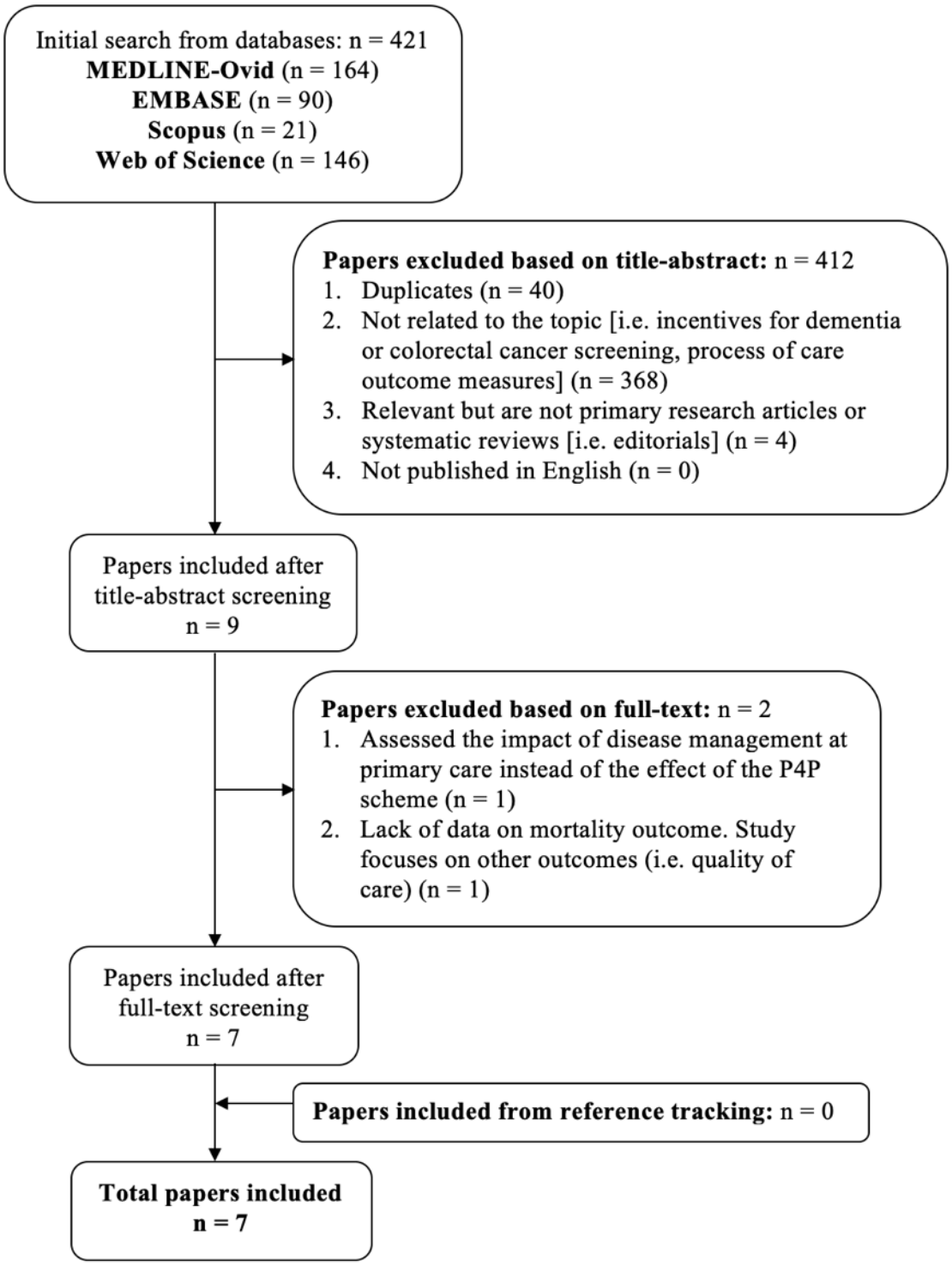

Figure 2.2: The literature search screening for the relationship between financial incentives for diabetes care and mortality

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Appendices

Appendix A2.1: Literature Search Tables

Table 2.1: Literature search performed in MEDLINE-Ovid for the diabetes-related hospitalizations, and hospitalization costs

#	Searches	Results
1	avoidable hospital* OR preventable hospital* OR unplanned hospital* OR ambulatory care sensitive*	1941
	-Final search statement for the concept "avoidable hospitalization"	
2	primary health care/ OR "continuity of patient care"/	86064
3	General Practitioners/	6245
4	physicians, family/ OR physicians, primary care/	18957
5	general practice/ OR family practice/	73998
6	Physician Incentive Plans/	2192
7	Fee-for-Service Plans/	3302
8	Family Doctor* OR Family Physician* OR Family Practice OR General Practice OR Primary medical care OR Primary health care delivery OR Primary health care OR Primary healthcare OR Family medicine or General practi* OR Primary care physician* OR Primary care	259508
9	Primary care incentive OR Financial incentive* OR Financial Awards OR Fee for service OR pay for performance* OR pay-for-performance* OR pay-for-performance incentive*	12131
10	2 OR 3 OR 4 OR 5 OR 8	277604
	-Final search statement for the concept "primary care settings"	
11	6 OR 7 OR 9	13666
	-Final search statement for the concept "financial incentive"	
12	diabetes management OR diabetes care	10354
	-Final search statement for the concept "diabetes management"	
13	1 OR 12	12278
	-Search statement to find results related to diabetes care or hospitalizations	
14	10 AND 11 AND 13	125
	-Final search statement for the entire search on Ovid	

-Comments added describing the specific sections of the search are italicized

* Truncations used to broaden the search

Table 2.2: Literature search performed in MEDLINE-Ovid for mortality

#	Searches	Results
1	primary health care/ OR "continuity of patient care"/	86097
2	General Practitioners/	6248
3	physicians, family/ OR physicians, primary care/	18965
4	general practice/ OR family practice/	74010
5	Physician Incentive Plans/	2192
6	Fee-for-Service Plans/	3307
7	Family Doctor* OR Family Physician* OR Family Practice OR General Practice OR Primary medical care OR Primary health care delivery OR Primary health care OR Primary healthcare OR Family medicine or General practi* OR Primary care physician* OR Primary care	259611
8	Primary care incentive OR Financial incentive* OR Financial Awards OR Fee for service OR pay for performance* OR pay-for-performance* OR pay-for-performance incentive*	12145
9	1 or 2 or 3 or 4 or 7	277706
	-Final search statement for the concept "primary care settings"	
10	5 or 6 or 8	13680
	-Final search statement for the concept "financial incentive"	
11	diabetes management OR diabetes care	10359
	-Final search statement for the concept "diabetes management"	
12	Mortality/	41662
13	Death/	16984
14	mortality* OR death* OR risk of mortality OR risk of death	1372862
15	12 OR 13 OR 14	1372862
	-Final search statement for the concept "mortality"	
16	11 OR 15	1382541
	-Search statement to find results related to diabetes care or mortality	
17	9 AND 10 AND 16	164
	-Final search statement for the entire search on Ovid	

-Comments added describing the specific sections of the search are italicized

* Truncations used to broaden the search

Appendix A2.2: Literature Review Tables

Table 2.3: Summary of papers that assessed the relationship between financial incentives for diabetes care and diabetes-related hospitalizations and hospitalization costs

Author & Year	Exposure Variable(s)	Outcome Variable(s)	Methods	Study Findings	Strengths/ Limitations
Bottle *et al.* (2008)	• Quality of primary care using QOF (P4P) scores in England	• Hospital admissions for diabetes (i.e. total diabetes admission rate and ketoacidosis admission rate)	• Cross-sectional and ecological • QOF data – April 2004 to March 2005 • **Population:** Individual with diabetes registered in family practices • **Confounders/Covariates:** neighbourhood SES, prevalence of diabetes, QOF scores, age- and sex-adjusted admissions rate • **Analysis:** Analysis at primary care trust level, calculated *directly standardized rates* for each primary care trust, standardized admission ratios, regression for total and ketoacidosis admissions	• Weak, but significant negative association between total QOF scores for glycemic control and hospital admissions for ages 60 and over (both total and ketoacidosis) • Non-significant associations for patients younger than 60. • Neighborhood SES had a strong association with hospital admissions.	• Large study • Cross-sectional • No patient-level data
Bruni *et al.* (2009)	• P4Pa and P4C incentives in Emilia-Romagna region of Italy	• Hyperglycaemic admissions linked with ketoacidosis and hyperosmolar nonketotic coma	• Cross-sectional study • **Population:** Type 2 diabetics above the age of 35 • **Confounders:** Patient-physician-, and district level confounders • **Analyses:** Multilevel logit	• Significant association between outcome and one set of incentives received for diabetes care • Larger share of diabetes-related payment is associated with lower probability of	• Adjusted for GP, patient, and district level factors • Multilevel modelling • Cross-sectional

			model with 3 hierarchal level (patient, GP, district), uses IGLS algorithm with 1st order marginal quasi likelihood procedure	hyperglycaemic emergency admissions • P4Pa coefficient is significant while P4C coefficient is not	data • Patient comorbidity not controlled for
Chen *et al.* (2010)	• P4P status (P4P participating vs. non-P4P-participating physician) in Hawaii • Receipt of QOC (Yes vs. No)	• Receipt of QOC for 1 year (Patients who had claims for at least 2 A1C tests and 1 LDL cholesterol test) • Hospitalization rates (all-causes)	• Longitudinal (January 1, 1999 to December 31, 2006) • **Population:** Diabetes patients aged between 18 to 75 who saw P4P or non-P4P physicians • **Confounders:** Age, sex, comorbidity index, number of PCPs seen, visit to an endocrinologist, insulin dependence, year • **Analysis:** Univariate analyses, multivariate models, random-effects logit model, random-effects negative binomial models.	• Patients with P4P physician were significantly more likely to receive QOC • Patients who received QOC were significantly less likely to be hospitalized • During one year, there was no significant difference in hospitalization rates for patients who consulted P4P-physicans compared to those who did not consult them • Patients who consulted P4P physician for 3 consecutive years were significantly less likely to be hospitalized	• Longitudinal study • Attempted to control for confounding • Another DM program introduced shortly after P4P • Did not compare trends for pre- vs. post-P4P
Chen *et al.* (2016a)	• Patient enrollment into P4P for diabetes care in Taiwan • Time dummy variables • Interaction terms of the two	• Number of essential exams/tests patients received • COC index • Hospitalization for diabetes-related conditions	• Natural experiment and longitudinal study design • **Population**: Type 2 diabetes patients age 18 years and older (MCC vs. non-MCC patients) • **Intervention:** patients enrolled into P4P in 2005; **Comparison:** patients never enrolled into P4P • **Confounders:** Patient, and provider characteristics • **Analysis:** DID, GEE models, logarithmic and logit link functions	• P4P led to increase in number of exams, improved COC between patients and physicians, & significant reduction in the likelihood of having a hospital admission, and ED visit • Similar findings for MCC vs. non-MCC • Effects reduced after second year of P4P	• Attempted to control for confounding • Longitudinal study • Not generalizable due to unique healthcare system

Cheng *et al.* (2012)	• P4P program for diabetes care in Taiwan	• Number of essential exams/tests, health care use (i.e. diabetes-related hospitalizations; physician visits), health care expenses (i.e. diabetes-related hospitalizations, physician visits)	• Natural experiment and longitudinal design • 2004 to 2009 – 6-year data • **Population:** Diabetes patients over the age of 18 • **Intervention group:** Patients enrolled in P4P in 2005; **Comparison:** Patients from same physicians but not enrolled in P4P • All participants matched set and consecutive participants matched set • **Confounders:** Patient's sex, age, DCSI score, CIC count, hospital location, hospital accreditation • **Analysis:** DID method, GEE, poisson distribution, negative binomial distribution, log link function with gamma distribution, bootstrap for standard errors	• **All participants matched set:** Positive and statistical significant difference between both groups, difference decreased over time for exams. P4P had significant positive effect on visits but difference declined over time. Net effect of P4P on hospitalizations suggest fewer hospitalizations over time and marginally significant. No difference in hospitalization expenses • **Consecutive participants matched set:** Similar findings. However, magnitude of the effect on hospitalizations were larger. Lower hospital expenses reported in intervention group than the comparison group and the net difference increased over time.	• Longitudinal study • DID between intervention and comparison
Cheng *et al*. (2015)	• Trends and factors in Taiwan's healthcare system	• Healthcare use and costs of services such as physician visits, hospital admissions, antidiabetic drug prescriptions	• Repeated cross-sectional study analyzed for 2000, 2005, 2010 • **Population:** Type 2 diabetes patients aged 20 years and above matched to non-diabetes individuals; P4P vs. non-P4P • **Confounders:** Patient characteristics, time, disease severity, policy intervention, and care seeking pattern	• 2000 to 2005 total healthcare costs increased for diabetes and non-diabetes patients, but from 2005 to 2010 a greater decrease in costs for diabetes than non-diabetes • Completeness of tests and adherence to medications increased over time • P4P enrollment associated with lower risk of admissions, and total medical costs	• Comparison group • Causality cannot be inferred • Repeated cross-sectional study • No biochemical data to confirm patient's disease diagnosis

			• **Analysis:** DID, GLM with negative binomial distribution, GLM with log-link and gamma distribution, trend analyses, logistic models	• Diabetes duration, NHI registration locations, P4P program, care seeking pattern were correlated with diabetes management and costs	
Chien *et al.* (2012)	• Hudson Health plan's P4P for diabetes care in New York	• Diabetes care processes (i.e. HbA1C, blood pressure), outcomes (i.e. HbA1C <9) • Emergency department visit/admission and inpatient care for diabetes	• Two quasi experimental and one cross-sectional analyses • First Analysis: Compare between the Hudson plan and non-Hudson Medicaid plan • 2003 to 2007 data • Second Analysis: Patients continuously enrolled in P4P for 6 months or more • Third: Cross-sectional survey • **Population:** Diabetes patients from the Hudson Health plan • **Confounders:** Second Analysis: Patient characteristics • **Analysis:** (First) DID, GEE with binomial family and logistic link; (Second) interrupted-time series, logistic regression models with clustering	• No significant difference in process of care and outcome measures between two groups • Younger adults and those with comorbidities had greater odds for ED visit or hospitalization for diabetes & reduced odds of receiving recommended care	• Attempted to control for confounding • Had comparison group • Missing data issue • Not generalizable due to unique P4P

Dusheiko *et al.* (2011a)	• Quality of DM in family practises measured using QOF (P4P) clinical indicators in England	• Unplanned hospital admissions for short-term diabetic complications (i.e. due to poor short-term glycemic control, acute hyperglycemia, nonspecific hyperglycemia, and hypoglycemia)	• Cross-sectional and longitudinal analysis; ecological • QOF incentive scheme data for 2004/2005 to 2006/2007 • **Population:** Diabetic patients from English family practices • **Confounders:** low income scheme index, population (i.e. income, education) and practice characteristics • **Analysis:** Unit of analysis at family practice level, random effects multiple regression count data, fixed-effects count data multiple regression	• **Cross-sectional:** High proportion of patients with good or moderate measure of glycemic control significantly linked to lower rates for all admissions. No significant association for hypoglycemic admissions • **Longitudinal:** Increase in proportion of patients with good and moderate glycemic control was significantly associated with lower admissions especially for acute and nonspecific hyperglycemia • No significant difference between good and moderate control on admissions	• Cross-sectional and longitudinal • Controlled for practice and population covariates • No individual-level data
Dusheiko *et al.* (2011b)	• Quality of disease management for 10 diseases (i.e. diabetes) in general practice using QOF (P4P) data in England	• Hospital costs: total, emergency admissions, elective admissions, and outpatient visits	• Cross-sectional and panel data methods - 2004/5 to 2007/8 • **Population:** Patients registered in English general practice • **Confounders:** Individual, small area needs, indicators of supply variables • **Analysis:** OLS models using practice cluster and robust standard errors, other cross section and panel data models	• Only the quality measure for stroke care was statistically significant • The aggregate quality measure of weighting all 10 diseases together showed a negative significant result • 10 separate models on hospital costs showed that the quality measures for asthma, CHD, diabetes, hypothyroidism were negative and significantly associated to expenditure • Stroke care had consistent results of lowering hospital costs	• Controlled for some confounding • Uses cross-section and panel data methods

Fiorentini *et al.* (2011)	• Financial incentives in Emilia-Romagna region of Italy (i.e. P4P, P4Pa, P4C)	• Avoidable hospitalizations using two indicators: 27 medical DRGs and ACSCs	• Cross-sectional study using 2005 dataset • **Population**: Patients aged 18 and 74 years • **Confounders:** Patient-, physician-, and district level confounders • **Analysis:** Multilevel modeling, 3-level logit model, intraclass correlation coefficients	• P4Pa did not have a significant effect, but P4P and P4C affected the probability of avoidable admissions using 27 DRGs • P4Pa is only significant when conducted with a subpopulation of type 2 diabetes patients and using admissions via acute complications for diabetes as the outcome variable	• Attempted to control for confounding • Cross-sectional data • Not generalizable due to variance of incentives
Forbes *et al.* (2017)*	• UK's QOF	• Processes and outcomes of care • Includes holistic and personalised care, mortality, service use and etc.	• Systematic review • Empirical quantitative reports • Includes RCTs and longitudinal studies • Studies that controlled longitudinal trends, before-after analysis, systematic reviews • Search performed on electronic databases for studies published between 2004 to May 2016	• Three systematic reviews and five primary studies • Studies were rated as good quality • Results: Modest slowing in the increase in admissions and consultation rates, improvements in certain diabetes outcomes, no significant effect on mortality	• First review to assess these outcomes for QOF for long-term diseases • Qualitative research not included • Other factors may have confounded the relationship
Gibson *et al.* (2013)	• Primary health care resourcing (i.e. payment incentives, amount of primary health care provided)	• Diabetes-related hospitalizations	• Systematic review • Databases: EconLit, Medline, Google scholar • Published articles – 2002 to 2012 • **Confounders:** Adjusted for individual level, population health risk or community level factors	• Ten studies included • All except one showed significant association between level of primary health care resourcing and outcome • Economic incentives provided to PCPs to improve care for diabetes patients decreased the probability of hospitalization	• Adjusted certain confounders • Lack of studies looking at financial incentives

Harrison *et al.* (2014)	• Quality and Outcomes framework (QOF P4P) in the England	• Admissions for ACSCs. Compared it with non-incentivized ACSCs and non-ACSCs	• Longitudinal study – April 1 to March 31 (1998/9 to 2010/11) • **Population:** Patients registered with family practice in England • Controlled for trends in admission rates between incentivized ACSCs and the other comparison groups • **Analyses:** clustering, used inverse hyperbolic sine transformation for admission rates, used trend adjusted rates, interrupted time series for supplementary analysis	• Incentivized ACSC had a lower trend-adjusted admission rate than non-incentivized and non-ACSC. As years go by the rate difference became larger • After the introduction of QOF, admission rate for incentivized ACSC decreased at a rate of 3.6%/year • Overall, moderate & sustained reduction in emergency admissions for incentivized ACSCs	• Longitudinal study • Controlled for trends in the admission rate • Several other policy changes occurred at the same time • No control group as all family practices used incentives
Huang *et al.* (2016)	• Diabetes P4P program in Taiwan	• Number of recommended exams, rate of attending diabetes visits, and hospitalization rate due to diabetes-related ACSCs	• Longitudinal study • Follow-up between 1 to 5 years during the study period of 2003 to 2011 • Patients with MCC vs. those without • **Intervention:** Patients newly enrolled to P4P from 2004 to 2007; **Comparison:** Patients never enrolled in P4P • **Population:** Type 2 diabetic patients age 20 years and older • **Confounders:** Healthcare provider and patient characteristics • **Analysis:** DID, GEE models, poisson distribution, and sensitivity analysis was conducted	• **Non-MCC:** P4P had significant positive net effect for number of exams and number of visits. Hospitalizations increased for non-P4P but P4P had lesser admissions. • **MCC:** P4P had significant positive effect on number of exams and visits. P4P had fewer admissions through study and was significant effect. P4P's effect was stronger in MCC patients.	• Nationally representative data • Longitudinal • Results may not be generalizable due to differences in healthcare systems and P4P in Taiwan

Iezzi *et al.* (2014)	• DM program with financial incentives in Emilia-Romagna region of Italy	• Diabetic avoidable hospitalizations (i.e. diabetic ACSCs) • Admissions for short-term and long-term diabetes complications	• Longitudinal using panel data • 2003 to 2005 • **Population:** Type 2 diabetes diagnosed patients • Physician groups: never vs. always incentivized • **Confounders:** Physician level, and district level variables • **Analysis:** Poisson regression, NB model, LR test, Hausman specification test, fixed and random effect models	• Financial incentives have a negative and statistical significant effect on three dependent variables (i.e. total admissions, long-term and short-term complications) • Patients with PCPs who has higher share of income from this DM program are less likely to be admitted for diabetes-related avoidable hospitalizations	• Longitudinal study • Attempted to control for confounding • Robustness check • No pre-intervention data • Does not provide effects over the long-run
Laberge & Pefoyo (2016)	• Primary care policy changes introduced in 2003 (i.e. Financial incentives in BC, while in AL they transformed primary care and provided funding for PCNs)	• Annual age-sex standardized rate of diabetes hospitalizations per 100 patients	• Longitudinal study using ecological perspective • Used administrative health databases and physician billing claims from April 1, 1996 to March 31, 2010 • **Population:** Individuals < 75 years old with diabetes at index date of each year in AL and BC • **Confounders:** Age, sex, and trends of hospitalizations rates over time • **Analyses:** Age-sex standardized, data was set as time-series and were analyzed using fixed-effects regression model	• Increased hospitalizations over time but at a slower pace (i.e. decreased rate over time) • Decrease in rate before and after 2003 • No significant effect of post 2003 on outcome → reform introduced in 2003 does not have a significant effect on the decrease in hospitalization rate	• Longitudinal study • Use of fixed-effects model • Patient characteristics not controlled for

Lee *et al.* (2010)	• P4P program for diabetes care in Taiwan	• Number of exams/tests conducted each year, diabetes-related physician visits, hospital admissions, and health care expenses to NHI	• Natural experimental design • Comparing 2005 vs. 2006 • **Population:** With ICD-9-CM codes 250 or A181 between 2004 to 2006; also filled diabetes prescription claims for 3 months each year • **Intervention group:** enrolled in P4P in 2006; **Comparison:** Patients with diabetes who never joined P4P • **Analyses:** DID regression, Poisson distribution, negative binomial distribution, normal distribution in regression models, and GEE	• Increase in average number of exams/tests and physicians visits in both groups, but more in intervention group • Intervention group had fewer diabetes-related hospitalizations • Expenses for diabetes-related inpatient services decreased for intervention and increased for comparison group • P4P improved service use, physician follow-up, and was associated with lower hospital admissions and hospitalization costs	• A comparison group included • Pre- versus post-P4P analyses • Selection bias due to voluntary enrollment • Cross-sectional study
Lin *et al.* (2016)*	• P4P program in Taiwan	• Hospitalizations for diabetic complications, and all-cause mortality	• Retrospective cohort design; longitudinal • Patients included from January 2002 to December 2006 and observed to end of 2012 • **Population:** Diabetes patients above 30 and first diagnosed with Type 2 diabetes • Two sets: Full P4P participation and Partial participation; each group with a control group matched • **Confounders:** Characteristics of patient, provider, and the cohort • **Analysis:** Multivariable Cox regression	• Full participation of DM P4P had a significant lower risk of being hospitalized for complications compared to controls • Hazard ratio for all-cause mortality was lower for those in full and partial P4P programs versus controls	• Large nationwide diabetes population • Longitudinal • Other factors may affect relationship • Unclear if death was due to diabetes because of the lack of data

Peterson *et al*. (2017)	• Extending the CareFirst's commercial medical home program (includes financial incentives) to Medicare FFS patients in the United States	• All-cause and ACSC hospitalizations, ED visits, quality of care process measures, cost spending	• Longitudinal – 1-year baseline and 2.5-years intervention period • **Population:** Medicare patients • **Intervention:** 14 panels (primary care practitioners participating in a unit) selected to participate in the expansion program; **Comparison:** 42 panels participating in the commercial but not the expansion program • **Confounders:** Patient characteristics • **Analysis:** DID with multivariate linear regressions, accounted for patient and panel level clustering • Separate analysis conducted for high-risk patients	• Intervention group was associated with significant reduction in the probability of receiving all 4 recommended diabetes processes of care; this was not seen for high-risk group • For all other outcomes, the intervention group and the high-risk group was not significantly associated with any outcome changes • Reduction in all-cause hospitalizations seen in intervention group when compared to baseline, however, similar trends seen in the comparison group	• Controlled certain variables • Intervention vs. comparison groups • Not experimental • Generalizability concern

Yu *et al.* (2014)	• Taiwan's P4P for diabetes care	• Emergency care for diabetic hypoglycaemia	• Retrospective longitudinal • **Population:** New onset of Type 2 diabetes patients (2001 – 2009) • (1) P4P (i.e. regular & irregular treatment) vs. non-P4P; (2) Before and After effects of P4P • **Confounders:** Patient age & gender, premium based monthly salary, residence, catastrophic illness status, comorbidity, DCSI, level of healthcare organization, ownership of organization, hospital annual service volume and physician annual service volume for diabetes patients • **Analysis:** Chi-square, and cox proportional hazards model	• Hazard ratio for emergency care was higher in patients in P4P (regular and irregular treatment) compared to not enrolled in P4P • Diabetic hypoglycaemia emergency visits were significantly higher after P4P than before	• Longitudinal study • Attempted to control for confounding • Not generalizable due to unique healthcare system

P4P, Pay-for-performance; P4Pa, Pay-for-participation; P4C, Pay-for-compliance; DRGs, Diagnostic related groups; ACSC, Ambulatory Care Sensitive Conditions; GP, general practitioner; BC, British Columbia; AL, Alberta; PCN, Primary Care Networks; NHI, National Health Insurance; ICD-9-CM International Classification of Diseases Ninth Revision Clinical Modification; DID, Difference-in-Differences; GEE, General Estimated Equations; QOF, Quality and Outcomes Framework; ACSC, Ambulatory Care Sensitive Conditions; PCP, Primary care physician; vs, versus; QOC, Quality of care; A1C, glycated hemoglobin ; LDL, low-density lipoprotein; DCSI, Diabetes Complication Severity Index; CIC, Chronic illness with complexity; DM, Diabetes management; OLS, Ordinary Least Squares; CHD, Chronic Heart Disease; MCC, Multiple Chronic Condition; COC, Continuity of Care; ED, Emergency Department; NHI, National Health Insurance; GLM, Generalized Linear Models; UK, United Kingdom; RCT, Randomized Controlled Trial; FFS, Fee-for-service.
*Lin *et al.* (2016) and Forbes *et al.* (2017) studies consist both hospitalization and mortality outcomes data, thus is included in Tables 2.3 and 2.4.

Table 2.4: Summary of papers that assessed the relationship between financial incentives for diabetes care and mortality

Author & Year	Exposure Variable(s)	Outcome Variable(s)	Methods	Study Findings	Strengths/ Limitations
Ashworth *et al.* (2013)	• Practice (i.e. QOF indicators) and population predictors of the PHI in England	• PHI score, maximum potential PHI score, and PHI% performance score	• Cross-sectional – 2009/2010 • **Population:** 8136 general practises in England • PHI score is the estimated mortality reduction. It's constructed from 20 QOF clinical indicators, mortality reduction estimates, comorbidity correction factor, prevalence calculations • **Analysis:** Univariate and multivariate analyses, two-level multilevel regression models, clustered at primary care trust level • Sensitivity analysis undertaken using 11 QOF indicators with RCT evidence of mortality reduction.	• Based on the performance of the 20 QOF indicators, the estimated mean reduction in mortality rate was 258.9 lives per 100,000 registered patients per annum • PHI score weakly correlated with total QOF score and clinical QOF score • PHI% score moderately correlated with total and clinical QOF scores • Overall, weak correlation between PHI and QOF scores, implying that the financial rewards of the QOF are not reducing mortality	• New metric produced in England • Cross-sectional study • PHI measures impact of QOF-related activity instead of the P4P itself
Chen *et al.* (2016b)	• P4P program in Taiwan	• All-cause mortality	• Retrospective, longitudinal cohort study • **Population:** Type 2 diabetes patients diagnosed prior to December 31, 2003 • **Intervention group:** patients 18 years and older enrolled newly in P4P in 2004; **Comparison:** Patients not in P4P using PSM • **Confounders:** demographic, utilization, clinical	• After an average of 5.13 years of follow-up, the cumulative survival rate was higher for P4P group than non-P4P • Unadjusted analysis, but with PSM indicates mortality rate significantly lower in P4P group vs. non-P4P group. When adjusted for covariates, there was no difference in mortality between P4P and non-P4P	• Longitudinal study • Accounted for selection bias • Some relevant variables were not controlled for in the PSM • Cause of death unknown • Mortality rates were not

			parameters • **Analysis:** Chi-squared and t-t-tests, log-rank test, time-dependent Cox regression model, competing risk adjusted cox regression, GEE	• P4P group had significantly higher physician visits, exams, hypoglycemic drug use, insulin and statin uses vs. non-P4P	compared between before and after P4P
Fleetcroft *et al.* (2010)	• P4P contract (QOF) in England focusing on 25 clinical indicators	• Population mortality reduction per 100,000	• Cross-sectional and modelling study • 2003 and 2005 data were used for baseline performance for 2004 P4P and 2006 revision of P4P • **Population:** English population • **Adjusted variables:** Comorbidity, pre-existing trends • **Analysis:** Mid estimate – Health gains between indicators were additive and reduced by a factor of 20.4/29.3 to adjust for comorbidity, Higher estimate- Similar method but comorbidity ignored, Lower estimate – Highest indicator for each health domain used and accounted for comorbidity.	• Reduced mortality was found in 25 out of 80 indicators in 2004 and 2006 P4P (includes diabetes indicators) • 2004 - additional 11 lives saved per 100,000/ year when performance improved from pre contract to level of targets for full incentive payment • 2006 - no additional mortality reduction • Disease domains with largest reduction in mortality are heart disease, diabetes, and hypertension	• Compared baseline performance • Comorbidity accounted for • Difficult to indicate causation • Some baseline data obtained from large databases while others from small studies

Forbes *et al.* (2017)*	• UK's QOF	• Processes and outcomes of care • Includes holistic and personalised care, mortality, service use and etc.	• Systematic review • Empirical quantitative reports • Includes RCTs and longitudinal studies • Studies that controlled longitudinal trends, before-after analysis, systematic reviews • Search performed on electronic databases for studies published between 2004 to May 2016	• Three systematic reviews and five primary studies • Studies were rated as good quality • Results: Modest slowing in the increase in admissions and consultation rates, improvements in certain diabetes outcomes, no significant effect on mortality	• First review to assess these outcomes for QOF for long-term diseases • Qualitative research not included • Other factors may have confounded the relationship
Kontopantelis *et al.* (2015)	• Practice's performance on QOF indicators in England	• All-cause and cause-specific premature mortality for QOF-linked conditions (i.e. diabetes, heart failure, and etc.)	• Longitudinal spatial study • **Population:** Focus on the England population • **Confounders:** Area and population characteristics, 2010 deprivation, urban versus rural, ethnicity, and morbidity load. Age and sex-standardized outcomes. • **Analysis:** Multiple linear regression models with spatial weighted estimation. Additional sensitivity analyses performed.	• All-cause and cause-specific mortality rates decreased over time • No statistical significant relationship between practice's performance on QOF indicators and all-cause and cause-specific mortality rates	• Longitudinal study • Population-level data • Potential underestimation of deaths • Unmeasured confounding

Lin *et al.* (2016)*	• P4P program in Taiwan	• Hospitalizations for diabetic complications, and all-cause mortality	• Retrospective cohort design; longitudinal • January 2002 to December 2006 and observed to end of 2012 • **Population:** Diabetes patients above 30 and first diagnosed with Type 2 • Two sets: Full P4P participation and Partial participation; each group with a control group matched • **Confounders:** Characteristics of patient, provider, and the cohort • **Analysis:** Multivariable Cox regression	• Full participation of DM P4P had a significant lower risk of being hospitalized for complications compared to controls • Hazard ratio for all-cause mortality was lower for those in full and partial P4P programs versus controls	• Large nationwide diabetes population • Longitudinal • Other factors may affect relationship • Unclear if death was due to diabetes because of the lack of data
Ryan *et al.* (2016)	• QOF P4P program in the UK	• Age- and sex-adjusted mortality per 100,000 for QOF disease areas (i.e. diabetes) composite outcome • **Secondary:** Age- and sex-adjusted mortality for IHD, cancer, and non-targeted QOF conditions	• Longitudinal – 1994 to 2010 data • **Comparison:** 27 countries with high-income epidemiological profile without large-scale P4P. • **Population:** UK and comparison countries • **Analysis:** DID, linear regression, root mean-squared prediction error ratio test, non-parametric permutation test, parametric t-tests • Sensitivity Analysis: Synthetic comparison groups were developed due to the violation of parallel trends assumption	• Before start of QOF, UK had the highest age and sex-standardized mortality than the combined comparison countries for composite, IHD, cancer; but lower for death not related to QOF • However, mortality for UK and synthetic comparison was identical • QOF was not significantly associated with mortality for composite, IHD, cancer or non-target diseases, when compared to synthetic comparison	• Cross-national study • Longitudinal study • Coding differences in practices & systems • Lack of individual-level data

P4P, Pay-for-performance; QOF, Quality and Outcomes Framework; DM, Diabetes Management; UK, United Kingdom; IHD, Ischaemic Heart Disease; DID, Difference-in-Differences; PHI, Public Health Impact; RCT, Randomized Controlled Trial; PSM, Propensity Score Matching; CCI, Charlson Comorbidity Index; DCSI, Diabetes Complication Severity Index; GEE, General Estimated Equations; vs, versus.
* Lin *et al.* (2016) and Forbes *et al*. (2017) studies consist both hospitalization and mortality outcomes data, thus is included in Tables 2.3 and 2.4.

Chapter 3

3 The Impact of the Diabetes Management Incentive on Diabetes-related Services in Ontario

3.1 Introduction

Diabetes mellitus is a chronic disease that affects millions of individuals worldwide.[1] The number of individuals with this disease increased from 108 million in 1980 to approximately 422 million in 2014.[1] In Canada, over 2.2 million individuals aged 12 and over were diagnosed with diabetes in 2017, of which 965,100 individuals were from the province of Ontario.[2] Moreover, Diabetes Canada estimated the prevalence of diabetes (type 1 and type 2 diagnosed) to increase to about 4.8 million by 2029.[3,4] This was estimated using the Canadian Diabetes Cost Model which provided the projections on the prevalence of diabetes in Canada using national data from the National Diabetes Surveillance System and Statistics Canada's medium population projection.[4] Diabetes places a substantial economic burden on the Canadian healthcare system. The direct cost of diabetes to the healthcare system was an estimated $3.6 billion in 2018, and it is expected to rise to $4.7 billion by 2028.[5]

Patients diagnosed with diabetes often develop diabetes-related complications such as kidney failure, retinopathy, heart attack, and stroke.[6] These complications can be life-threatening, leading to hospitalizations, and reduce life expectancy by five to fifteen years.[6] Currently, there is no cure to diabetes. However, appropriate diabetes management, treatment, and monitoring can potentially reduce the incidence of diabetes-related complications, and improve patient's morbidity and mortality risk over the long-term.[7,8] Previous literature documented that effective diabetes management in primary care settings can potentially reduce complications associated with diabetes.[7,9,10] This is because, patients who have access to a family physician (FP) who provides effective diabetes management will: order required tests, follow-up with patients regarding their test results, and support patients with managing their disease (e.g. recommend lifestyle modifications).[9]

In order to strengthen primary care such as improve its access, and increase emphasis on chronic disease management, the Ontario Ministry of Health and Long-term Care (MOHLTC) initiated primary care reform in the early 2000s. New primary care Patient Enrolment Models (PEMs) were introduced as an integral part of the primary care reform initiatives. Physicians practicing in these new models were reimbursed via blended fee-for-service (FFS) or blended capitation payments combined with various pay-for-performance (P4P) incentives. Prior to the primary care reform, most FPs were solely paid by the traditional FFS. Following the reform, the majority of the FPs switched to either blended FFS or blended capitation models. Participation in these models were voluntary for physicians and patients.[11,12] P4P incentives were given to FPs in PEMs who provided diabetes management, congestive heart failure management, and other preventive care services to their eligible patients.[11]

Several countries such as the United States (US), Italy, Taiwan, Australia, the United Kingdom (UK), and Canada introduced P4P incentives to FPs to improve diabetes management at primary care settings.[7,10,13–15] FPs in most of these countries were rewarded with these incentives if they improved process of care measures (e.g. prescribing laboratory tests) and for improved intermediate outcomes (e.g. controlled patient's glycated hemoglobin [HbA1C] levels).[14,16] The aim of these incentives was to motivate and influence the FP's behaviour to provide a higher quality of care to their patients.[7]

Existing literature that assessed the effectiveness of these incentives in improving the provision of diabetes-related services has been mixed. Some studies found that P4P incentives increased diabetes-related services in primary care. Vamos *et al*. (2011)[17] assessed the association between the Quality and Outcomes Framework (QOF) P4P scheme and diabetes management at primary care in the UK, and observed an improvement in the recording of diabetes-related process of care measures (e.g. if HbA1C, cholesterol, and blood pressure were measured) and in prescribing medications.[17] Likewise, two other studies found similar findings regarding the P4P program for diabetes care introduced in Taiwan.[14,18] A longitudinal study by Chen *et al*. (2010)[19] examined the effectiveness of a P4P program implemented in Hawaii in a

preferred provider organization setting, and found that patients with physicians who participated in the P4P program were more likely to receive two HbA1C tests and one low-density lipoprotein cholesterol test in one year compared to those without. Similar results were observed when patients visited the P4P-participating physicians for three consecutive years.[19]

Although there were studies that found the P4P incentives to increase diabetes-related services, some studies found the effect to decline over time or have no effect. Cheng *et al*. (2012)'s[20] longitudinal study on the P4P program in Taiwan concluded that the P4P program has a positive and statistically significant effect on completing the essential examinations or tests for diabetes care. However, the magnitude of this effect decreased over the study period.[20] Similar results were found in another study in Taiwan using diabetic patients with and without multiple chronic conditions.[21] In contrast, one study found no difference in the clinical testing for HbA1C, lipid, and eye exam comparing the Hudson's Health Plan which contains a P4P program for diabetes care, to other non-incentivized health care plans in New York (a state in the US).[22] In Ontario, Canada, researchers assessed the relationship between a Diabetic Management Assessment (DMA) fee code, and quality of diabetes care measured by the frequency of retinal eye examination, cholesterol, and HbA1C tests.[8] The researchers found a gradual increase in the proportion of diabetic patients receiving the recommended tests; however, longitudinal results revealed that the magnitude of improvement seen after the DMA was introduced was similar to the pre-DMA period.[8,23]

The plausible reason behind such mixed findings in the literature may be due to the differences in the nature of the incentives, study design, and the institutional environment within which P4P incentives were implemented.[16,20,24] Moreover, limited attention has been paid to unmeasured confounding. Therefore, the relationship between the P4P incentives and provision of diabetes-related services remains unclear.

In Ontario a P4P incentive for diabetes care, named the Diabetes Management Incentive (DMI), was introduced by the MOHLTC on April 1, 2006.[13,25–27] FPs practicing in specific PEMs were eligible to bill this incentive for their enrolled patients.[25] Table 3.1

lists the specific PEMs that were eligible for the DMI. On the other hand, FPs practicing in the traditional FFS, FPs not participating in the specific PEMs, and non-enrolled patients in the specific PEMs were ineligible for the DMI. However, as of April 1, 2009 all FPs were eligible to bill the DMI for their patients with diabetes regardless of their participation and patient's enrollment status in a PEM.[13,26] In order to claim the DMI, the FP must provide ongoing diabetes management to their patient, and complete a flow sheet which tracks the required elements for diabetes care (e.g. track patient's HbA1C levels), consistent with the Diabetes Canada's Clinical Practice Guidelines. The full set of elements that needs to be tracked, and a sample of the flow sheet is found in Appendix A3.1.[13,25–28] The FPs claim the DMI by submitting the Q040 fee code to the MOHLTC for their patient once per 12-month period, and its' value is $60 per annum per patient.[25,26,29] On October 1, 2015, an additional requirement for the DMI claim was introduced which was that, FPs must provide a minimum three K030 services to the patient within the same 12-month period (i.e. FPs are only eligible for the P4P incentive (DMI) if they have billed at least three K030 fee codes).[27,30] The K030 is the DMA fee code that was introduced on April 2002 for providing diabetes-related services other than insulin therapy support to patients.[8,27,31] Details regarding the DMA can be found in Appendix A3.1. The K030 DMA can be claimed a maximum four times per patient per 12-month period at a value of $39.20 each time it is billed.[8,27,31]

To date, it is unknown if the introduction of DMI is associated with an increase in diabetes-related services. Existing literature that have assessed the relationship between P4P financial incentives for diabetes care and diabetes-related services have been uncertain. Moreover, limitations found in the previous studies make it difficult to generalize those findings to the DMI context in Ontario. Therefore, the objective of this study is to examine the impact of DMI on diabetes-related services in patients diagnosed with diabetes in Ontario. Provision of diabetes-related services will be captured through the DMA billing code K030. This study uses patient-level longitudinal data, and compares diabetic patients enrolled to FPs in PEMs eligible to bill DMI to those affiliated with the traditional FFS FPs.

3.2 Methods

3.2.1 Data Sources

The data for this study were obtained from multiple Ontario healthcare administrative databases housed at ICES. These datasets were linked using unique encoded identifiers and analyzed at ICES. This is a longitudinal, population-based, cohort study that used data spanning from fiscal years 2002 to 2008 (i.e. April 1st 2002 to March 31st 2009). The study began from fiscal year 2002 as DMA was introduced then, and concluded at the end of the 2008 fiscal year as DMI was made available to all FPs on April 1st, 2009. The Ontario Diabetes Dataset (ODD) was used to identify adults diagnosed with diabetes from April 1st, 1991 and onwards in Ontario.[32,33] The ODD was created using the Ontario Health Insurance Plan (OHIP) claims database, Canadian Institute for Health Information (CIHI) Discharge Abstract Database (DAD)/Same Day Surgery (SDS) data, and Registered Persons Database (RPDB).[33] An adult (19+) diabetic patient in the ODD was defined as those with two OHIP claims with the diagnosis recorded as diabetes, or one OHIP fee code: K029 (Insulin Therapy Support), K030 (DMA), K045 (Diabetes management by a specialist), K046 (Diabetes team management), and Q040 (DMI) claim, or one diabetes-related hospital admission within two years. The ODD does not contain individuals with gestational diabetes, and does not distinguish between type 1 and type 2 diabetes.[34] However, the majority of the individuals included in this study are expected to have type 2 diabetes given they are diagnosed during the adulthood.[34] The ODD provides the patient's diagnosis date, and their age at the diagnosis date.

The RPDB was another database used in this study, which provided patient-level demographic information (e.g. age, and sex) for all individuals eligible for OHIP coverage.[8,32,33] Postal codes from RPDB and Statistics Canada's Postal Code Conversion File (PCCF) were utilized to obtain census dissemination area (DA) level income quintiles, and rural residence.[35] The rural residence definition included individuals in rural and small town (i.e. in areas with an urban area population size less than 10,000, plus rural areas).[36] The Ontario Marginalization Index was used to determine material deprivation index,[37,38] which focuses on the inability for individuals to have access to or attain basic material needs. This dimension is composed of indicators from 2001 and

2006, and compiled at the census DA level. It is categorized into five quintiles,[37–39] and can be used as a proxy for patient's socioeconomic status.[37,38] The Aggregated Diagnosis Groups (ADGs) from the Johns Hopkins Adjusted Clinical Groups (ACGs) System Version 10.0 was used to determine patient's comorbidity.[40] The ACG system allocates the 9th revision of the International Classification of Diseases (ICD-9) and the 10th revision (ICD-10) codes into one of the 32 diagnosis clusters named the ADGs. Each disease or condition is grouped into one of the 32 ADGs based on five clinical criteria: severity of the condition, duration of the condition, etiology of the condition, diagnostic certainty, and speciality care involvement.[40–42] Each patient can be assigned to as little as zero and as many as 32 ADGs[43]; the greater the number of ADGs the more comorbid the patient is.

The Client Agency Program Enrolment (CAPE) tables and Corporate Provider Database (CPDB) were used to identify patients enrolled to FPs practicing in PEMs, and the type of PEM the patient and physician were enrolled to. Patients who were not enrolled to a FP from CAPE were assigned to FPs via a virtual roster algorithm. The virtual roster method determined the patient's FP by identifying the responsible physician who claimed the highest amount of OHIP billings for that patient from 18 core primary care fee codes during the previous two years.[44,45] The CPDB also provided information on FPs practicing in Ontario such as their eligibility. The ICES Physician Database (IPDB) was used to obtain physician's demographic information such as their age, sex, International Medical Graduate (IMG) status, and the year they graduated from their medical degree. The OHIP claims database was used to examine the OHIP billings claimed by Ontario FPs, and the details of these claims (e.g. date of service and codes for the service).

3.2.2 Study Population

The ODD was used to identify Ontario adults diagnosed with diabetes on or between April 1st, 1991 to April 1st of each fiscal year from 2002 to 2008. In other words, patients diagnosed with the disease on or prior to the beginning (April 1st) of that specific fiscal year were included. This captured old and newly-diagnosed patients each fiscal year. Patients were included if they were first diagnosed with diabetes at or between the ages 19 and 75 years. Patients were excluded from the study if they died on or before April 1st,

2002, or had missing data for age, sex, and ICES key number (IKN). The IKN is the patient's unique encoded identifier used to link data across the administrative databases. Following this, patients were further excluded if they had missing data for any of the patient and physician-level characteristics used in this study (listed in Section 3.2.3), or had missing data for the location of physician's practice using Local Health Integration Networks (LHINs: Regional administrative units in Ontario) (see Figure 3.1). Patients with complete data were then categorized into two study groups. The first group was the DMI eligible group which comprised of patients with a FP exposed to DMI for all three years (2006 to 2008). The physicians of these patients had to be in the 'Eligible for DMI' section from Table 3.1. The second group was the DMI ineligible group which consisted of patients who were affiliated with a FP practicing traditional FFS throughout the study (i.e. the patient's physician was never exposed to the DMI). The DMI eligible group is labelled as the 'DMI group', and the DMI ineligible group is labelled as the 'comparison group' throughout the remainder of this thesis. Patients who did not fit the criteria to be in either study group were excluded from analysis. Overall, there were 2,760,989 patient-year observations for analysis (2,652,076 observations for the DMI group and 108,913 observations for the comparison group). This panel dataset is unbalanced in nature (i.e. some patients were not observed or had no data for some of the years in the study).

One concern with having an unbalanced panel dataset is a potential efficiency loss from having missing data,[46] and may induce bias to the parameter estimates.[47] Therefore, to alleviate the above complications, the main analysis was conducted on the balanced panel of the dataset (i.e. only in those who were observed each year during the study period from fiscal years 2002 to 2008). However, the analysis using unbalanced panel data was conducted to ascertain robustness of the conclusions. The balanced panel ended up with 1,207,157 patient-year observations for analysis. Figure 3.1 shows the process by which the study population was selected. Table 3.2 shows the number of patients in each study group for each fiscal year for the main analysis (i.e. balanced panel), and in the unbalanced panel.

3.2.3 Variables

The exposure measure in this study was whether the patient's FP was eligible to bill the DMI from fiscal years 2006 to 2008. Using this exposure, a dichotomous variable was created to reflect the two study groups of patients: DMI group (took the value 1) and comparison group (took the value 0). The outcome variable of interest was the DMA fee codes billed (measures diabetes-related services) for each patient. This variable was also a dichotomous variable which reflected whether or not the patient had three or more DMA fee codes billed by their physician during each fiscal year. The quantity 'three or more' was chosen because it represents effective management of diabetes. Usually diabetic patients visit their FP every three to four months to complete the necessary bloodwork (e.g. HbA1C blood test), discuss diabetes management, and have their diabetes care elements tracked in a flow sheet (e.g. track their HbA1C test result). Most diabetic patients are required to have their HbA1C measured approximately every three months to ensure that the patient is meeting their glycemic targets based on the Diabetes Canada's Clinical Practice Guidelines.[48] Therefore, following these guidelines, the FP should be able to bill at least three DMA fee codes for the patient within one year. In addition, as of October 1, 2015, the DMI can be billed only if the FP renders a minimum three DMA services for the patient over the one-year period, thus the rationale as to why the quantity 'three or more' was selected.[27,30]

Various patient- and physician-level characteristics were controlled in the analysis. Patient characteristics included were age, sex, comorbidity (defined by the number of ADGs), rural residence, duration of diabetes (measured in years), income quintiles (ranged from quintile 1 (Q1) = lowest income to quintile 5 (Q5) = highest income), and material deprivation (ranged from Q1 = least deprived to Q5 = most deprived). Physician characteristics included were age, sex, IMG status (0 = Canadian Medical Graduate (CMG), and 1 = IMG), and years since graduation (measures physician's experience).

3.2.4 Statistical Analysis

3.2.4.1 Main Analysis

Individual patient-level data were utilized to conduct all analyses. Descriptive statistics were obtained for each fiscal year to describe the patient-level characteristics, and the DMI and DMA fee code billings for the DMI and comparison groups. Descriptive statistics were also obtained for physician-level characteristics for FPs who provided care to patients in the DMI group, and for FPs who provided care to patients in the comparison group. Categorical variables were described in frequencies and percentages, while continuous variables were described using means and standard deviations. In addition, a chi-square test and an independent sample t-test were performed to compare the outcome measure (DMA fee codes billed) between the two study groups. The DMA outcome variable was also treated as a continuous variable (i.e. number of DMA fee codes billed) for the descriptive analyses, hence why a t-test was also performed. The two tests were only performed for the 2002 and 2008 fiscal years to evaluate if differences in the DMA billings were present between the two groups at the beginning and end of the study period.

Multivariable linear regression models with the difference-in-difference (DID) methodology were used to study the relationship between the DMI and diabetes-related services (measured by DMA billings). The DID methodology is used to estimate the effect of a policy change by comparing the difference in the outcomes between two groups (i.e. study group that was exposed to the policy change, and a comparison group that was not exposed), before and after the policy change was introduced.[49] The DID effect in this study was estimated using a multivariable linear regression model which included the following variables: 1) a dichotomous variable that indicated the two study groups (DMI group versus comparison group), 2) a pre- and post-period dichotomous variable that reflected if the year of observation was before versus after DMI was introduced, and 3) a variable for the interaction between the variables from 1) and 2).[49,50] The estimated coefficient of the interaction variable captured the impact of DMI on the probability of having three or more DMA fee codes billed by patient's physician. A time trend measure was also included in the model, and it was labeled as 'τ'. This was the

DID unadjusted pooled ordinary least squares (OLS) model (Model 1). Previous literature in this area had explored the effectiveness of P4P incentives for diabetes care by controlling for patient- and physician-level characteristics, as they can potentially confound this relationship.[8,18,19,22] Therefore, a DID adjusted pooled OLS model (Model 2) that controlled for patient- and physician-level characteristics to account for observed heterogeneity was used. All patient- and physician-level characteristics discussed in Section 3.2.3 were included except for physician's years since graduation, as it was highly correlated with physician's age. Patient and physician's age-squared variables were included. Within-clustering of patients was also used to adjust standard errors, as patients were observed over time.

Although Model 2 reduced bias from confounding by controlling for observed characteristics, unobserved individual-specific heterogeneity (i.e. heterogeneity due to patient's race, preferences) may still be present, and can potentially bias the relationship.[22,51] Assuming that the above patient-specific factors are time-invariant, patient fixed-effects DID model adjusting for patient and physician-level characteristics was then performed (Model 3).[51,52] A fixed-effects model removes the effect of unobserved time-invariant patient factors so that the net effect of the DMI on the outcome can be examined. Finally, patients may have their own specific time trend as over time patients' behaviours can change (i.e. medical compliance, visiting their FPs on a regular basis, etc.), and this is not accounted by the fixed-effects DID model. Therefore, a high-dimensional fixed-effects DID model adjusting for patient and physician-level characteristics and individual fixed-effects was used to control for the patient-specific time trend (Model 4).[52,53] In addition, a two-way clustering for within patients and between physician levels was allowed for in this model. It is essential to cluster at the physician-level as a FP's behaviour and the way they deliver care would affect all patients who received care from that specific physician in a similar manner.[54]

This study used linear regression models to evaluate the effect of DMI on a binary outcome. When evaluating binary outcomes, nonlinear probability models such as logit and probit models are commonly used.[55,56] However, a linear probability model (LPM)

can be used to estimate consistent parameter estimates. The LPM for a binary outcome 'y' is specified as:

$$P(Y = 1|x) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 \ldots + \beta_k x_{ik} + u_i;$$

where x_i is the covariates, k is the number of covariates, and u_i is the error term.[55–57] This linear model is interpreted as the probability that the event will occur given x_i. Although there are a couple of disadvantages of LPM such as heteroscedasticity (can be dealt with using robust standard errors in Stata software), and predicted probabilities, '$\hat{Y}$', may lie outside the range of zero and one[57]; the LPM has a number of advantages that led to its use in this study. One of the main advantages of using the LPM is that the interpretations of the coefficients are much easier compared to nonlinear models, especially when there are interaction terms involved.[58,59] In addition, the coefficient estimates in a LPM can be directly interpreted as the "mean marginal effect" of the covariate on the outcome, while extensive calculations are required to determine the marginal effects in a logit model.[60] Second, using nonlinear models becomes more complicated when working with panel data.[61] This was one of the main reasons the LPM was used in this study, as it is less complicated to perform fixed-effects and high-dimensional fixed-effects using a linear model compared to a nonlinear model. Lastly, it has been claimed that in large samples the LPM produces similar findings as the logit and probit models.[58,62] Therefore, the LPM was used in this study to estimate the impact of DMI on the probability of having three or more DMA fee codes billed by patient's physician. However, the coefficient of the interaction variable from the LPM, and the average derivative of the interaction variable from the logit model were compared to illustrate that the impact of DMI on the outcome is similar between the two type of models.[59] This was done for Models 1 and 2 only, as performing the fixed-effects logit model is very complex and high-dimensional fixed-effects logit model is not feasible. All data analyses were performed using Stata 15.1 at ICES Western site.

The equations for the four multivariable linear regression models with the DID methodology described above are presented below:

$$P(Y_{it} = 1|x) = \beta_0 + \beta_1 DMI_i + \beta_2 period_t + \beta_3 DMI_i \times period_t + \beta_4 \tau + u_{it} \quad (1)$$

$$P(Y_{it} = 1|x) = \beta_0 + \beta_1 DMI_i + \beta_2 period_t + \beta_3 DMI_i \times period_t + \beta_4 \tau + \beta_x X_{it} + u_{it} \quad (2)$$

$$P(Y_{it} = 1|x) = \beta_0 + \beta_1 DMI_i + \beta_2 period_t + \beta_3 DMI_i \times period_t + \beta_4 \tau + \beta_x X_{it} + \varepsilon_i + u_{it} \quad (3)$$

$$P(Y_{it} = 1|x) = \beta_0 + \beta_1 DMI_i + \beta_2 period_t + \beta_3 DMI_i \times period_t + \beta_x X_{it} + \varepsilon_i + \gamma_{it} + u_{it} \quad (4)$$

Equations (1) to (4) specify Models 1 to 4 respectively. $P(Y_{it} = 1|x)$ is the probability of having three or more DMA fee codes billed for patient i by their physician in fiscal year t; DMI_i is a dichotomous variable equals to 1 if patient i is in the DMI group and 0 if patient i is in the comparison group; $period_t$ is a pre- and post- dichotomous variable equals to 0 if the year of the observation is before DMI was introduced and 1 if it was after DMI was introduced; $DMI_i \times period_t$ is the interaction variable which denotes the DID estimate; τ is a time trend which denotes the year of observation; X_{it} is the set of observable covariates (i.e. patient and physician-level characteristics); ε_i is the unobserved individual patient fixed-effects; γ_{it} is the high-dimensional fixed-effects in which the patient interacts with their own time trend; and u_{it} is the error term.

3.2.4.2 Subgroup Analysis

Subgroup analyses were also performed to examine if the impact of DMI on the DMA fee codes billed varied among different subpopulations. The analyses were performed in two subgroups: 1) comorbidity (those with below versus at or above median number of ADGs at baseline), and 2) sex (males versus females). If any one of the two subgroup analyses revealed the impact of DMI on the outcome to be statistically significant but with a large difference in the magnitude of effect among the levels of that subgroup, interactions were then tested in that subgroup. Using interactions is a more persuasive approach when proving that a difference in the effect of DMI among the different levels of that subgroup is present.[63] Subgroup analysis was performed in the comorbidity subgroup, because patients with comorbidities (or have multiple chronic conditions) will have complex health needs, and a higher demand for healthcare services.[64–66] In diabetic patients, increase in the healthcare utilization (i.e. care from FPs, specialists, and hospitals) is found with increasing number of comorbidities.[66] Therefore, it is important

to assess if the impact of DMI varied in this subgroup. In addition, a few studies have found that P4P incentive schemes may not benefit patients with multiple chronic conditions as the guidelines from these incentives focus on specific diseases and may not be appropriate for those with a greater comorbidity.[67,68] This further increases the need for this subgroup analysis. Subgroup analysis by sex was also performed, because sex-specific differences have been noted in diabetic patients for the quality of care received, and for their medical compliance. Women are less likely to attain the recommended targets for diabetes (e.g. targets for HbA1C, lipids), and be compliant with the medical recommendations.[69,70] One potential reason behind this is due to behavioural factors as one study found that women with diabetes had a higher prevalence of depression and diabetes-related distress than men, and that lower psychological well-being was associated with lower levels of self-care attitudes, satisfaction of treatment, and diabetes empowerment.[71,72] If women have poor medical compliance, then they will less likely visit their FP to have their diabetes monitored and controlled. Likewise, existing literature have found women to less likely to receive monitoring and treatment for diabetes compared to men.[69,70] Therefore, it is important to assess if the impact of DMI on the provision of diabetes-related services differ by sex.

3.2.4.3 Sensitivity Analysis

Two sensitivity analyses were conducted to evaluate the robustness of the study findings. First, a sensitivity analysis was performed treating the DMA outcome as a continuous variable to check if the findings remained similar to the main results. Second, to reduce potential selection bias that arose from only assessing patients who were part of the balanced panel (i.e. patients who were observed each and every year during the study period), an analysis was performed using the unbalanced panel dataset (i.e. all patients including those without data for some of the years in the study). The unbalanced panel of the dataset was made up of those who were in the balanced panel, those in the DMI group who entered the dataset after April 1, 2002 (patients diagnosed with diabetes after the study began) but on or prior to April 1, 2006 to be eligible for the DMI group, and those from the DMI group who had no data for some of the fiscal years. Subgroup analyses

were performed in both sensitivity analyses along the lines of the balanced panel analysis.

3.3 Results

3.3.1 Descriptive Results

In total, there were 172,451 adult diabetic patients in Ontario who were included in this study (15,559 patients were in the comparison group and 156,892 patients were in the DMI group). Patient and physician characteristics for both study groups for fiscal years 2002 to 2005 (i.e. before DMI introduction) are reported in Table 3.3 and the corresponding data for fiscal years 2006 to 2008 (i.e. after DMI introduction) are presented in Table 3.4. On average, patients in the DMI group were slightly younger, had fewer number of ADGs (i.e. less comorbid), and had slightly less duration of diabetes compared to the comparison group. In addition, in the DMI group, there was a slightly greater proportion of female patients, and patients who resided in rural areas, in lesser deprived quintiles, and higher income quintiles compared to the comparison group. The number of physicians providing care in each study group differed for each fiscal year, with the number decreased from 1,191 in 2002 to 797 physicians in 2008 in the comparison group. On average, the physicians providing care to the DMI group were younger, had fewer years of experience, and were less likely to be IMGs. Furthermore, there was a greater proportion of female physicians providing care in the DMI compared to the comparison group.

As for the DMI billings (Tables 3.3 and 3.4), the proportion of patients in the DMI group who had a DMI billed by their physician increased from 21.91% in 2006 to 27.43% in 2008. Similarly, an increase was observed in this group for the proportion of patients with three or more DMA fee codes billed by their physician per year (0.63% in 2002 to 7.85% in 2008), and in the average number of DMA fee codes billed per year. The proportions and averages for the DMA fee code billings were higher in the DMI compared to the comparison group. In the comparison group, the proportion of patients with three or more DMA fee codes billed by their physician increased from 0.39% in 2002 to 1.79% in 2008, however, it was not a steady increase throughout. The difference

in the DMA fee codes billed between the two study groups was compared at baseline and at final fiscal year; and a statistical significant difference was detected between the two groups ($p < 0.001$) (Appendix A3.2). Figure 3.2 presents the trends in the DMA fee code billings in the DMI and comparison groups. Figure 3.2a shows that there was a sharp increase in the average number of DMA fee codes billed in the DMI group; and the gap between the two groups widened following the introduction of DMI. A sharp increase was also observed in the DMI group for the proportion of patients with three or more DMA fee codes billed by patient's physician per year (Figure 3.2b). The difference in this proportion between the study groups increased from 0.002 (2002) to 0.061 (2008).

3.3.2 Regression Results

The linear regression results for the estimated impact of DMI on having three or more DMA fee codes billed by patient's physician are presented in Table 3.5. All four models show that DMI has a positive and statistically significant effect on the probability of having three or more DMA fee codes billed by patient's physician ($p < 0.01$). This finding suggests that there is an increase in the provision of diabetes-related services after the introduction of DMI. The DID unadjusted pooled OLS model (Model 1) indicates that the effect of DMI is an increase in the probability of having three or more DMA fee codes billed by patient's physician by 4.2 percentage points ($95\%\ confidence\ interval\ [CI]\ 4.0, 4.3\ percentage\ points$). However, a slight decrease in the effect size was observed after adjusting for patient- and physician-level characteristics (Model 2), and a similar magnitude of effect as Model 2 was observed in the fixed-effects DID model (Model 3). Lastly, the high-dimensional fixed-effects DID model (Model 4) showed the smallest estimated effect compared to the previous models; 2.1 percentage points increase in the probability of having three or more DMA fee codes billed by patient's physician ($95\%\ CI\ 1.5, 2.6\ percentage\ points$). Since Model 4 adjusts for patient-specific time trend, individual patient fixed-effects, and observable patient and physician-level characteristics; therefore, this model is likely to be closer to the true effect of the DMI on the study outcome.

The average marginal effects of DMI on having three or more DMA fee codes billed by patient's physician were compared between Models 1 and 2 to equivalent models

performed using a logistic regression model (Appendix A3.3). Since similar marginal effects were obtained from the logistic and LPM regression models, the estimates from the LPM are reliable.

Patient and physician-level characteristics in the regression models displayed certain effects on patients having three or more DMA fee codes billed by their physician (Table 3.5). Patient's age has a positive and statistical significant effect on the probability of having three or more DMA fee codes billed by patient's physician based on Model 2. In Models 3 and 4 patient's age cannot be identified, because it was correlated with the time trend variable. However, the quadratic term for age was present, and it was positive and statistically significant in Models 3 and 4. Females (based on Model 2), and those with higher number of ADGs (based on all models) were significantly less likely to have three or more DMA fee codes billed by their physician. The remaining patient-level, and all physician-level characteristics did not have a statistically significant effect on the outcome in the final model (Model 4).

3.3.3 Results from the Subgroup Analysis

Subgroup analyses performed across the two subgroups (comorbidity, and sex) are presented in Table 3.6. The results for the impact of DMI on having three or more DMA fee codes billed by patient's physician in the subgroups were similar to the main results. Based on the final model, the comorbidity subgroup analyses showed the effect size to be similar in both comorbidity groups. However, subgroup analyses by sex revealed the effect to be slightly larger in males compared to females ($Model\ 4$: $\hat{\beta}_{3(Males)} = 0.023;\ 95\%\ CI\ 0.017, 0.029;\ \hat{\beta}_{3(Females)} = 0.018;\ 95\%\ CI\ 0.012, 0.024$). Following this, interactions were tested to examine if there was a statistically significant difference in the impact of DMI on having three or more DMA fee codes billed by patient's physician according to patient's sex. Interactions were performed in Models 1 and 2 only, because patient's sex is a time-invariant characteristic that is constant for each patient, thus, its effect is omitted in fixed-effects and high-dimensional fixed-effects models. Findings from the interactions revealed that the difference in the DMI's effect on the

outcome between males and females is statistically significant ($Model\ 2: \hat{\beta} = -0.006; 95\%\ CI\ -0.008, -0.005$).

3.3.4 Results from the Sensitivity Analysis

The first sensitivity analysis was performed assessing the impact of DMI on the outcome treated as a continuous variable instead of a binary variable. This variable measured the number of DMA fee codes billed for the patient in each fiscal year. Similar to the main results, the DMI has a positive and statistically significant effect on the number of DMA fee codes billed. The second sensitivity analysis was performed using patients who were part of the unbalanced panel dataset. In total, there were 480,517 adult diabetes patients part of the unbalanced panel, and Table 3.2 illustrates the number of patients in each study group for each fiscal year. Similar results were observed in the unbalanced panel as the main results of this study. Subgroup analyses were also performed in the unbalanced panel dataset, and the results were consistent with the results from the subgroup analyses in the main study. For the comorbidity subgroup analysis in the unbalanced panel, the same median number of ADGs at baseline as the main study population was used. This was done to be consistent with the subgroup analysis performed in the main study, and also, because the median number of ADGs at baseline could not be computed for the unbalanced panel as not all patients were present at baseline (2002). Results for the sensitivity analysis are not presented in this chapter, but are available upon request.

3.4 Discussion

To date, the literature assessing the impact of P4P incentives on diabetes-related services has been mixed. Furthermore, no research has been performed assessing the effect of DMI on diabetes-related services in Ontario. Therefore, the aim of this study was to evaluate the impact of DMI on diabetes-related services (measured by DMA billings) in diabetic patients in Ontario. Results from this study revealed that the proportion of patients who had three or more DMA fee codes billed by their physician increased in both study groups, however, the increase was much smaller for the comparison group. A large increase was also observed in the average number of DMA fee codes billed in the DMI group in 2008 compared to 2002. The main regression results revealed that DMI

increased the provision of diabetes-related services, and the findings were consistent through all four DID models. However, the magnitude of the effect was much smaller in Model 4 compared to Model 1. This was observed as Model 4 compared to Model 1 controlled for the observable patient- and physician-level characteristics, individual patient fixed-effects, and the patient-specific time trend as these factors can potentially affect the study relationship. The estimated magnitude of effect was an increase in the probability of having three or more DMA fee codes billed by patient's physician by 2.1 percentage points. As for the subgroup analyses, findings revealed the DMI's effect was similar across the comorbidity groups. However, there was a difference in the magnitude of effect found between males and females, in which the effect size was slightly larger in males. A potential reason behind this finding is that female diabetic patients are known to have poor medical compliance, and are less likely to receive diabetes-related services compared to males.[19,69,70] The main findings of this study were based on the balanced panel of patients. By focusing on the same patients over time, any changes seen in the outcome after DMI was introduced can be more likely linked to the incentive; thus having a higher internal validity. However, sensitivity analyses were performed using the unbalanced panel of the dataset to ensure that findings from this study were robust. This patient cohort improves the external validity of the study as it consists a larger cohort which includes: those from the balanced panel, those in the DMI group without data for some of the fiscal years, and those in the DMI group who were diagnosed with diabetes after April 1, 2002 but on or prior to April 1, 2006. Findings from the unbalanced panel were consistent with the main study results. An additional sensitivity analysis was performed using a continuous DMA outcome, and findings were very similar to the main study results.

The results found in this study are consistent with a number of existing studies that also reported P4P incentives increased diabetes-related services in primary care.[14,15,17,19,20] One study assessed the impact of a P4P scheme that was introduced in Australia on quality of care, measured by whether the FP ordered a HbA1C test during a consultation with the patient.[15] The study's findings revealed that the introduction of this scheme led to a 20 percentage point increase in the probability of ordering a HbA1C test.[15] Another study observed that the odds of receiving at least two HbA1C tests and one lipid test were

1.16 times greater in patients who saw a P4P-participating physician versus those who saw a non-P4P-participating physician.[19] These results underscore that P4P incentives can influence the FP's behaviour, and improve quality of diabetes care at primary care.[7] Therefore, this in turn reflects the improvement in delivering diabetes-related services for diabetes management such as ordering tests (i.e. HbA1C test, lipids test).[9] Over time, this will induce improvements in intermediate outcomes (e.g. cholesterol control)[9,16] and eventually in patient outcomes (e.g. avoidable hospitalizations and mortality risk).[10]

On the other hand, a few studies found that P4P incentives for diabetes care have no effect on diabetes-related services,[8,22] which differed from what was found in this study. For instance, Chien *et al*. (2012)[22] noted that there was no statistically significant difference in the diabetes care process (e.g. lipid, HbA1C exam rates) comparing the Hudson Health Plan's P4P program to other non-incentivised healthcare plans in New York. Possible reasons to why the results of the current study differed from some literature can be due to the differences in the level of analysis (e.g. Chien *et al*.'s study[22] used plan-level data), sample size, nature of the P4P incentive, design of the study, and institutional setting of the study.

In this study, there was also an interesting observation which was that the proportion of patients with three or more DMA fee codes billed by their physician was increasing before DMI was introduced, and the proportions were larger in the DMI group (Figure 3.2b). This suggests that physicians providing care to patients in the DMI group were already billing the DMA fee codes more than the physicians providing care in the comparison group. However, once the DMI was introduced, the improvement was much larger than the pre-incentive period, suggesting that the DMI did have a positive effect on the outcome. The increasing trend in the DMA billings observed in the DMI group prior to the introduction of DMI, may be due to the primary care reform which began in the early 2000s in Ontario. The reform introduced new PEMs, in which one of the objectives was to increase emphasis on disease prevention and chronic disease management.[11] Therefore, over time more and more FPs switched from the traditional FFS into one of the new PEMs in the DMI group, hence there was a slight increasing trend in the billing of the DMA fee codes prior to the introduction of DMI.

Another issue that needs to be noted is that even though there was an increase in the proportion of patients with three or more DMA fee codes billed by their physician from 2002 to 2008, and the number of patients with DMI billed from 2006 to 2008; the numbers were not large enough. In the DMI group in 2008, only 27.43% of the patients received DMI billings and 7.85% of the patients had three or more DMA fee codes billed by their physician. Therefore, there is a low uptake of the DMI and DMA fee codes and there are a couple of reasons to why this may be the case. First, the size of the incentive and the fee code may have been too small for the physicians.[8,22,52] Other P4P programs such as the QOF in the UK pays FPs up to 25% of the physician's income. Moreover, for the QOF, family practices earn points based on clinical and organisational quality indicators with more points obtained for intermediate outcome indicators.[16] Points are then converted to payments to the family practice adjusting for disease prevalence and list size.[16] Second, some physicians may be unaware of the DMI and DMA fee codes, especially right after switching to PEMs. Third, there have been other P4P incentives introduced around the same time period which may have affected the intake of the DMI. Fourth, the administrator burden of completing the diabetes flow sheet may be an issue for some practices as it is very detailed, thus, can be straining to complete for each patient.[8] Lastly, patients demand to complete the required diabetes tests may be low or they may not visit their FP frequently enough for the FP to provide diabetes-related services and bill the DMI and DMA fee codes.[52]

This study also found that females, and those with a higher comorbidity had a lower probability of having three or more DMA fee codes billed by their physician. Similar to this study, previous studies had also found females[8,19] less likely to receive quality of care or recommended tests. In addition, Kiran *et al*. (2012)[8] observed that, those with 10 or more ADGs (higher comorbidity) to less likely to receive all three recommended tests (i.e. retinal eye exam, HbA1C and cholesterol test). On the other hand, contrasting results were also found in existing literature such as Chen *et al*. (2010)[19] and Chien *et al*. (2012)[22] found those with higher comorbidities to more likely receive quality or recommended diabetes care.

There are some strengths of the current study. This is the first study to evaluate the impact of DMI on diabetes-related services in patients diagnosed with diabetes comparing patients whose physicians were exposed to DMI to a comparison group. This study also helps fill the knowledge gap regarding the effectiveness of DMI using panel data from 2002 to 2008. Using panel data is advantageous as, it gives more efficiency, informative data, variability, less collinearity among variables, and present ways to deal with heterogeneity.[51,73] Lastly, the patient cohort in this study was derived from validated health administrative databases such as the ODD which has a high sensitivity (86%), and specificity (97%).[32,33]

There were also some limitations of this study. First, the comparison group in this study was much smaller compared to the DMI group. This can be an issue, since in a small group, patients with data that are outside the normal range or with extreme data observations may skew the results. Moreover, this can result in having two study groups that are not comparable with each other. Second, although several patient- and physician-level characteristics, time-invariant patient factors, and patient-specific time trend were controlled; some selection bias may still remain. Most FPs who provided care to patients in the DMI group were initially practicing in the traditional FFS, however, over time these physicians switched into the PEMs voluntarily. On the other hand, FPs providing care to the comparison group were physicians who practiced in the traditional FFS throughout the entire study. Therefore, differences among the physicians between the two study groups may have introduced some bias. In addition, the descriptive results revealed that there were slight differences observed between the DMI and comparison group for the patient- and physician-level characteristics. Therefore, patient- and physician-level characteristics were adjusted for in the multivariable analyses to help reduce the bias. Lastly, findings from this study may not be generalizable to other jurisdictions due to the differences in how the P4P incentives for diabetes care is designed, or its size in Ontario versus other jurisdictions outside of Ontario.

In terms of future research, more research is required to further explore the impact of DMI on diabetes-related services beyond fiscal year 2008. As of April 1, 2009, all FPs (including FPs in traditional FFS) became eligible for DMI. Therefore, future research

can assess the effects of DMI on diabetes-related services in patients enrolled to physicians in PEMs and in patients with FFS physicians separately. Future works could also explore LHIN-level analysis. Research can also be performed assessing the effect of DMI on improving intermediate outcomes of diabetes such as HbA1C and cholesterol levels to understand if the incentive helped improve patients' health. This study found that DMI has improved the provision of diabetes-related services, and it would be worthwhile to investigate the benefits to patients' health. Finally, it is important to assess the effect of this incentive on healthcare system costs and determine if this incentive is cost-effective.

3.5 Conclusions

The findings from this study revealed that DMI has increased the provision of diabetes-related services in patients diagnosed with diabetes. The estimated magnitude of effect of DMI is an increase in the probability of having three or more DMA fee codes billed by patient's physician by at least 2 percentage points. Moreover, the effect of DMI on having three or more DMA fee codes billed by patient's physician were similar across the comorbidity subgroups. However, subgroup analyses by sex revealed the effect of DMI is slightly larger in males than in females. Findings from this study are important since all FPs are currently eligible to bill the DMI, and it may also have a positive effect on the provision of diabetes-related services in the current population.

3.6 Tables and Figures

Table 3.1: Physicians' eligibility for the Diabetes Management Incentive (DMI) as of 2006

Physician's Eligibility Status[a]	
Eligible for DMI	**Ineligible for DMI**
Family physicians in the following PEMs can bill the DMI for their enrolled patients: Family Health Networks, Family Health Groups, Family Health Organizations, Comprehensive Care Models, Group Health Centre, St. Joseph's Health Centre, Primary Care Networks, Health Service Organizations, Rural and Northern Physician Group Agreement, and South Eastern Ontario Academic Medical Organization	Fee-for-service (FFS) family physicians, family physicians not in the 'Eligible for DMI' section (found on the left), and non-enrolled patients receiving care from family physicians in PEMs.

DMI, Diabetes Management Incentive; PEMs, Patient Enrolment Models.
[a] However, as of April 1, 2009, the DMI is expanded to cover all family physicians practicing in Ontario.
Source: (Ministry of Health and Long-Term Care, 2006)[25]
Hyperlink: http://www.anl.com/MOHGUIDE/00 Diabetes Management Incentive - April 2006.pdf

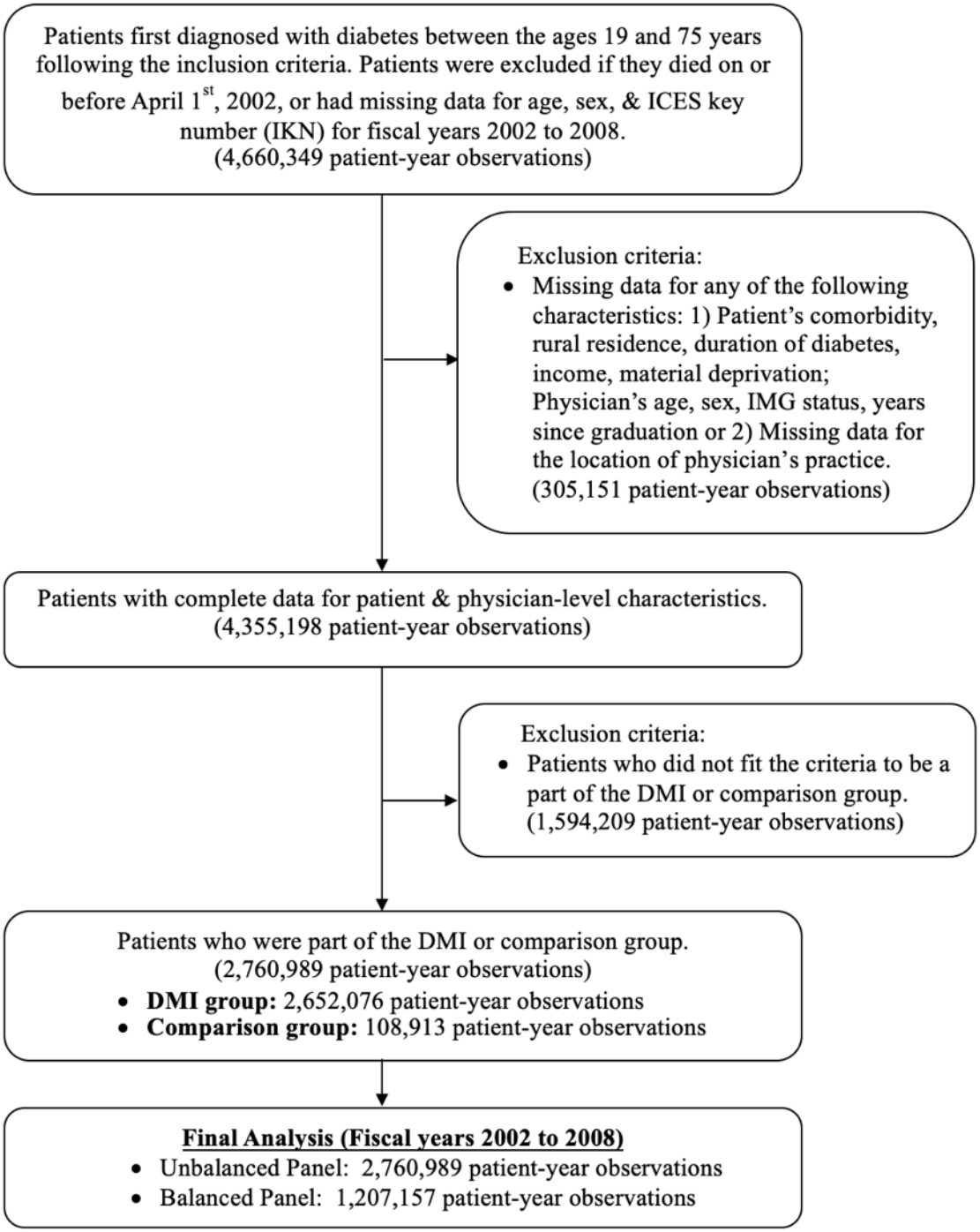

Figure 3.1: Flow chart for the selection of study population

Table 3.2: Number of patients in each study group in the balanced and unbalanced panels for fiscal years 2002 to 2008

Fiscal Year	Number of patients in the balanced panel[a]		Number of patients in the unbalanced panel[b]	
	Comparison group	DMI group	Comparison group	DMI group
2002	15,559	156,892	15,559	162,643
2003	15,559	156,892	15,559	321,160
2004	15,559	156,892	15,559	361,036
2005	15,559	156,892	15,559	412,363
2006	15,559	156,892	15,559	464,958
2007	15,559	156,892	15,559	464,958
2008	15,559	156,892	15,559	464,958

DMI, Diabetes Management Incentive.

[a] The sum of the number of patients from both study groups and for all fiscal years combined results in the total number of patient-year observations for the balanced panel (i.e. 1,207,157 patient-year observations).

[b] The sum of the number of patients from both study groups and for all fiscal years combined results in the total number of patient-year observations for the unbalanced panel (i.e. 2,760,989 patient-year observations).

Table 3.3: Patient- and physician-level characteristics by study group before DMI was introduced

Variables	2002		2003		2004		2005	
	Comparison group	DMI group	Comparison group	DMI group	Comparison group	DMI group	Comparison group	DMI group
Patient characteristics								
Number of patients	15,559	156,892	15,559	156,892	15,559	156,892	15,559	156,892
Age, mean (SD)	60.22 (11.97)	59.24 (12.61)	61.22 (11.97)	60.24 (12.61)	62.22 (11.97)	61.24 (12.61)	63.22 (11.97)	62.24 (12.61)
Sex, n (%)								
Male	8,229 (52.89%)	80,847 (51.53%)	8,229 (52.89%)	80,847 (51.53%)	8,229 (52.89%)	80,847 (51.53%)	8,229 (52.89%)	80,847 (51.53%)
Female	7,330 (47.11%)	76,045 (48.47%)	7,330 (47.11%)	76,045 (48.47%)	7,330 (47.11%)	76,045 (48.47%)	7,330 (47.11%)	76,045 (48.47%)
Rural residence, n (%)								
No	15,553 (99.96%)	156,416 (99.70%)	15,529 (99.81%)	155,803 (99.31%)	15,514 (99.71%)	155,434 (99.07%)	15,500 (99.62%)	155,109 (98.86%)
Yes	6 (0.04%)	476 (0.30%)	30 (0.19%)	1,089 (0.69%)	45 (0.29%)	1,458 (0.93%)	59 (0.38%)	1,783 (1.14%)
Number of ADGs, mean (SD)	4.92 (2.83)	4.79 (2.85)	4.93 (2.85)	4.84 (2.89)	5.11 (2.90)	4.97 (2.97)	5.14 (2.95)	5.06 (3.02)
Duration of diabetes (years), mean (SD)	5.74 (3.55)	5.62 (3.58)	6.74 (3.55)	6.62 (3.58)	7.74 (3.55)	7.62 (3.58)	8.74 (3.55)	8.62 (3.58)
Material deprivation quintiles, n (%)								

Q1 (least deprived)	2,320 (14.91%)	29,616 (18.88%)	2,405 (15.46%)	30,779 (19.62%)	2,531 (16.27%)	31,735 (20.23%)	2,592 (16.66%)	32,515 (20.72%)
Q2	3,235 (20.79%)	34,255 (21.83%)	3,235 (20.79%)	34,085 (21.73%)	3,256 (20.93%)	34,196 (21.80%)	3,293 (21.16%)	34,333 (21.88%)
Q3	3,490 (22.43%)	34,055 (21.71%)	3,509 (22.55%)	34,056 (21.71%)	3,445 (22.14%)	33,848 (21.57%)	3,434 (22.07%)	33,717 (21.49%)
Q4	3,399 (21.85%)	30,864 (19.67%)	3,327 (21.38%)	30,266 (19.29%)	3,286 (21.12%)	29,840 (19.02%)	3,232 (20.77%)	29,486 (18.79%)
Q5 (most deprived)	3,115 (20.02%)	28,102 (17.91%)	3,083 (19.81%)	27,706 (17.66%)	3,041 (19.54%)	27,273 (17.38%)	3,008 (19.33%)	26,841 (17.11%)
Income quintiles, n (%)								
Q1 (lowest income)	3,385 (21.76%)	30,132 (19.21%)	3,574 (22.97%)	32,592 (20.77%)	3,531 (22.69%)	32,316 (20.60%)	3,480 (22.37%)	32,024 (20.41%)
Q2	3,753 (24.12%)	36,052 (22.98%)	3,943 (25.34%)	36,844 (23.48%)	3,887 (24.98%)	36,493 (23.26%)	3,883 (24.96%)	36,315 (23.15%)
Q3	3,486 (22.41%)	33,419 (21.30%)	3,115 (20.02%)	31,719 (20.22%)	3,163 (20.33%)	31,877 (20.32%)	3,198 (20.55%)	32,108 (20.47%)
Q4	2,773 (17.82%)	29,989 (19.11%)	2,742 (17.62%)	28,947 (18.45%)	2,776 (17.84%)	29,370 (18.72%)	2,796 (17.97%)	29,606 (18.87%)
Q5 (highest income)	2,162 (13.90%)	27,300 (17.40%)	2,185 (14.04%)	26,790 (17.08%)	2,202 (14.15%)	26,836 (17.10%)	2,202 (14.15%)	26,839 (17.11%)
DMI and DMA fee code billings								
Patients with DMI billed[a], n (%)	-	-	-	-	-	-	-	-
Patients with DMA billed, n (%)								
< 3	15,499 (99.61%)	155,910 (99.37%)	15,478 (99.48%)	155,414 (99.06%)	15,479 (99.49%)	154,792 (98.66%)	15,476 (99.47%)	154,211 (98.29%)
≥ 3	60 (0.39%)	982 (0.63%)	81 (0.52%)	1,478 (0.94%)	80 (0.51%)	2,100 (1.34%)	83 (0.53%)	2,681 (1.71%)

DMA fee codes billed, mean (SD)	0.04 (0.27)	0.07 (0.36)	0.04 (0.30)	0.09 (0.43)	0.05 (0.31)	0.11 (0.49)	0.05 (0.31)	0.14 (0.55)
Physician characteristics[b]								
Number of physicians[c]	1,191	6,525	1,088	6,408	1,012	6,315	875	5,783
Age, mean (SD)	53.56 (12.15)	49.61 (10.95)	54.17 (12.09)	50.04 (10.85)	54.82 (11.93)	50.56 (10.67)	55.83 (12.03)	51.06 (10.43)
Sex, n (%)								
Male	898 (75.40%)	4,343 (66.56%)	817 (75.09%)	4,235 (66.09%)	750 (74.11%)	4,166 (65.97%)	640 (73.14%)	3,774 (65.26%)
Female	293 (24.60%)	2,182 (33.44%)	271 (24.91%)	2,173 (33.91%)	262 (25.89%)	2,149 (34.03%)	235 (25.86%)	2,009 (34.74%)
Years since graduation, mean (SD)	26.12 (12.24)	22.18 (11.13)	26.76 (12.16)	22.61 (11.07)	27.47 (12.07)	23.11 (10.93)	28.44 (12.22)	23.64 (10.73)
IMGs, n (%)	301 (25.27%)	948 (14.53%)	287 (26.38%)	946 (14.76%)	274 (27.08%)	998 (15.80%)	241 (27.54%)	960 (16.60%)

DMI, Diabetes Management Incentive; SD, standard deviation; ADGs, Aggregated Diagnosis Groups; DMA, Diabetic Management Assessment; IMGs, International Medical Graduates.

[a] DMI was introduced on April 1, 2006.

[b] Physician-level characteristics for physicians who provided care to patients in the comparison group versus DMI group.

[c] Based on the DMI group definition used in this study, some of the patients in the DMI group had a family physician practicing traditional fee-for-service (FFS) prior to 2006. Therefore, some of the FFS physicians who provided care to patients in the comparison group were the same physicians who provided care to some of the patients in the DMI group in the above fiscal years. Therefore, there is some overlap in the number of physicians who provided care in each study group.

Table 3.4: Patient- and physician-level characteristics by study group after DMI was introduced

Variables	2006		2007		2008	
	Comparison group	DMI group	Comparison group	DMI group	Comparison group	DMI group
Patient characteristics						
Number of patients	15,559	156,892	15,559	156,892	15,559	156,892
Age, mean (SD)	64.22 (11.97)	63.24 (12.61)	65.22 (11.97)	64.24 (12.61)	66.22 (11.97)	65.24 (12.61)
Sex, n (%)						
Male	8,229 (52.89%)	80,847 (51.53%)	8,229 (52.89%)	80,847 (51.53%)	8,229 (52.89%)	80,847 (51.53%)
Female	7,330 (47.11%)	76,045 (48.47%)	7,330 (47.11%)	76,045 (48.47%)	7,330 (47.11%)	76,045 (48.47%)
Rural residence, n (%)						
No	15,486 (99.53%)	154,788 (98.66%)	15,467 (99.41%)	154,536 (98.50%)	15,444 (99.26%)	154,332 (98.37%)
Yes	73 (0.47%)	2,104 (1.34%)	92 (0.59%)	2,356 (1.50%)	115 (0.74%)	2,560 (1.63%)
Number of ADGs, mean (SD)	5.18 (3.00)	5.10 (3.04)	5.25 (3.03)	5.14 (3.09)	5.37 (3.15)	5.27 (3.20)
Duration of diabetes (years), mean (SD)	9.74 (3.55)	9.62 (3.58)	10.74 (3.55)	10.62 (3.58)	11.74 (3.55)	11.62 (3.58)
Material deprivation quintiles, n (%)						
Q1 (least deprived)	2,686 (17.26%)	33,290 (21.22%)	2,776 (17.84%)	33,863 (21.58%)	2,824 (18.15%)	34,313 (21.87%)

Q2	3,279 (21.07%)	34,530 (22.01%)	3,243 (20.84%)	34,562 (22.03%)	3,294 (21.17%)	34,633 (22.07%)
Q3	3,414 (21.94%)	33,469 (21.33%)	3,429 (22.04%)	33,274 (21.21%)	3,364 (21.62%)	33,160 (21.14%)
Q4	3,206 (20.61%)	29,207 (18.62%)	3,175 (20.41%)	29,020 (18.50%)	3,175 (20.41%)	28.844 (18.38%)
Q5 (most deprived)	2,974 (19.11%)	26,396 (16.82%)	2,936 (18.87%)	26,173 (16.68%)	2,902 (18.65%)	25,942 (16.53%)
Income quintiles, n (%)						
Q1 (lowest income)	3,450 (22.17%)	31,784 (20.26%)	3,438 (22.10%)	31,703 (20.21%)	3,431 (22.05%)	31,641 (20.17%)
Q2	3,854 (24.77%)	35,982 (22.93%)	3,825 (24.58%)	35,722 (22.77%)	3,782 (24.31%)	35,431 (22.58%)
Q3	3,211 (20.64%)	32,314 (20.60%)	3,235 (20.79%)	32,380 (20.64%)	3,263 (20.97%)	32,543 (20.74%)
Q4	2,833 (18.21%)	29,847 (19.02%)	2,846 (18.29%)	30,145 (19.21%)	2,872 (18.46%)	30,317 (19.32%)
Q5 (highest income)	2,211 (14.21%)	26,965 (17.19%)	2,215 (14.24%)	26,942 (17.17%)	2,211 (14.21%)	26,960 (17.18%)
DMI and DMA fee code billings						
Patients with DMI billed, n (%)	0 (0%)	34,381 (21.91%)	0 (0%)	37,574 (23.95%)	0 (0%)	43,032 (27.43%)
Patients with DMA billed, n (%)						
< 3	15,486 (99.53%)	150,660 (96.03%)	15,436 (99.21%)	147,969 (94.31%)	15,280 (98.21%)	144,576 (92.15%)
≥ 3	73 (0.47%)	6,232 (3.97%)	123 (0.79%)	8,923 (5.69%)	279 (1.79%)	12,316 (7.85%)

DMA fee codes billed, mean (SD)	0.05 (0.32)	0.34 (0.79)	0.08 (0.40)	0.42 (0.90)	0.11 (0.51)	0.52 (1.01)
Physician characteristics[a]						
Number of physicians	835	4,800	802	5,238	797	5,600
Age, mean (SD)	56.54 (12.01)	51.16 (10.07)	56.88 (12.14)	51.20 (10.34)	57.11 (12.24)	51.48 (10.50)
Sex, n (%)						
Male	609 (72.93%)	3,044 (63.42%)	584 (72.82%)	3,279 (62.60%)	574 (72.02%)	3,465 (61.88%)
Female	226 (27.07%)	1,756 (36.58%)	218 (27.18%)	1,959 (37.40%)	223 (27.98%)	2,135 (38.12%)
Years since graduation, mean (SD)	29.18 (12.26)	23.75 (10.41)	29.52 (12.48)	23.76 (10.71)	29.79 (12.53)	24.01 (10.90)
IMGs, n (%)	228 (27.31%)	735 (15.31%)	212 (26.43%)	878 (16.76%)	225 (28.23%)	1,013 (18.09%)

DMI, Diabetes Management Incentive; SD, standard deviation; ADGs, Aggregated Diagnosis Groups; DMA, Diabetic Management Assessment; IMGs, International Medical Graduates.

[a] Physician-level characteristics for physicians who provided care to patients in the comparison group versus DMI group.

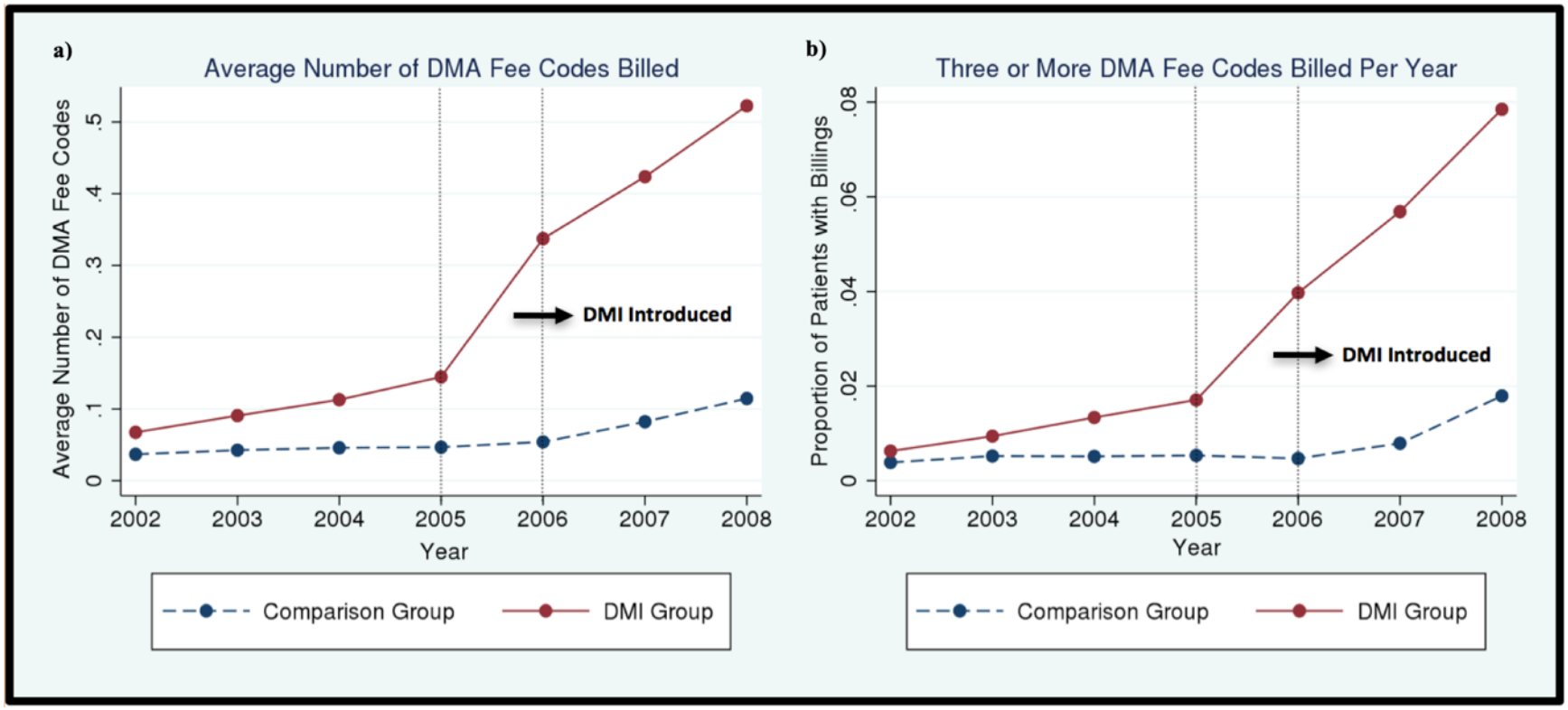

Figure 3.2: a) Average number of DMA fee codes billed for patients by patient's physician; b) Proportion of patients with three or more DMA fee codes billed by patient's physician per year

Both graphs show the trends in the DMA fee code billings from fiscal years 2002 to 2008 by study group. The arrow on the graphs point the period when DMI was introduced.

Table 3.5: Estimated impact of DMI on having three or more DMA fee codes billed by patient's physician

Variables	Model 1: DID Unadjusted Pooled OLS $\hat{\beta}$ (95% CI)	Model 2: DID Adjusted Pooled OLS $\hat{\beta}$ (95% CI)	Model 3: Fixed-Effects DID $\hat{\beta}$ (95% CI)	Model 4: High-dimensional Fixed-Effects DID $\hat{\beta}$ (95% CI)
DMI	0.007*** (0.006, 0.007)	0.002*** (0.002, 0.003)		
Period (Ref: Pre-DMI period)	-0.021*** (-0.023, -0.020)	-0.020*** (-0.022, -0.019)	-0.016*** (-0.017, -0.014)	-0.011*** (-0.016, -0.006)
DMI*Period (DID Effect)	0.042*** (0.040, 0.043)	0.040*** (0.039, 0.042)	0.040*** (0.039, 0.042)	0.021*** (0.015, 0.026)
τ (time trend)	0.008*** (0.007, 0.008)	0.008*** (0.007, 0.008)	-2.805*** (-3.197, -2.413)	
Patient characteristics				
Age		0.002*** (0.001, 0.002)		
Age-squared		-0.000*** (-0.000, -0.000)	0.000*** (0.000, 0.000)	0.002*** (0.002, 0.002)
Female (Ref: Male)		-0.003*** (-0.004, -0.002)		
Rural residence (Ref: Urban)		0.003 (-0.002, 0.007)	-0.003 (-0.009, 0.002)	-0.001 (-0.008, 0.006)
Number of ADGs		-0.001*** (-0.001, -0.001)	-0.001*** (-0.001, -0.001)	-0.001*** (-0.001, -0.001)
Duration of diabetes (years)		0.000** (0.000, 0.000)	2.799*** (2.407, 3.191)	0.332 (-0.593, 1.257)
Material deprivation quintiles (Ref: Q1 (least deprived))				
Q2		0.002** (0.000, 0.003)	0.003*** (0.001, 0.005)	-0.000 (-0.003, 0.002)

Q3		0.001 (-0.000, 0.003)	0.003*** (0.001, 0.006)	-0.002 (-0.004, 0.001)
Q4		0.003*** (0.002, 0.005)	0.007*** (0.005, 0.009)	0.000 (-0.003, 0.004)
Q5 (most deprived)		0.003*** (0.002, 0.005)	0.008*** (0.005, 0.011)	-0.000 (-0.004, 0.003)
Income quintiles (Ref: Q1 (lowest income))				
Q2		0.001 (-0.001, 0.002)	0.003*** (0.002, 0.005)	0.001 (-0.001, 0.003)
Q3		-0.000 (-0.002, 0.001)	0.004*** (0.002, 0.006)	0.001 (-0.002, 0.003)
Q4		-0.002** (-0.004, -0.000)	0.004*** (0.002, 0.006)	-0.000 (-0.003, 0.002)
Q5 (highest income)		-0.002** (-0.004, -0.001)	0.005*** (0.003, 0.008)	-0.001 (-0.003, 0.002)
Physician characteristics				
Age		0.000** (0.000, 0.001)	0.004*** (0.004, 0.005)	0.000 (-0.001, 0.001)
Age-squared		-0.000*** (-0.000, -0.000)	-0.000*** (-0.000, -0.000)	-0.000 (-0.000, 0.000)
Female (Ref: Male)		0.002*** (0.001, 0.003)	0.004*** (0.002, 0.007)	0.001 (-0.003, 0.004)
IMG status (Ref: CMG)		-0.007*** (-0.008, -0.006)	0.001 (-0.001, 0.004)	0.002 (-0.003, 0.007)
Constant	-15.237*** (-15.710, -14.764)	-15.185*** (-15.718, -14.652)	150.173*** (129.136, 171.210)	
R-squared	0.021	0.026	0.029	0.528
Number of patients	172,451	172,451	172,451	172,451
Observations	1,207,157	1,207,157	1,207,157	1,207,157

DMI, Diabetes Management Incentive; DMA, Diabetic Management Assessment; DID, Difference-in-difference; OLS, Ordinary least squares; 95% CI, 95% confidence interval; Ref, Reference; ADGs, Aggregated Diagnosis Groups; IMG, International Medical Graduate; CMG, Canadian Medical Graduate.
Robust 95% CI in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Table 3.6: Estimated impact of DMI on having three or more DMA fee codes billed by patient's physician in the two subgroups

Outcome Variable	Model 1: DID Unadjusted Pooled OLS $\hat{\beta}_3$ (95% CI)		Model 2: DID Adjusted Pooled OLS[a] $\hat{\beta}_3$ (95% CI)		Model 3: Fixed-Effects DID[a] $\hat{\beta}_3$ (95% CI)		Model 4: High-dimensional Fixed-Effects DID[a] $\hat{\beta}_3$ (95% CI)	
Subgroup Analysis #1: Comorbidity (Comparing patients with below versus at or above median number of ADGs at baseline)								
	<4 ADGs at baseline	≥ 4 ADGs at baseline	<4 ADGs at baseline	≥ 4 ADGs at baseline	<4 ADGs at baseline	≥ 4 ADGs at baseline	<4 ADGs at baseline	≥ 4 ADGs at baseline
Three or more DMA fee codes billed	0.043*** (0.041, 0.046)	0.041*** (0.039, 0.042)	0.042*** (0.040, 0.044)	0.039*** (0.038, 0.041)	0.041*** (0.039, 0.044)	0.040*** (0.038, 0.041)	0.022*** (0.014, 0.030)	0.020*** (0.015, 0.025)
Subgroup Analysis #2: Sex (Comparing males versus females)								
	Males	Females	Males	Females	Males	Females	Males	Females
Three or more DMA fee codes billed	0.045*** (0.043, 0.047)	0.038*** (0.036, 0.040)	0.044*** (0.042, 0.045)	0.037*** (0.035, 0.039)	0.043*** (0.041, 0.045)	0.037*** (0.036, 0.039)	0.023*** (0.017, 0.029)	0.018*** (0.012, 0.024)

DMI, Diabetes Management Incentive; DMA, Diabetic Management Assessment; DID, Difference-in-difference; OLS, Ordinary least squares; 95% CI, 95% confidence interval; ADGs, Aggregated Diagnosis Groups.

[a] Models 2-4 controlled for patient characteristics (age, age-squared, sex, rural residence, number of Aggregated Diagnosis Groups, duration of diabetes, material deprivation quintiles, neighborhood income quintiles), and physician characteristics (age, age-squared, sex, International Medical Graduate status).

Robust 95% CI in parentheses.

*** $p<0.01$

Note: Each of the two subgroup analyses were performed separately using Models 1-4 each. Full regression results are available upon request.

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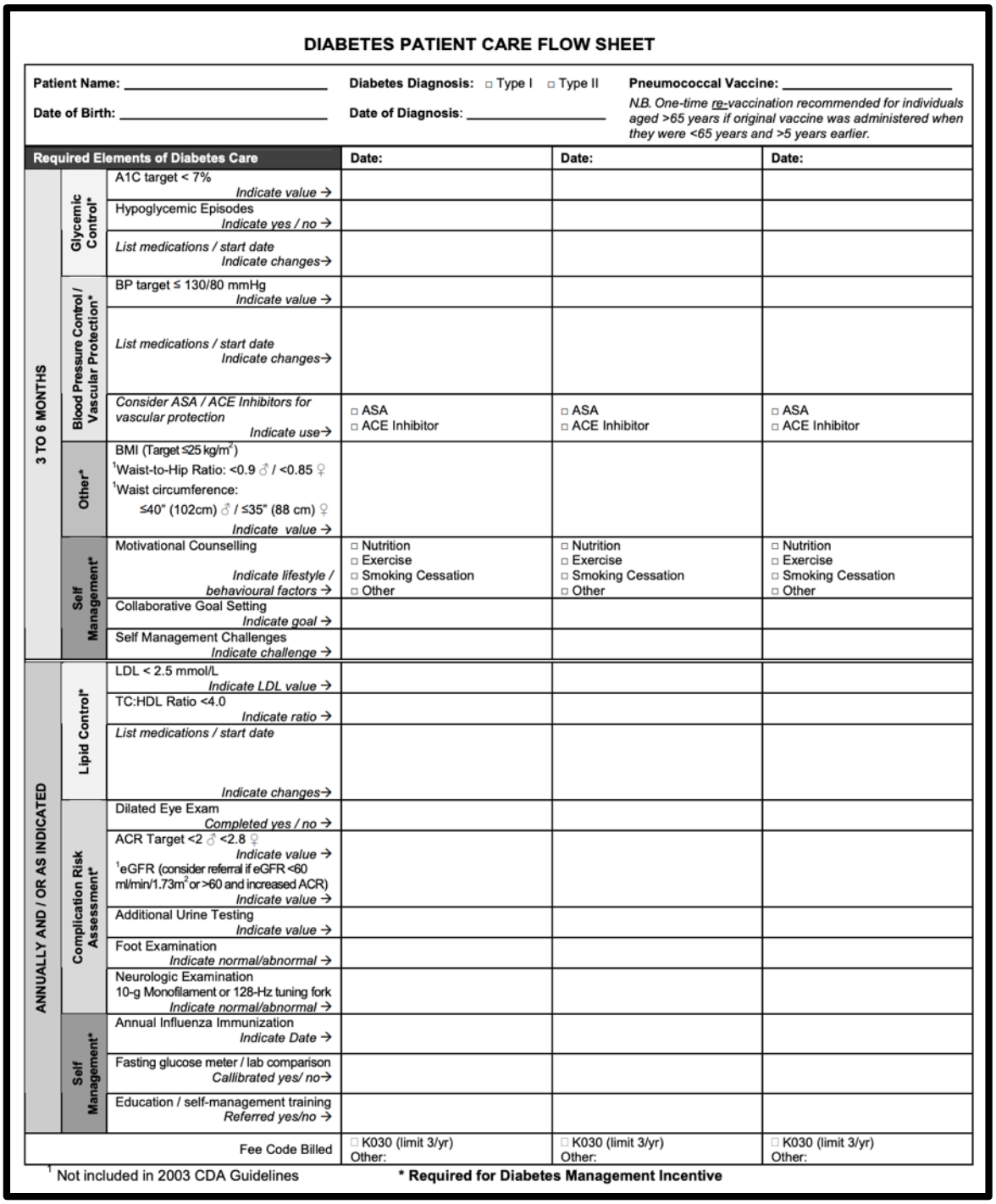
Appendices

Appendix A3.1: Information on the DMI and DMA

Table 3.7: Additional information on the Diabetes Management Incentive (DMI) and Diabetic Management Assessment (DMA) fee code

Diabetes care Billing Codes	Additional Notes
DMI (Q040)	• 'Payable to FPs providing ongoing management to a diabetic patient in consistent with the Clinical Practice Guidelines set by Diabetes Canada • FPs must provide documentation that tracks the following at minimum: a. HbA1C, cholesterol, lipids, body mass index, weight, blood pressure, and medication dosage b. Discussion and preventive measures must be offered that includes vascular protection, influenza and pneumococcal vaccination c. Patient self-management support and health promotion counselling d. Albumin to creatinine ratio e. Discussion and offer referral for dilated eye examinations f. Foot and neurologic examinations • A flow sheet or any other documentation that records all the required elements from the most current Diabetes Canada's Clinical Practice Guidelines that were provided to the patient during the previous 12 months must be kept in the patient's medical record'[27]
DMA (K030)	• 'All-inclusive service paid to the most responsible physician for providing continuous diabetes management to the diabetic patient • Service includes: an intermediate assessment, level 2 paediatric assessment, or a partial assessment that focuses on the diabetic target organ systems, counselling, and a diabetic flow sheet must be kept in the patient's medical record • Flow sheet must track the following: • HbA1C, lipids, cholesterol, urinalysis, medication dosage, blood pressure, fundal examination, weight, body mass index, and peripheral vascular examination • If the above record is not kept or if the DMA is provided to the patient the same day as any other consultation or visit by the same physician, the DMA will be paid at no cost to the physician'[27]

DMI, Diabetes Management Incentive; DMA, Diabetic Management Assessment; FPs, family physicians; HbA1C, glycated hemoglobin.
Source: (Ministry of Health and Long-Term Care, 2015)[27]
Hyperlink:http://www.health.gov.on.ca/en/pro/programs/ohip/sob/physserv/sob_master20181115.pdf



DIABETES PATIENT CARE FLOW SHEET

Patient Name: _____ **Diabetes Diagnosis:** □ Type I □ Type II **Pneumococcal Vaccine:** _____

Date of Birth: _____ **Date of Diagnosis:** _____ *N.B. One-time re-vaccination recommended for individuals aged >65 years if original vaccine was administered when they were <65 years and >5 years earlier.*

		Required Elements of Diabetes Care	Date:	Date:	Date:
3 TO 6 MONTHS	Glycemic Control*	A1C target < 7% *Indicate value →*			
		Hypoglycemic Episodes *Indicate yes / no →*			
		List medications / start date *Indicate changes→*			
	Blood Pressure Control / Vascular Protection*	BP target ≤ 130/80 mmHg *Indicate value →*			
		List medications / start date *Indicate changes→*			
		Consider ASA / ACE Inhibitors for vascular protection *Indicate use→*	□ ASA □ ACE Inhibitor	□ ASA □ ACE Inhibitor	□ ASA □ ACE Inhibitor
	Other*	BMI (Target ≤25 kg/m²) [1]Waist-to-Hip Ratio: <0.9 ♂ / <0.85 ♀ [1]Waist circumference: ≤40" (102cm) ♂ / ≤35" (88 cm) ♀ *Indicate value →*			
	Self Management*	Motivational Counselling *Indicate lifestyle / behavioural factors →*	□ Nutrition □ Exercise □ Smoking Cessation □ Other	□ Nutrition □ Exercise □ Smoking Cessation □ Other	□ Nutrition □ Exercise □ Smoking Cessation □ Other
		Collaborative Goal Setting *Indicate goal →*			
		Self Management Challenges *Indicate challenge →*			
ANNUALLY AND / OR AS INDICATED	Lipid Control*	LDL < 2.5 mmol/L *Indicate LDL value →*			
		TC:HDL Ratio <4.0 *Indicate ratio →*			
		List medications / start date *Indicate changes→*			
	Complication Risk Assessment*	Dilated Eye Exam *Completed yes / no →*			
		ACR Target <2 ♂ <2.8 ♀ *Indicate value →*			
		[1]eGFR (consider referral if eGFR <60 ml/min/1.73m² or >60 and increased ACR) *Indicate value →*			
		Additional Urine Testing *Indicate value →*			
		Foot Examination *Indicate normal/abnormal →*			
		Neurologic Examination 10-g Monofilament or 128-Hz tuning fork *Indicate normal/abnormal →*			
	Self Management*	Annual Influenza Immunization *Indicate Date →*			
		Fasting glucose meter / lab comparison *Callibrated yes/ no→*			
		Education / self-management training *Referred yes/no →*			
		Fee Code Billed	□ K030 (limit 3/yr) Other:	□ K030 (limit 3/yr) Other:	□ K030 (limit 3/yr) Other:

[1] Not included in 2003 CDA Guidelines

*** Required for Diabetes Management Incentive**

Figure 3.3: Sample diabetes patient care flow sheet from April 2006

Source: Ministry of Health and Long-Term Care: Diabetes Management Incentive.[25]
Hyperlink: http://www.anl.com/MOHGUIDE/00 Diabetes Management Incentive - April 2006.pdf

Appendix A3.2: DMA Fee Code Billings Compared at Baseline and Final Year

Table 3.8: DMA fee code billings compared between comparison and DMI group at baseline and final fiscal year

Variables	2002			2008		
	Comparison group (n = 15,559)	**DMI group** (n = 156,892)	***p*-value**	**Comparison group** (n = 15,559)	**DMI group** (n = 156,892)	***p*-value**
Patients with DMA fee codes billed, n (%)						
< 3	15,499 (99.61%)	155,910 (99.37%)	<0.001	15,280 (98.21%)	144,576 (92.15%)	<0.001
≥ 3	60 (0.39%)	982 (0.63%)		279 (1.79%)	12,316 (7.85%)	
Average number of DMA fee codes billed, mean (SD)	0.04 (0.27)	0.07 (0.36)	<0.001	0.11 (0.51)	0.52 (1.01)	<0.001

DMI, Diabetes Management Incentive; DMA, Diabetic Management Assessment; SD, standard deviation.

Appendix A3.3: Linear Probability Model versus Logit Model

Table 3.9: The estimated impact of DMI on having three or more DMA fee codes billed by patient's physician compared between the Linear Probability Model (LPM) versus a Logit model

Variables	Model 1: DID Unadjusted Pooled OLS (LPM) Average Marginal Effect[a] (95% CI)	DID Unadjusted Pooled Logit Model Average Marginal Effect[a] (95% CI)	Model 2: DID Adjusted Pooled OLS (LPM) Average Marginal Effect[a] (95% CI)	DID Adjusted Pooled Logit Model Average Marginal Effect[a] (95% CI)
DMI	0.024*** (0.024, 0.025)	0.024*** (0.024, 0.025)	0.020*** (0.019, 0.021)	0.023*** (0.022, 0.024)
Period (Ref: Pre-DMI period)	0.016*** (0.015, 0.017)	0.012*** (0.011, 0.013)	0.016*** (0.015, 0.017)	0.011*** (0.010, 0.012)
DMI*Period (DID Effect)	0.042*** (0.040, 0.043)	0.042*** (0.040, 0.043)	0.040*** (0.039, 0.042)	0.040*** (0.038, 0.041)
τ (time trend)	0.008*** (0.007, 0.008)	0.010*** (0.009, 0.010)	0.008*** (0.007, 0.008)	0.010*** (0.009, 0.010)
Patient Characteristics				
Age			0.002*** (0.001, 0.002)	0.004*** (0.004, 0.005)
Age-squared			-0.000*** (-0.000, -0.000)	-0.000*** (-0.000, -0.000)
Female (Ref: Male)			-0.003*** (-0.004, -0.002)	-0.003*** (-0.004, -0.002)
Rural residence (Ref: Urban)			0.003 (-0.002, 0.007)	0.002 (-0.002, 0.005)
Number of ADGs			-0.001*** (-0.001, -0.001)	-0.001*** (-0.001, -0.001)

Duration of diabetes (years)			0.000** (0.000, 0.000)	0.000*** (0.000, 0.000)
Material deprivation quintiles (Ref: Q1 (least deprived))				
Q2			0.002** (0.000, 0.003)	0.001* (-0.000, 0.003)
Q3			0.001 (-0.000, 0.003)	0.001 (-0.001, 0.002)
Q4			0.003*** (0.002, 0.005)	0.003*** (0.001, 0.004)
Q5 (most deprived)			0.003*** (0.002, 0.005)	0.003*** (0.001, 0.005)
Income quintiles (Ref: Q1 (lowest income))				
Q2			0.001 (-0.001, 0.002)	0.001 (-0.001, 0.002)
Q3			-0.000 (-0.002, 0.001)	-0.000 (-0.002, 0.001)
Q4			-0.002** (-0.004, -0.000)	-0.002*** (-0.004, -0.001)
Q5 (highest income)			-0.002** (-0.004, -0.001)	-0.003*** (-0.004, -0.001)
Physician Characteristics				
Age			0.000** (0.000, 0.001)	0.002*** (0.001, 0.002)
Age-squared			-0.000*** (-0.000, -0.000)	-0.000*** (-0.000, -0.000)
Female (Ref: Male)			0.002*** (0.001, 0.003)	0.002*** (0.000, 0.003)
IMG status (Ref: CMG)			-0.007*** (-0.008, -0.006)	-0.008*** (-0.009, -0.007)
Number of patients	172,451	172,451	172,451	172,451
Observations	1,207,157	1,207,157	1,207,157	1,207,157

DMI, Diabetes Management Incentive; DMA, Diabetic Management Assessment; DID, Difference-in-difference; OLS, Ordinary least squares; LPM, Linear Probability Model; 95% CI, 95% confidence interval; Ref, Reference; ADGs, Aggregated Diagnosis Groups; IMG, International Medical Graduate; CMG, Canadian Medical Graduate.

[a] Average marginal effect indicates the effect of the variable on the probability of having three or more DMA fee codes billed by the patient's physician. The estimated coefficient ($\hat{\beta}$) in the LPM can be directly interpreted as the average marginal effect, however, this cannot be done for the logit model. For the logit model, the average marginal effect is calculated by first determining the derivative of the equation for the logistic regression with respect to a specific variable of interest.[57,60] Following this, the observed values in the data were used to calculate the average marginal effect. The average marginal effect was calculated using the margins command in Stata 15.1.

Robust 95% CI in parentheses.

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

Chapter 4

4 The Impact of the Diabetes Management Incentive on Hospitalizations and Mortality Risk in Ontario

4.1 Introduction

Diabetes is one of the most common chronic disease in the world, and was estimated to be the seventh leading cause of death in 2016.[1] In 2017, more than 2.2 million Canadians aged 12 and older were living with diabetes.[2] From this population, 965,100 individuals were from the province of Ontario.[2] The estimated direct cost of diabetes to the healthcare system in Ontario was $1.5 billion in 2018,[3] and hospitalizations account for a large portion of this cost.[4]

Hospitalizations in patients with diabetes are often due to diabetes-related short-term and long-term complications. Patients with diabetes develop a number of short-term complications such as hypoglycemia, and complications caused from severe hyperglycemia such as diabetic ketoacidosis and hyperosmolar hyperglycemic state.[5–8] Over time, patients with diabetes develop micro- and macrovascular complications which are complications due to damages in the small and large blood vessels respectively.[7] Some of the long-term complications include retinopathy, nephropathy, neuropathy, and circulatory complications.[5,8,9] It is no wonder that patients with diabetes are more likely to be hospitalized. In 2008/09, compared to those without diabetes, diabetic individuals were three times more likely to be hospitalized for cardiovascular disease, 12 times more likely to be hospitalized for an end-stage renal disease, and 20 times more likely to be hospitalized for non-traumatic lower limb amputation.[3,7] Diabetes complications do not only lead to hospitalizations, but can also be linked with premature death.[3,10]

Although there is currently no cure to diabetes, effectively monitoring and managing the disease can reduce the incidence of diabetes-related complications. Specifically, effective diabetes management at primary care settings can reduce the risk of hospitalizations, thus diabetes is an ambulatory care sensitive condition (ACSC).[5,6,11–15] Patients who have access to a family physician (FP) providing sufficient care will order necessary tests, and

help patients control and manage their disease by targeting modifiable risk factors, thus, reducing the risk of hospitalizations for acute and long-term complications.[6,11,13,16,17] Effective diabetes management can also reduce the risk of hospitalization costs, and mortality from several causes such as chronic kidney disease, stroke, and ischaemic heart disease.[16,18]

In an effort to improve access to primary care and place more emphasis on chronic disease management, Ontario introduced a primary care reform in the early 2000s. The Ontario government developed a number of new primary care organizational and funding models (i.e. Patient Enrolment Models (PEMs)) which physicians and patients can voluntarily enroll in.[19] Prior to the reform, FPs were paid through a fee-for-service (FFS) basis.[20] However, physicians who were practicing in the new models were reimbursed through various blends of payments including fee-for-service, capitation (fixed payment per patient per annum), salary, and pay-for-performance (P4P) incentives for preventive care services and chronic disease management such as diabetes.[19,21]

P4P incentives are monetary rewards given to physicians in addition to their existing base payment (i.e. FFS or capitation) for achieving specific performance targets such as improving preventive and chronic care provided to patients.[22,23] Some evidence suggests that P4P incentives increase the services provided to diabetic patients (e.g. ordering tests and prescribing medications), and improve intermediate outcomes (e.g. hemoglobin A1C (HbA1C), cholesterol, blood pressure, and serum creatinine levels).[24] Overtime, improvements in the patient's health, and reduction in hospitalization costs are expected.[11,12,25]

Several countries have introduced P4P incentives to improve diabetes management at primary care such as the United Kingdom (UK), Taiwan, Italy, and Canada.[6,11,12,22,25] However, the literature on the effect of these incentives on hospitalizations and mortality have been mixed. In England, a longitudinal study found that after the introduction of the Quality and Outcomes Framework (QOF) P4P scheme, the admission rate for ACSCs including diabetes incentivized under this program, was lower than the rate for non-incentivized ACSCs and non-ACSCs.[23] In Taiwan, two studies found that patients with

diabetes in the Taiwan's P4P program for diabetes had fewer hospitalizations compared to those who were not enrolled in the program.[25,26] In Hawaii, Chen *et al.* (2010)[27] found diabetic patients who saw a P4P-participating physician for three years consecutively were less likely to be hospitalized compared to those who visited a non-P4P participating physician. In Italy, Fiorentini *et al*. (2011)[15] found P4P and Pay-for-Compliance (P4C) incentives decreased the probability of avoidable hospitalizations for several diseases, including diabetes in the patient population. In contrast, the Pay-for-Participation (P4Pa) incentive had a statistically significant negative effect only when assessed in the type 2 diabetic patient subpopulation.[15]

A few studies found that P4P incentives for diabetes care have no effect on diabetes-related hospitalizations. For instance, Bottle *et al.* (2008)[28] found a nonsignificant association between the QOF points for diabetes care and diabetes admissions in patients under the age of 60. In the QOF, family practises earned points for patients who attained the targets for clinical indicators.[23] Bruni *et al.* (2009)[6] found the P4C in Italy did not have a significant effect on hyperglycemic emergency admissions in patients with type 2 diabetes. One study conducted in Canada observed that the policy change at primary care in British Columbia (BC) in 2003 (i.e. introduced financial incentives for disease management such as diabetes to FPs) had no significant effect on the diabetes-related hospitalization rate.[11] In contrast, one study in Taiwan found an increase in emergency visits for diabetic hypoglycemia.[29]

To date, very limited literature exists on the relationship between financial incentives for diabetes care and hospitalization costs. A study from Taiwan found that diabetic patients in the P4P program had lower expenses for inpatient services (i.e. diabetes-related hospitalizations) compared to those not enrolled in the program.[25] Cheng *et al.* (2012)[26] also observed similar findings for patients enrolled in the P4P program in Taiwan consecutively for five years compared to their comparison group. Two other studies briefly mentioned the estimated reduction in hospitalization costs that came with the decrease in hospitalizations after QOF was introduced in UK.[12,23] In contrast, one study that examined the relationship between the quality of disease management after QOF was

introduced, and total hospital costs for ten chronic diseases (including diabetes), found a significant reduction in hospital costs for stroke care only.[13]

The literature on the effect of financial incentives for diabetes care on mortality also produced conflicting results. Fleetcroft *et al.* (2010)[30] estimated the potential mortality reduction associated with the QOF P4P scheme (2004 and 2006 versions) in England. Findings from the study revealed potential mortality reduction was seen over one year with the 2004 version, however, no additional mortality reduction was seen with the 2006 contract. Moreover, diabetes was one of the diseases with the largest estimated mortality reduction.[30] Likewise, Lin *et al.* (2016)[31] found that the risk of all-cause mortality was lower in type 2 diabetic patients who were part of the P4P program in Taiwan compared to those who were not. Conversely, two longitudinal studies that assessed the QOF scheme found no statistical significant effect on mortality.[16,17] This is contrast to Fleetcroft *et al.* (2010),[30] which was a cross-sectional study.

Overall, the relationship between P4P incentives for diabetes care on patient outcomes (i.e. hospitalizations, mortality), and hospitalization costs have been mixed. The reasons behind these mixed findings are due to the differences in the institutional setting of the study, the design of the study, and the context of the P4P incentive.[23,31] Additionally, certain limitations from some of the existing studies such as the use of an ecological study design, not controlling for potential confounders, and the lack of a control group may also explain the inconsistent findings.

In Ontario, the Ministry of Health and Long-Term Care (MOHLTC) introduced a P4P incentive for diabetes management to FPs on April 1, 2006 called the Diabetes Management Incentive (DMI).[22,32–34] This incentive is a $60 annual payment per patient provided to FPs for delivering ongoing management of diabetes to patients, and tracking the required elements for diabetes care in accordance with the Clinical Practice Guidelines set by Diabetes Canada (Appendix A3.1).[22,32–34] To claim the DMI, the FP must bill the Q040 code for their patient once per 12-month period.[32,33,35] When DMI was first introduced, only FPs practicing in specific PEMs were eligible to bill for their enrolled patients (see Table 3.1 for the specific PEMs). DMI was ineligible to FPs

practicing in the traditional FFS, FPs not practicing in the specific PEMs eligible for DMI, and non-enrolled patients (i.e. patients not enrolled to FPs practicing in PEMs). However, as of April 1, 2009 all FPs are eligible to bill the DMI, and regardless of the patient's enrollment status.[22,33]

As of now, it is unknown if the introduction of DMI is associated with a reduction in hospitalizations, hospitalization costs, and mortality risk in Ontario. Moreover, findings from existing literature cannot be applied to the DMI context due to the inconsistent results, study limitations, and the differences in the P4P incentives' design. Therefore, the objective of this study is to assess the impact of DMI on diabetes-related hospitalizations, hospitalization costs, and mortality risk in patients diagnosed with diabetes in Ontario. This will be examined comparing patients enrolled to FPs practicing in PEMs eligible for DMI to patients affiliated with a FP practicing in the traditional FFS.

4.2 Methods

4.2.1 Data Sources

Data for this study were obtained from multiple healthcare administrative databases housed at ICES. These datasets were linked using unique encoded identifiers and analyzed at ICES. Overall, this data was a longitudinal population-based data that extended from fiscal years (April 1st to March 31st of the following year) 2002 to 2008.

The Ontario Diabetes Dataset (ODD) was used to identify adult patients (19 years and older) diagnosed with diabetes, and it contains those diagnosed from April 1, 1991 and onwards.[5,36] The ODD identified an adult diabetic patient if within two years they had at least two Ontario Health Insurance Plan (OHIP) claims with a diabetes diagnosis, one diabetes-related hospital admission, or one OHIP fee code: Q040 (DMI), K029 (Insulin Therapy Support), K030 (Diabetic Management Assessment [DMA]), K045 (Diabetes management by a specialist), and K046 (Diabetes team management) claim.[5,36] Individuals with gestational diabetes are not included in the ODD, and this database does not distinguish between type 1 and type 2 diabetes.[37] Although, the majority of the individuals included would be expected to have type 2 diabetes.[37] The ODD provides information regarding the patient's diagnosis such as the age or date they were first

diagnosed. The Canadian Institute for Health Information (CIHI) Discharge Abstract Database (DAD) was used to obtain information on inpatient hospitalizations. The CIHI-DAD provided patient demographic, administrative, and clinical information for hospital discharges in Ontario.[5,38] Additionally, the intensity of resources consumed by the patient during their stay at the hospital can be determined using CIHI-DAD.[38,39]

The Registered Persons Database (RPDB) was used to obtain demographic information such as age, and sex for those eligible for the Ontario's healthcare coverage (OHIP).[5,36,40] The RPDB and the Statistics Canada Postal Code Conversion File (PCCF) were used to determine patient's income (measured using neighbourhood income quintiles) at the census dissemination area (DA) level, and rural residence.[41] Individuals were considered to be in rural and small town if they were in areas with an urban area population less than 10,000, and in rural areas.[42] The Ontario Marginalization Index was used to determine material deprivation, the inability for individuals and communities to access and attain basic material needs.[43–45] The Aggregated Diagnosis Groups (ADGs) from the Johns Hopkins Adjusted Clinical Groups (ACGs) System Version 10.0 were used to measure patient's comorbidity.[46] Each patient can have between zero and 32 ADGs[47,48]; and the more ADGs they have the more comorbid they are.

Two databases, the Client Agency Program Enrolment (CAPE) tables and Corporate Provider Database (CPDB), were used to identify patients enrolled to FPs practicing in PEMs, and identify the PEM they were enrolled to. A virtual roster method was used for patients who were not formally enrolled to a FP from CAPE. This method linked the patient to the FP who claimed the highest number of OHIP billings for 18 common primary care fee codes during the previous two years.[49,50] Information on the FP's eligibility were also obtained from the CPDB. The FP's demographic information (i.e. age, sex, International Medical Graduate (IMG) status, year they graduated from their medical degree) were obtained from the ICES Physician Database (IPDB). Lastly, the OHIP claims database provided details on the OHIP billings that were claimed for the patient by their FPs in Ontario.

4.2.2 Study Population

Adults diagnosed with diabetes at or between the ages 19 to 75 years from April 1st, 1991 to April 1st of each fiscal year from 2002 to 2008 were identified using the ODD. Patients were excluded from the study if they had missing data for age, sex, or ICES key number (IKN) for fiscal years 2002 to 2008, or died on or before April 1st, 2002. The IKN is an unique encoded patient identifier. Patients were further excluded from the study if they had missing data for any of the other patient- and physician-level characteristics used in this study (listed in Section 4.2.3), or for the location of physician's practice using Local Health Integration Networks (LHINs). Patients were then classified into one of the two study groups. Patients with FPs exposed to DMI for at least three years (2006 to 2008 fiscal years) were part of the DMI eligible group. The FPs must be in the 'Eligible for DMI' section from Table 3.1. Conversely, patients affiliated with a FP practicing in the traditional FFS throughout the study period were part of the DMI ineligible group (i.e. patients' FPs were never exposed to DMI during the study period). The DMI eligible and DMI ineligible groups are labelled as the "DMI group" and "comparison group," respectively throughout the thesis. Patients who did not fit the criteria for either group were excluded from the study. The above inclusion/exclusion criterions left the study with 2,760,989 patient-year observations (DMI group: 2,652,076 observations; comparison group: 108,913 observations). This dataset was an unbalanced panel which implies that not all patients in the dataset had observations or data for all years in the study.

A couple of issues with using an unbalanced panel data are: potential computation and estimation issues,[51] and potential efficiency loss with having missing data[52] which affects the validity of the study.[53] Therefore, patients from the balanced panel (i.e. patients with observations for every fiscal year from 2002 to 2008) were selected as the main study population. The balanced panel has 1,207,157 patient-year observations. The unbalanced panel data were still used to perform a sensitivity analysis to assess the robustness of the study findings. A flow chart depicting the process of how the study population was selected is found on Figure 3.1, while Table 3.2 shows the number of patients in the DMI

and comparison groups for each fiscal year for the main study population (i.e. balanced panel) and unbalanced panel data.

4.2.3 Variables

The exposure variable of interest in this study was a dichotomous variable that indicated whether the patient's FP was eligible to bill the DMI during the fiscal years 2006 to 2008. This variable took a value of 1 for patients in the DMI group and a value of 0 for those in the comparison group. For the outcome variables of interest, there were three main types: (1) hospitalizations for diabetes-related complications divided into two categories: (i) short-term and (ii) long-term; (2) associated hospitalization costs for diabetes-related complications that were: (i) short-term and (ii) long-term; and (3) Mortality Risk Score (MRS). The hospitalization outcomes were measured by examining each fiscal year and identifying whether or not the patient had at least one hospitalization for diabetes-related short-term complications in that year, and also separately done for long-term complications. This was denoted using two dichotomous variables; one for short-term complications, and the other for long-term complications. In addition, there were two other variables that measured the number of hospitalizations the patient had during each year for each type respectively. Similar to Petrosyan *et al*. (2017)[5], the diabetes-related hospitalizations were identified by focusing on the most responsible diagnosis code (using the 10th revision of the International Classification of Diseases [ICD-10] codes) of diabetes-related short-term and long-term complications as defined in the Organization for Economic Co-operation and Development (OECD)'s Healthcare Quality Indicator (HCQI) Project.[54–57] The hospitalizations for diabetes-related short-term complications included were those with a diagnosis of diabetic ketoacidosis, mixed ketoacidosis, hyperglycemic hyperosmolar coma, or hypoglycemic or insulin coma.[5,56,57] The diabetes-related long-term complications included were circulatory complications, neurologic, ophthalmic, renal, or multiple complications.[5,56,57] Appendix A4.1 shows the specific ICD-10 codes that coded these complications.

The hospitalization cost outcomes measured the associated costs for the patient's hospitalization(s) for diabetes-related (i) short-term complications, and (ii) long-term complications for each fiscal year. Patients who were not hospitalized for diabetes-related

short-term complications for that fiscal year took a value of zero for their cost outcome for short-term complications; this was also similarly done for long-term complications. Hospitalization costs were computed using the ICES costing macro, which calculated the cost for each inpatient case by multiplying the resource intensity weight (RIW) with the cost per weighted case (CPWC) (see Box 4.1).[39] Each hospital inpatient has a RIW, the amount of hospital resources used by that inpatient compared to an average inpatient (RIW = 1.0000).[39,58] To determine the RIW, patients are first assigned to a Case Mix Group based on their clinical and resource utilization in the hospital, and then are stratified into an age group under the Case Mix Group. A base RIW is already calculated for each Case Mix Group age group, thus, for each case their RIW is adjusted based on their comorbidity, length of stay, and interventions received. The CPWC is the unit cost for acute inpatient hospitalizations, and is calculated by summing up the total hospital costs for inpatient acute care in Ontario, and divided by the sum RIWs for all Ontario cases (Box 4.1).[39] All hospitalization costs were standardized to 2002 Canadian dollars.

The last outcome was the MRS which predicts patient's risk of all-cause death within one year. The MRS is a point-scoring system calculated for patients each fiscal year using their age, sex, and 28 of the 32 ADG categories according to Austin & Walraven (2011).[48] To calculate the patient's MRS, the following must be summed together: patient's age minus 20 years, the component for patient's sex (i.e. if patient was a male then they got a score of three), and the component scores for each of the ADGs the patient had (see Box 4.2).[48] The scores for each of the 28 ADGs, sex, and age used to calculate MRS is presented in Austin & Walraven.[48] The MRS ranges from negative to positive scores, and the lower the score, the lower the patient's risk of death is within one year.

Variables for patient- and physician-level characteristics were also included. Patient-level characteristics included were age, sex, rural residence, comorbidity (measured using the number of ADGs), duration of diabetes (measured in years), income quintiles (ranged from quintile 1 (Q1) = lowest income to quintile 5 (Q5) = highest income), and material deprivation (ranged from Q1 = least deprived to Q5 = most deprived). The physician-

level characteristics included were age, sex, years since graduation (measured their experience), and IMG status (0 = Canadian Medical Graduate (CMG), and 1 = IMG).

4.2.4 Statistical Analysis

4.2.4.1 Main Analysis

Descriptive data were obtained to describe patient-level characteristics, DMI billings, and outcome measures by study group for each fiscal year from 2002 to 2008. The continuous variables were described using mean and standard deviations, while categorical variables were expressed as frequencies and percentages. The number of hospitalizations for diabetes-related short-term complications, and the associated cost outcome were focused only in those who had been hospitalized for this complication at least once during the study period. This was done to examine how the number of hospitalizations, and costs changed over time in patients hospitalized for that complication. Furthermore, it ensures us that the outcomes are focused on the same group of patients each year. A similar approach was adopted for the number of hospitalizations, and associated cost for long-term complications. Outcome measures were compared between the DMI and comparison group at baseline (2002) and final year (2008), using a chi-square test for the dichotomous hospitalization variables, Wilcoxon rank-sum test for the number of hospitalizations and hospitalization cost variables, and a t-test for MRS. This was performed to detect if differences in the outcomes were present between the two study groups at the beginning and end of the study period. Descriptive statistics were also reported for physician-level characteristics of FPs of patients in the DMI group, and FPs of patients in the comparison group.

This study used multivariable linear regression models with a difference-in-difference (DID) approach to assess the relationship between DMI and each of the following outcomes: diabetes-related hospitalizations, associated costs, and MRS. A natural-log transformation was performed for the number of diabetes-related hospitalizations, and associated costs. This transformation was applied to help alleviate the skewness found in the residuals.[59] Moreover, there was a large number of zero values for the number of hospitalizations and cost outcomes, and the natural logarithm function of zero is

undefined, thus, a value of one was added to all values for those variables prior to the transformation to ensure no zero values were present.[59] In addition, similar to the descriptive statistics, analyses performed for the number of hospitalizations and cost outcome for diabetes-related short-term complications were performed only in those hospitalized at least once for this complication throughout the study. For the number of hospitalizations, and the associated cost outcome for diabetes-related long-term complications, a similar approach was used.

The DID approach computes the difference in the outcomes between the DMI and comparison group, comparing before-and-after DMI was introduced.[60,61] The regression models used included a dichotomous variable that indicated if the patient was in the DMI or comparison group, a pre-post binary variable that indicated if the observation was from before DMI was introduced (2002 to 2005 fiscal years) or after DMI was introduced (2006 to 2008 fiscal years), and a variable for the interaction between the previous two dichotomous variables.[60–62] The interaction variable presented the DID estimate (i.e. the effect of DMI on the outcome). This model also included a variable for time trend. The first model was the DID unadjusted pooled ordinary least squares (OLS) model (Model 1). Patients in this study had repeated observations over time, thus, within-clustering of patients was accounted for. In addition, it is essential to acknowledge that certain observable patient- and physician-level characteristics such as age and sex can potentially confound the study relationship. Therefore, this study assessed the effects of DMI on each outcome controlling for patient- and physician-level characteristics.[6,13,15,17,31,63,64] All patient and physician characteristics mentioned in section 4.2.3, except for physician's years since graduation as it was correlated with physician's age, were included. Furthermore, both patient's and physician's age-squared variables were included in this model. This model was the DID adjusted pooled OLS model (Model 2).

Although Model 2 accounted for observed heterogeneity, the concern of potential individual-specific unobserved heterogeneity such as patient's race or their preferences can bias the effect of DMI on the outcomes.[51,63] To reduce this bias, a DID model with individual patient fixed-effects was used to control for any unobserved patient-specific heterogeneity that were assumed to be time-invariant[51,62] (Model 3). This model also

controlled for patient- and physician-level characteristics, and accounted for within-clustering of patients. Finally, it is important to acknowledge that each patient has their own specific time trend as their behaviours (i.e. medical compliance to treatments, lifestyle modifications) can change over time. This should be accounted for to get closer to the true effect of DMI. Therefore, a high-dimensional fixed-effects DID model controlling for patient- and physician-level characteristics, individual fixed-effects, and the patient-specific time trend[65] (Model 4) was used. This model also accounted for a two-way clustering (i.e. within patients, and between physicians).

In the current study, the majority of the outcomes were treated as a continuous outcome, however two of the hospitalization outcomes were binary outcomes. These two outcome variables measured 'whether or not the patient had at least one hospitalization' for diabetes-related short-term complications, and another for the diabetes-related long-term complications in each fiscal year. Frequently, nonlinear probability models (i.e. logit, probit models) are used to assess binary outcomes.[66,67] However, a linear regression model can also be used to assess these outcomes, and it is called the linear probability model (LPM).[66–68] In this study, a LPM was used to assess the effect of DMI on the probability of being hospitalized for diabetes-related short-term, and long-term complications. To show that the coefficients from the LPM are reliable, coefficients from this model will be compared to the average marginal effects from a logit model[69,70] performed for the diabetes-related short-term complication. Both quantities can be compared as they present the average marginal effects, and the focus will be on the interaction term (i.e. DID estimate). This comparison will be performed for Models 1 and 2 only as estimating a logit model with fixed-effects is difficult to estimate and a high-dimensional fixed-effects logit model is not available.

The equations for the four multivariable linear regression models with the DID methodology used in this study are indicated below:

$$Y_{it} = \beta_0 + \beta_1 DMI_i + \beta_2 period_t + \beta_3 DMI_i \times period_t + \beta_4 \tau + u_{it} \quad (1)$$

$$Y_{it} = \beta_0 + \beta_1 DMI_i + \beta_2 period_t + \beta_3 DMI_i \times period_t + \beta_4 \tau + \beta_x X_{it} + u_{it} \quad (2)$$

$$Y_{it} = \beta_0 + \beta_1 DMI_i + \beta_2 period_t + \beta_3 DMI_i \times period_t + \beta_4 \tau + \beta_x X_{it} + \varepsilon_i + u_{it} \quad (3)$$

$$Y_{it} = \beta_0 + \beta_1 DMI_i + \beta_2 period_t + \beta_3 DMI_i \times period_t + \beta_x X_{it} + \varepsilon_i + \gamma_{it} + u_{it} \quad (4)$$

Equations (1) to (4) specify Models 1 to 4 respectively. In the above four models, Y_{it} is the binary or continuous outcome variable (i.e. the probability of being hospitalized or natural logarithm of the number of hospitalizations for diabetes-related short-term or long-term complications; natural logarithm of the hospitalization costs for diabetes-related short-term or long-term complications; or MRS) for patient i in fiscal year t; DMI_i is a dichotomous variable equal to 1 if patient i is in the DMI group and 0 if patient i is in the comparison group; $period_t$ is a pre- and post- dichotomous variable equal to 1 if the year of the observation is after DMI was introduced and 0 if it was before; $DMI_i \times period_t$ is the interaction variable which denotes the DID estimate; τ is a time trend; X_{it} is the set of observable covariates (i.e. patient and physician-level characteristics); ε_i is the unobserved individual patient fixed-effects; γ_{it} is the high-dimensional fixed-effects in which the patient interacts with their own time trend; and u_{it} is the error term. All data analyses were performed using Stata 15.1 at the ICES Western site.

4.2.4.2 Subgroup Analysis

Subgroup analyses were performed to examine if the impact of DMI on the study outcomes differed among different subpopulations: 1) comorbidity (patients with below versus at or above median number of ADGs at baseline), and 2) sex (males versus females). Subgroup analyses were not performed for the number of hospitalizations and cost outcomes due to the small sample size. Interactions were performed for the respective subgroup if findings from that subgroup analysis revealed the effect of DMI on the outcome to be statistically significant, with a large difference in the magnitude of effect among the levels of that subgroup. Subgroup analysis by comorbidity was performed as patients with comorbidities or multiple chronic conditions have more complex health needs, and are likely to have poor outcomes.[71–73] There is also a strong correlation with greater number of comorbidities and increase in healthcare utilization (e.g. FP care, hospital admissions), and it has also been linked with greater healthcare

expenses.[73,74] Some studies have also indicated that P4P incentive schemes may not benefit patients with multiple chronic conditions as the specific-guidelines for these incentives focus on specific diseases,[75,76] or that these patients are likely to be excluded from the P4P.[77] Therefore, it is vital to assess if the impact of the DMI on the outcomes differed based on patient's comorbidity. Subgroup analysis by sex was also performed, because female diabetic patients are less likely to attain the recommended targets for diabetes, have medical compliance, have high-use of diabetes preventive care, and receive monitoring and treatment for diabetes.[78–80] In addition, they have a greater risk of depression[81–83] which is associated with increased healthcare utilization (i.e. hospital inpatient stays, emergency department visits) and overall healthcare expenditure.[83] Existing literature have found female diabetic patients to have higher hospitalization rates compared to males,[84,85] however, contrasting results have also been observed.[86] The literature have also found female diabetic patients to have a greater risk of mortality compared to males.[87] As a result, it would be worthwhile to investigate if the impact of DMI on the study outcomes differed based on patient's sex.

4.2.4.3 Sensitivity Analysis

A sensitivity analysis was performed to assess the robustness of the study findings. The sensitivity analysis was performed in the unbalanced panel dataset (i.e. all patients, which also includes those without observations for some of the years in the study) following the main and subgroup analyses performed in the main study population (i.e. balanced panel). This was performed to alleviate potential selection bias that was derived from focusing only on patients who were in the balanced panel. Patients in the unbalanced panel included those who were in the DMI group that entered the study after April 1, 2002 but on or prior to April 1, 2006, those in the DMI group without any data for some of the fiscal years, and those in the balanced panel.

4.3 Results

4.3.1 Descriptive Results

The main study population consisted of 172,451 adult patients with diabetes from Ontario (156,892 patients in the DMI group, and 15,559 patients in the comparison group). The

characteristics for this patient population and for their FPs by study group are presented in Table 3.3 for prior to the introduction of DMI, and Table 3.4 for after the introduction of DMI. In contrast to the comparison group, patients in the DMI group were marginally younger, had fewer years diagnosed with diabetes, and fewer number of ADGs. Moreover, in the DMI group compared to the comparison group, there was a greater proportion of female patients, and patients located in rural areas, in lower-deprived quintiles, and higher income quintiles. As for the FPs, those who provided care to patients in the DMI group were younger, less likely to be IMGs, and had fewer years of experience. There was also a greater proportion of female FPs providing care to patients in the DMI group versus the comparison group.

Once the DMI was introduced, the proportion of patients in the DMI group who had a DMI billed increased from 21.91% in 2006 to 27.43% in 2008 (Table 3.4). The descriptive statistics for the study outcomes by study group before and after DMI was introduced are presented in Tables 4.2 and 4.3, respectively. Since the analysis for the 'number of hospitalizations' and 'hospitalization costs' were performed in a subset of the main study population, Table 4.1 indicates the number of patients included in the analysis for those outcomes. Analysis for all other study outcomes were performed using the entire main study population, thus, to be more coherent, Table 4.1 will also display the number of patients in each study group for the main study population. On average, the proportion of patients hospitalized and the number of hospitalizations for diabetes-related short-term and long-term complications were greater in the DMI group compared to the comparison group. In 2008, 0.18% and 0.70% of the patients in the DMI group were hospitalized for short-term and long-term complications respectively, while in the comparison group it was 0.15% and 0.63%. However, there were no statistically significant differences between the two study groups for almost all diabetes-related hospitalization outcomes at baseline and final year of study (Appendix A4.2). A statistical significant difference was only observed for the proportion of those hospitalized for diabetes-related long-term complications at baseline, and it was significant at the 10% level. In addition, in both study groups, a greater proportion of patients were hospitalized for diabetes-related long-term than short-term complications. The average hospitalization cost for diabetes-related short-term complications increased

in the DMI group from $733.19 in 2002 to $1,959.91 in 2008, and was greater than the average costs in the comparison group during fiscal years 2003 to 2008. The average hospitalization cost for long-term complications increased in the DMI group from $913.89 in 2002 to $3,923.89 in 2008. Increase in the hospitalization costs were also found in the comparison group. The hospitalization costs were compared between the two groups at baseline and final year of study, and no statistically significant differences were detected (Appendix A4.2). The average MRS increased in both study groups throughout the study, but was slightly lower in the DMI group than the comparison group. A statistically significant difference was detected between the two groups for MRS at baseline and final year (Appendix A4.2). Figures 4.1 to 4.3 presents the trends in the diabetes-related hospitalizations, hospitalization costs, and MRS. These figures showed that there were no significant changes between the two groups for the above outcomes comparing before and after DMI was introduced.

4.3.2 Regression Results

The estimated impact of DMI on the hospitalizations for diabetes-related short-term complications (i.e. probability of being hospitalized, and the number of hospitalizations) are presented in Table 4.4. Estimates from all four models indicate that DMI has no statistically significant effect on the probability of being hospitalized (Model 4: $\hat{\beta}_3 = 0.000;\ 95\%\ confidence\ interval\ [CI] - 0.001, 0.001$), and on the number of hospitalizations for diabetes-related short-term complications (Model 4: $\hat{\beta}_3 = -0.005;\ 95\%\ \mathrm{CI}\ -0.097,\ 0.086$). Only results from Model 4 are reported here since this model is the closest in estimating the true effect of DMI on the outcomes. The average marginal effects of DMI on the probability of being hospitalized for short-term complications from Models 1 and 2 were compared to equivalent logistic regression models (Appendix A4.3). Both estimation methods presented similar estimated marginal effects, thus, confirming that the estimates from the linear regression models are reliable. As for the patient-level characteristics, patient's age and sex (females) had a negative effect on hospitalizations for diabetes-related short-term complications as of Model 2. Patient's age was not identified in Models 3 and 4 as it was correlated with the time trend variable, however, the quadratic term for age was present.

This term was positive and statistically significant in Model 4 for the probability of being hospitalized for diabetes-related short-term complications only. In addition, the number of ADGs increased the hospitalizations for diabetes-related short-term complications. For the physician-level characteristics, patients with female physicians were less likely to be hospitalized for diabetes-related short-term complications, however, there was no statistically significant effect on the number of hospitalizations. All other patient- and physician-level characteristics did not have a statistically significant effect in the final model (Model 4).

The estimated impact of DMI on hospitalizations for diabetes-related long-term complications (i.e. probability of being hospitalized, and the number of hospitalizations) are presented in Table 4.5. All four regression models revealed DMI to have no statistically significant effect on the probability of being hospitalized (Model 4: $\hat{\beta}_3 = -0.000;\ 95\%\ CI - 0.002, 0.001$), and on the number of hospitalizations (Model 4: $\hat{\beta}_3 = -0.007;\ 95\%\ CI - 0.056, 0.042$) for diabetes-related long-term complications. The patient-level characteristics revealed specific effects on the hospitalization outcomes. Overall, the effect of patient's age on hospitalizations for diabetes-related long-term complications was inconsistent across models. Patient's sex (females) had a negative effect on hospitalizations for diabetes-related long-term complications as of Model 2. In contrast, patients with greater number of ADGs had increased hospitalizations for diabetes-related long-term complications. The remaining patient- and all physician-level characteristics did not have a statistically significant effect in the final model.

Table 4.6 presents the impact of DMI on hospitalization costs for diabetes-related short- and long-term complications. Once again, in all four models the effect of DMI on hospitalization costs was not statistically significant for diabetes-related short-term (Model 4: $\hat{\beta}_3 = -0.165;\ 95\%\ CI - 1.193,\ 0.863$), and long-term complications (Model 4: $\hat{\beta}_3 = -0.049;\ 95\%\ CI - 0.616,\ 0.518$). In addition, patient's age had an inconsistent effect on hospitalization costs for diabetes-related short- and long-term complications. Female patients (based on Model 2) displayed lower hospitalization costs, while the number of ADGs increased the hospitalization costs for diabetes-related short-

and long-term complications in the final model. All other patient- and all physician-level characteristics did not have a statistically significant effect in the final model.

Lastly, for the estimated impact of DMI on MRS (Table 4.7), findings from all four models revealed that the effect of DMI on MRS was not statistically significant

(Model 4: $\hat{\beta}_3 = 0.060;\ 95\%\ CI - 0.103,\ 0.223$). In addition, patient's age (Model 2) and its' squared term (Models 2 to 4) had a positive effect on MRS. This implied that patient's age had a nonlinear relationship with MRS, and that the MRS increased at a stronger rate as patients get older. Patients with increasing number of ADGs also had a greater MRS. Conversely, a decreased MRS was found in female patients (based on Model 2), patients with a longer duration of diabetes, patients in income quintiles 3 (statistically significant at 10% level) and 4 compared to the lowest income quintile, and those in material deprivation quintiles 4 and 5 (Q5 was statistically significant at 10% level) compared to the least deprived quintile. Furthermore, physician's age had a nonlinear relationship with the patient's MRS. A reduced MRS was found in patients whose physicians were IMGs. The remaining patient- and physician-level characteristics did not have a statistically significant effect in the final model.

4.3.3 Results from the Subgroup Analysis

Findings from the two subgroup analyses are presented in Table 4.8. The two subgroup analyses by comorbidity, and sex revealed that DMI had no statistically significant effect on the probability of being hospitalized for diabetes-related short- and long-term complications, and on the MRS in all subgroups.

4.3.4 Results from the Sensitivity Analysis

The sensitivity analysis was performed using the unbalanced panel dataset, and contained 480,517 adult patients with diabetes. Table 3.2 indicates the number of patients available in each study group each year. Similar to the results from the main analysis, DMI had no statistically significant effect on diabetes-related hospitalizations, hospitalization costs, and MRS. Subgroup analyses were also conducted in these patients, and the results were similar to the results from the subgroup analyses in the main study. It is important to note

that there was a slight change in the comorbidity subgroup analysis performed in the unbalanced panel. The patients here were compared using the exact same median number of ADGs at baseline used in the main study. This was done, because: 1) to be consistent with the main study, and 2) not all the patients in the unbalanced panel were present at baseline (2002), therefore, the median number of ADGs at baseline could not be determined in this cohort. The sensitivity analysis results are not presented in this chapter, but are available upon request.

4.4 Discussion

The purpose of this study was to assess the impact of DMI, introduced in Ontario in 2006, on diabetes-related hospitalizations, associated hospitalization costs, and mortality risk in patients with diabetes in Ontario. The descriptive results of this study revealed that, although the proportion of patients hospitalized and the number of hospitalizations for diabetes-related complications were greater in the DMI group compared to the comparison group, there were no statistically significant differences between the two groups for most hospitalization outcomes at baseline and final year. Additionally, more patients were hospitalized for diabetes-related long-term compared to short-term complications in both study groups. This finding was in contrast to Petrosyan *et al*. (2017)[5] as they found a higher incidence of hospitalizations for diabetes-related short-term than long-term complications in Ontario adults with diabetes. Potential reasons for the contrasting results are possibly due to the differences in the cohort selection, and the difference in the study window as they observed the diabetes-related hospitalization outcomes from 2009 to 2011. Findings from the current study also revealed that overall there was an increase in the average hospitalization cost for diabetes-related complications in both groups. Regarding the MRS, increase in the average MRS was consistently observed in both groups throughout the study, however, the MRS was lower in the DMI group.

Findings from the multivariable linear regression models with the DID approach revealed that DMI had no effect on the probability of being hospitalized, number of hospitalizations, or hospitalization costs for diabetes-related short-term and long-term complications, and on MRS. All four DID models revealed consistent findings for the

above outcomes. Subgroup analyses performed in the two type of subgroups confirmed that DMI had no effect on the study outcomes. Following this, a sensitivity analysis was conducted assessing the impact of DMI on the above study outcomes using the unbalanced panel dataset. This was done to assess the consistency of the study findings, and since this patient cohort was much larger, therefore, testing the objectives in this cohort can help improve the external validity of the study results. Results from this analysis were consistent with the main study findings.

Overall, P4P incentives were introduced in several countries to improve care for chronic conditions such as diabetes.[12,23] The motivation for this type of incentive is potential long-term benefits such as improvements in patient outcomes (i.e. hospitalizations, mortality) and reduce hospital costs.[6,11,12,16] However, findings from the current study revealed that Ontario's DMI did not reduce hospitalizations due to diabetes related short-term and long-term complications, hospitalization costs, or mortality risk. There are several potential reasons as to why this was observed. First, the low uptake of the DMI could be a potential reason, as in 2008, only 27.43% of the patients in the DMI group had a DMI billed. Second, based on Chapter 3 it was observed that the impact of DMI was an increase in the probability of having three or more DMA fee codes billed by patient's physician in the neighbourhood of two percentage points. This is a very small impact on the provision of diabetes-related services, and it is not large enough to translate to reduce hospitalizations, hospitalization costs, and mortality risk. Third, the study period was not long enough to detect the long-term effect of the DMI on the chosen outcomes. This study used three years of post-DMI data; and perhaps, more time is required in order to see improvements in these outcomes. Fourth, there may be other factors outside of the primary care settings, which may have led to the findings observed in this paper. For instance, the ranges of specialist or multidisciplinary care the patient received, or how they self-managed the disease at home can have an effect on the study outcomes and these factors were not accounted for. Finally, regarding the hospitalization outcome, the proportion of those who were hospitalized were low for both types of complications in this study. Therefore, this may have also been a reason to why the effect of DMI on the hospitalization outcomes was not observed. A few of the existing studies with a diabetic patient cohort[5,11,29,31] such as Petrosyan *et al*. (2017)[5] from Ontario and Lin *et al.* (2016)[31]

from Taiwan also had a small proportion of patients hospitalized or number of hospitalizations in their study. However, their rates were slightly higher than what was found in this study.

Previous published literature that have assessed the impact of P4P incentives for diabetes care on diabetes-related hospitalizations have been mixed. Findings from the current study were consistent with a few studies that found P4P to have no impact on hospitalizations,[6,11,28,63,88] however, a number of studies found P4P incentives for diabetes care reduced diabetes-related hospitalizations.[6,12,15,23,25–28,31,89] For instance, Lin *et al.* (2016)[31] found that in Taiwan, diabetic patients with full-participation in the diabetes P4P program had a lower risk of being hospitalized for chronic diabetic complications compared to the comparison group.

Additionally, the current study revealed that certain patient- and physician-level characteristics had effects on patients being hospitalized for diabetes-related complications. Patients who were older were more likely to be hospitalized for diabetes-related short-term complications, females were less likely to be hospitalized and had fewer diabetes-related hospitalizations, and patients with female physicians were less likely to be hospitalized for short-term complications only. In contrast, those more comorbid were more likely to be hospitalized and have a greater number of hospitalizations. Similar results have been observed in a few of the previous studies, especially in the research on the P4P schemes, regarding patient's sex,[15,31,63] age,[15] and comorbidity[15,27,63] on hospitalizations that included diabetes. However, contrasting results were also found in the literature such as, one study in Ontario found diabetic patients with comorbidities to less likely be hospitalized for diabetes-related long-term complications.[5]

Regarding the impact of P4P incentives for diabetes care on diabetes-related hospitalization costs, there is currently a lack of literature in this area. Nevertheless, findings from this study were consistent with the results from one study. Dusheiko *et al.* (2011)[13] used data from the QOF P4P scheme, and found disease management for 9 chronic diseases including diabetes were not significantly associated with reduced

hospital costs. Only disease management for stroke care was linked with reduced hospital costs.[13] The majority of the other studies found P4P was associated with a reduction in hospitalization costs, with two studies briefly mentioning the estimated reduction in costs due to the reduction in hospitalizations.[12,23,25,26] Interestingly, Cheng *et al*. (2012)[26] found compared to the comparison group (i.e. those who had never been enrolled in P4P), hospitalization costs were significantly lower only in diabetic patients who stayed in the P4P program throughout the study (i.e. 2005 to 2009). The current study also found certain patient characteristics were associated with the hospitalization costs. For instance, female patients had lower hospitalization costs for both types of complications while those with a higher comorbidity had greater hospitalization costs.

Existing literature on the impact of P4P incentives for diabetes on mortality have also been limited and inconsistent. Similar to this study, both Ryan *et al.* (2016)[16] and Kontopantelis *et al.* (2015)[17] found the QOF P4P scheme[16], and the primary care performance for the quality indicators included in the QOF[17] had no statistically significant effect on population-mortality. On the contrary, Fleetcroft *et al.* (2010)[30] found the QOF scheme (2004 version) reduced mortality. Another study that assessed the P4P program in Taiwan found the risk of mortality to be lower in diabetic patients participating in this program compared to their comparison group.[31] Regarding the patient- and physician-level characteristics, similar to the current study, Lin *et al*. (2016)[31] also found that the risk of all-cause mortality was higher in male diabetic patients. Counterintuitively, the current study also found that MRS was lower in patients who were in higher deprivation quintiles compared to those who were least deprived. This finding was found in the final two models, while Model 2 found MRS higher in patients who were in higher deprivation quintiles compared to those who were least deprived. The opposing findings that were observed can be due to the lack of variation in the data as there were only two years of census data (2001 and 2006 census years) for the material deprivation measure.[44] This study also revealed that patients who are older, and those who are more comorbid had a greater MRS, while, those with longer duration of diabetes, from income quintiles 3 and 4 compared to the lowest income quintile, and with physicians who are IMGs had a lower MRS.

In this study, the MRS was used to measure the risk of mortality instead of using actual deaths, because the score provided more information regarding the patient's risk of death. A surviving patient may have a high MRS which indicates that even though the patient is alive their risk of death is high, and such information cannot be obtained when analyzing actual deaths. In addition, diabetes is often not reported as the primary cause of death, and instead the cause is reported to be due to its' related complications.[7] As a result, analysis of death data due to diabetes can lead to underestimating the deaths caused by diabetes. This is one of the reasons to why MRS is used as an outcome in this study. Finally, the mortality trends in diabetic patients in Ontario from 1996 to 2009 have shown that the mortality rate has decreased in this patient population, and this is most likely due to the improved treatments, screenings, and management of diabetes.[90] Therefore, it is possible that there might not have been a lot of actual patient deaths in this study if this data were used, and it would be difficult to assess the true relationship between DMI and mortality risk in diabetic patients.

There are a number of strengths of this study. First, this is the first study to assess the impact of DMI on diabetes-related hospitalizations, diabetes-related hospitalization costs, and mortality risk in patients with diabetes in Ontario. Second, panel data spanning from fiscal years 2002 to 2008 was used to assess the impact of DMI in this study. An advantage of using panel data is using statistical methods to control for unobserved patient heterogeneity, thus being able to capture the effects of the policy change that cannot be detected in pure cross-sectional data.[51,91] Third, the diabetic patient cohort was derived from validated health administrative databases.[5,36] Finally, a comparison group was used to assess the impact of DMI on the study outcomes.

Nevertheless, there were also some limitations of this study. First, the time period of the study was not sufficiently long enough to see the effect of DMI on hospitalizations, associated costs, and mortality risk in diabetic patients. Second, the comparison group was much smaller compared to the DMI group in this study, and this can result in having two study groups that are not similar with each other. Third, potential selection bias may be an issue in this study. The majority of the FPs who provided care to patients in the DMI group were initially practicing in the traditional FFS and switched into PEMs

voluntarily. However, FPs who provided care to patients in the comparison group practiced in the traditional FFS throughout the study period. Therefore, differences in the physicians' performance or their unobserved characteristics between the two study groups could have introduced some bias. Fourth, in the past, the performance of the MRS was assessed only in the general adult population in Ontario, and not in disease-specific cohorts.[48] Therefore, it is unclear how well this score predicts the risk of mortality in diabetic patients. Finally, the diabetes-related hospitalizations in this study were identified based on the most responsible diagnosis code for the patient's stay at the hospital, therefore, hospitalizations that instead had diabetes-related short-term or long-term complications as the secondary diagnosis would have been missed out in this study. Furthermore, hospitalizations included in this study were acute inpatient hospitalizations from the CIHI DAD database where the patient had at least one overnight stay. Therefore, same-day surgeries or procedures for diabetes would also have not been captured.

Future research can build on what was performed in this paper by investigating the effects of the DMI on the patient outcomes and hospitalization costs beyond the fiscal year 2008. This analysis can be performed in patients enrolled to physicians in PEMs and patients affiliated with traditional FFS physicians separately. Outside of DMI, there are a number of other P4P incentives introduced in Ontario (e.g. Heart Failure Management incentive), thus, exploring the effectiveness of these incentives in improving patient outcomes and costs can help us gain more knowledge on the effectiveness of Ontario's P4P incentives. Furthermore, future research can identify which P4P incentives have produced large benefits to the population and the healthcare system, so features from that scheme can be used to revise other P4P incentives.

4.5 Conclusions

The effectiveness of P4P incentives for diabetes care in improving patient outcomes, and hospitalization costs are mostly inconsistent in the existing literature. This study uses data from healthcare administrative databases to assess the effect of DMI on diabetes-related hospitalizations, hospitalization costs, and mortality risk in patients diagnosed with diabetes in Ontario. Using four multivariable linear DID regression models comparing

patients in the DMI group to those in the comparison group, this study demonstrates that DMI has no significant impact on hospitalizations or associated costs for diabetes-related short-term and long-term complications, and on MRS. Similar findings were observed in all subgroups. Therefore, these results suggest that the introduction of DMI was not effective in reducing diabetes-related hospitalizations, hospitalization costs, and mortality risk in diabetic patients in Ontario.

4.6 Tables and Figures

1. $Cost\ for\ inpatient\ case = RIW \times CPWC$

2. $CPWC = \frac{total\ hospital\ costs\ for\ inpatient\ acute\ care\ in\ Ontario}{sum\ of\ RIWs\ for\ all\ Ontario\ cases}$

Box 4.1: Methods used to calculate the diabetes-related hospitalization costs

Note: RIW is the resource intensity weight for the specific patient; CPWC is the cost per weighted case for inpatient acute care for Ontario cases. The first formula shows how the hospitalization cost was calculated for a specific patient while the second formula shows how the cost per weighted case was calculated.

$$MRS = (subject's\ age - 20\ years) + (component\ score\ for\ subject's\ sex) + (component\ score\ for\ each\ of\ the\ 28\ ADGs\ the\ subject\ has\ diagnosis\ for)$$

Box 4.2: Method used to calculate the MRS

Note: MRS is the Mortality Risk Score for the specific patient; ADGs is the Aggregated Diagnosis Groups the specific patient had. The formula in the top indicates the MRS calculation as per Austin & Walraven (2011).[48]

Table 4.1: The number of patients hospitalized for diabetes-related complications and the total number of patients from the main study population (i.e. Balanced panel)

Fiscal Year	Number of patients for diabetes-related short-term complications[a]		Number of patients for diabetes-related long-term complications[b]		Total number of patients[c]	
	Comparison group	DMI group	Comparison group	DMI group	Comparison group	DMI group
2002	93	1,147	338	4,152	15,559	156,892
2003	93	1,147	338	4,152	15,559	156,892
2004	93	1,147	338	4,152	15,559	156,892
2005	93	1,147	338	4,152	15,559	156,892
2006	93	1,147	338	4,152	15,559	156,892
2007	93	1,147	338	4,152	15,559	156,892
2008	93	1,147	338	4,152	15,559	156,892

DMI, Diabetes Management Incentive.

[a] The number of patients in each study group for diabetes-related short-term complications are patients who were hospitalized at least once for this complication throughout the study. This is a subset of patients from the main study population. Descriptive statistics and multivariable regression analyses performed for the 'number of hospitalizations', and 'hospitalization costs' outcomes for this complication were performed in those patients.

[b] The number of patients in each study group for diabetes-related long-term complications are patients who were hospitalized at least once for this complication throughout the study. This is a subset of patients from the main study population. Descriptive statistics and multivariable regression analyses performed for the 'number of hospitalizations', and 'hospitalization costs' outcomes for this complication were performed in those patients.

[c] The number of patients in each study group in the main study population. Descriptive statistics and multivariable regression analyses for all other outcome variables (i.e. the two binary diabetes-related hospitalization variables, and Mortality Risk Score) were performed in those patients.

Table 4.2: Diabetes-related hospitalizations, hospitalization costs, and MRS by study group before DMI was introduced

Variables	2002		2003		2004		2005	
	Comparison group	DMI group	Comparison group	DMI group	Comparison group	DMI group	Comparison group	DMI group
Number of patients	15,559	156,892	15,559	156,892	15,559	156,892	15,559	156,892
Diabetes-related hospitalizations and hospitalization costs								
Short-term complications								
Patients hospitalized, n (%)	20 (0.13%)	191 (0.12%)	14 (0.09%)	191 (0.12%)	18 (0.12%)	218 (0.14%)	19 (0.12%)	218 (0.14%)
Number of hospitalizations[a]	21	237	17	229	24	263	20	278
Hospitalization costs[a] ($ CAD), mean (SD)	898.69 (2,138.15)	733.19 (2,925.45)	675.76 (1,900.60)	760.51 (2,495.49)	813.42 (2,009.62)	942.26 (3,412.89)	829.68 (2,025.76)	978.17 (2,840.83)
Long-term complications								
Patients hospitalized, n (%)	29 (0.19%)	406 (0.26%)	39 (0.25%)	459 (0.29%)	42 (0.27%)	585 (0.37%)	51 (0.33%)	679 (0.43%)
Number of hospitalizations[b]	35	490	49	542	45	678	57	809
Hospitalization costs[b] ($ CAD), mean (SD)	569.01 (2,475.65)	913.89 (4,119.48)	1,742.87 (7,264.44)	1,284.43 (6,392.21)	1,761.20 (11,153.79)	1,591.11 (6,232.89)	1,424.14 (4,501.63)	1,902.25 (6,619.33)

Mortality risk								
MRS, mean (SD)	45.09 (14.94)	44.03 (15.56)	46.26 (15.01)	45.24 (15.71)	47.71 (15.21)	46.63 (15.98)	49.02 (15.43)	47.96 (16.25)

MRS, Mortality Risk Score; DMI, Diabetes Management Incentive; $ CAD, Canadian dollars; SD, standard deviation.
[a] Only assessed in patients hospitalized at least once for diabetes-related short-term complications as indicated in Table 4.1.
[b] Only assessed in patients hospitalized at least once for diabetes-related long-term complications as indicated in Table 4.1.

Table 4.3: Diabetes-related hospitalizations, hospitalization costs, and MRS by study group after DMI was introduced

Variables	2006		2007		2008	
	Comparison group	DMI group	Comparison group	DMI group	Comparison group	DMI group
Number of patients	15,559	156,892	15,559	156,892	15,559	156,892
Diabetes-related hospitalizations and hospitalization costs						
Short-term complications						
Patients hospitalized, n (%)	12 (0.08%)	211 (0.13%)	20 (0.13%)	240 (0.15%)	23 (0.15%)	278 (0.18%)
Number of hospitalizations[a]	13	258	21	302	30	329
Hospitalization costs[a] ($ CAD), mean (SD)	937.81 (3,626.66)	1,114.16 (3,463.04)	1,147.29 (3,174.23)	1,594.18 (7,647.11)	1,631.44 (4,149.05)	1,959.91 (7,477.28)
Long-term complications						
Patients hospitalized, n (%)	75 (0.48%)	904 (0.58%)	81 (0.52%)	1,028 (0.66%)	98 (0.63%)	1,095 (0.70%)
Number of hospitalizations[b]	83	1,078	97	1,218	111	1,280
Hospitalization costs[b] ($ CAD), mean (SD)	2,375.30 (6,749.92)	2,816.62 (9,203.06)	2,671.33 (8,899.13)	3,257.52 (12,489.18)	4,108.91 (11,801.96)	3,923.89 (15,677.26)
Mortality risk						

MRS, mean (SD)	50.23 (15.76)	49.22 (16.50)	51.67 (16.08)	50.63 (16.85)	53.15 (16.60)	52.11 (17.28)

MRS, Mortality Risk Score; DMI, Diabetes Management Incentive; $ CAD, Canadian dollars; SD, standard deviation.
[a] Only assessed in patients hospitalized at least once for diabetes-related short-term complications as indicated in Table 4.1.
[b] Only assessed in patients hospitalized at least once for diabetes-related long-term complications as indicated in Table 4.1.

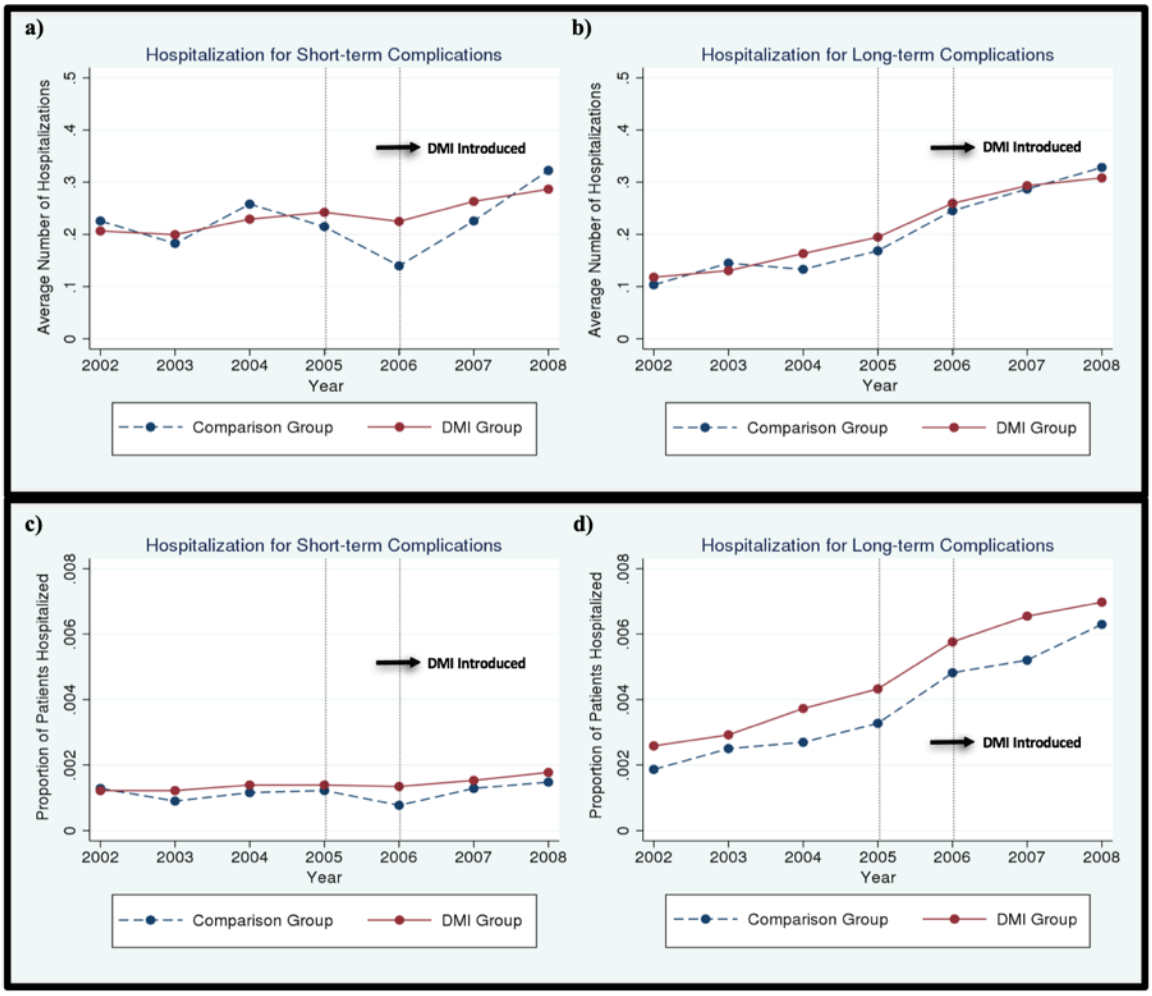


Figure 4.1: a) and b) Average number of hospitalizations for diabetes-related short-term and long-term complications respectively in patients; c) and d) Proportion of patients hospitalized for diabetes-related short-term and long-term complications respectively

The four graphs show the trends in the diabetes-related hospitalizations for fiscal years 2002 to 2008 by study group. The arrow on the graphs point to the period when DMI was introduced.

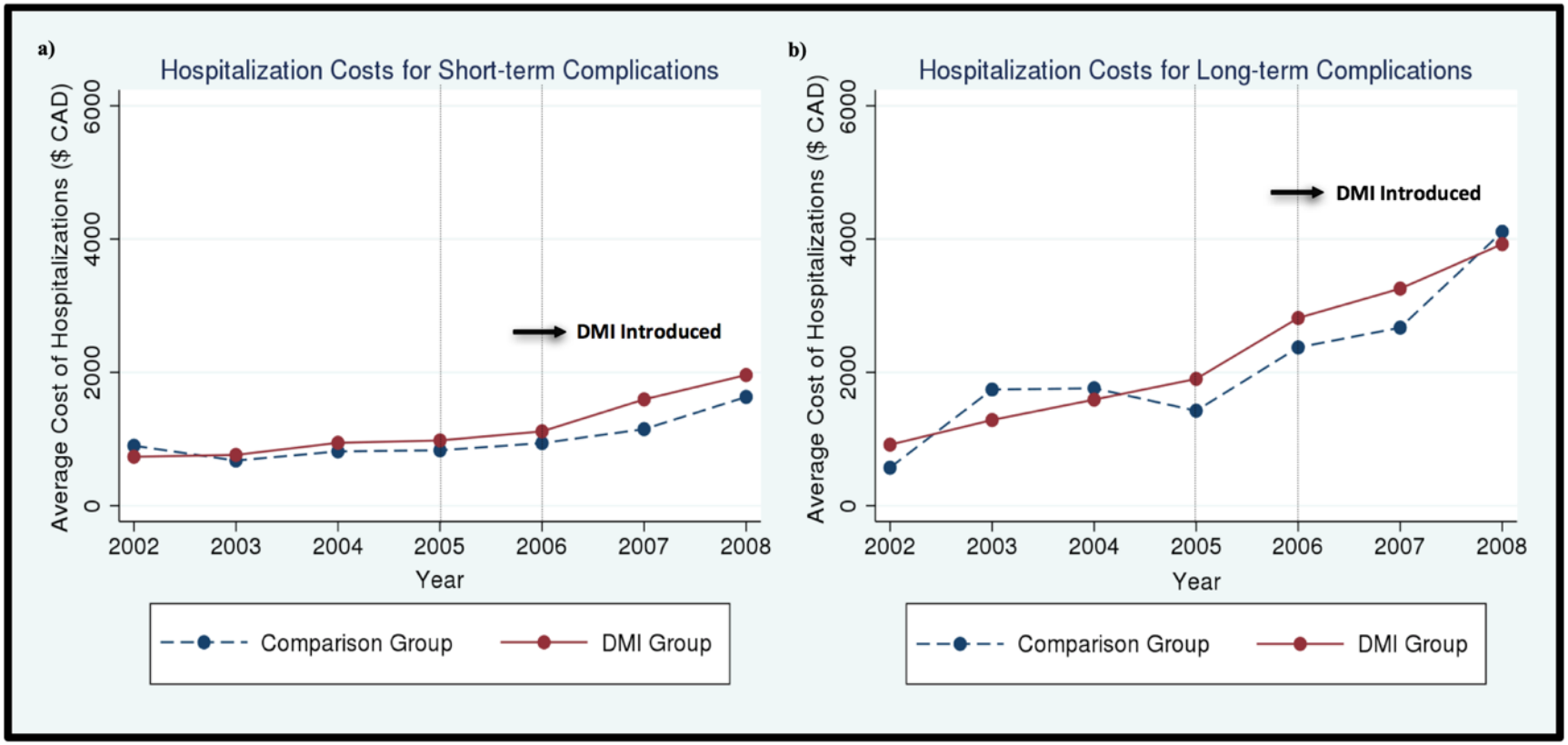


Figure 4.2: a) and b) Average hospitalization costs for diabetes-related short-term and long-term complications respectively in patients

Both graphs show the trends in the diabetes-related hospitalization costs from fiscal years 2002 to 2008 by study group. The arrow on the graphs point to the period when DMI was introduced.

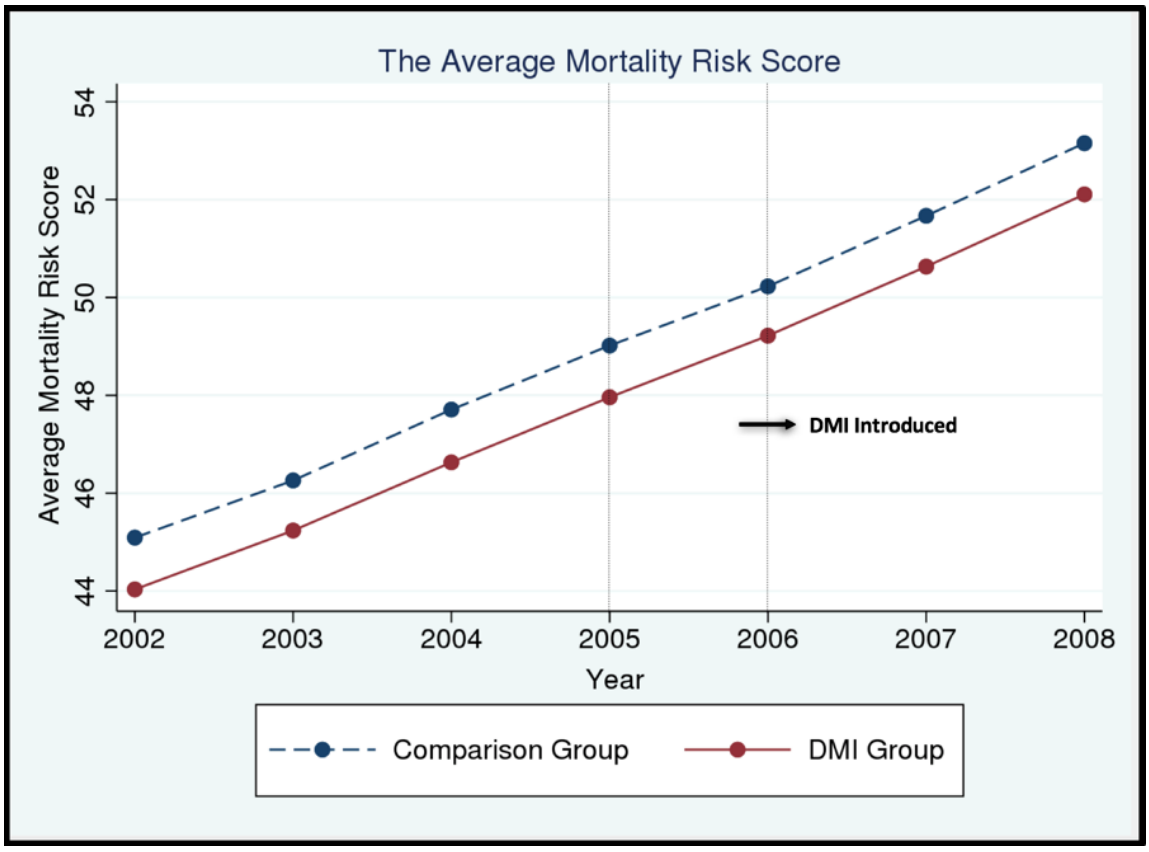


Figure 4.3: Average Mortality Risk Score (MRS) in patients

The above graph shows the trends in the MRS from fiscal years 2002 to 2008 by study group. The arrow on the graph points to the period when DMI was introduced.

Table 4.4: Estimated impact of DMI on hospitalizations for diabetes-related short-term complications

Variables	Model 1: DID Unadjusted Pooled OLS $\hat{\beta}$ (95% CI)		Model 2: DID Adjusted Pooled OLS $\hat{\beta}$ (95% CI)		Model 3: Fixed-Effects DID $\hat{\beta}$ (95% CI)		Model 4: High-dimensional Fixed-Effects DID $\hat{\beta}$ (95% CI)	
	Probability of being hospitalized	Number of hospitalizations[a] (Log-transformed)	Probability of being hospitalized	Number of hospitalizations[a] (Log-transformed)	Probability of being hospitalized	Number of hospitalizations[a] (Log-transformed)	Probability of being hospitalized	Number of hospitalizations[a] (Log-transformed)
DMI	0.000 (-0.000, 0.000)	-0.006 (-0.037, 0.025)	0.000 (-0.000, 0.000)	-0.003 (-0.033, 0.026)				
Period (Ref: Pre-DMI period)	-0.000 (-0.001, 0.000)	-0.036 (-0.089, 0.017)	-0.000* (-0.001, 0.000)	-0.019 (-0.064, 0.026)	-0.000 (-0.001, 0.000)	-0.005 (-0.052, 0.041)	-0.000 (-0.001, 0.000)	-0.008 (-0.097, 0.081)
DMI*Period (DID Effect)	0.000 (-0.000, 0.001)	0.021 (-0.031, 0.072)	0.000 (-0.000, 0.001)	0.008 (-0.036, 0.051)	0.000 (-0.000, 0.001)	-0.000 (-0.043, 0.043)	0.000 (-0.001, 0.001)	-0.005 (-0.097, 0.086)
τ (time trend)	0.000*** (0.000, 0.000)	0.012*** (0.005, 0.018)	-0.000** (-0.000, -0.000)	0.010*** (0.003, 0.016)	-0.037 (-0.133, 0.059)	-1.978 (-10.759, 6.803)		
Patient Characteristics								
Age			-0.001*** (-0.001, -0.001)	-0.007*** (-0.010, -0.003)				

Age-squared	0.000*** (0.000, 0.000)	0.000*** (0.000, 0.000)	-0.000** (-0.000, -0.000)	-0.000 (-0.000, 0.000)	0.000** (0.000, 0.000)	0.001 (-0.001, 0.003)
Female (Ref: Male)	-0.000*** (-0.001, -0.000)	-0.039*** (-0.053, -0.025)				
Rural residence (Ref: Urban)	0.000 (-0.001, 0.001)	-0.021 (-0.085, 0.043)	0.000 (-0.001, 0.002)	-0.001 (-0.080, 0.077)	0.000 (-0.002, 0.003)	0.025 (-0.083, 0.133)
Number of ADGs	0.001*** (0.001, 0.001)	0.036*** (0.033, 0.038)	0.001*** (0.001, 0.001)	0.052*** (0.050, 0.055)	0.001*** (0.001, 0.001)	0.054*** (0.051, 0.057)
Duration of diabetes (years)	0.000*** (0.000, 0.000)	-0.003*** (-0.005, -0.001)	0.038 (-0.058, 0.134)	1.978 (-6.799, 10.755)	0.006 (-0.100, 0.112)	0.546 (-9.104, 10.195)
Material deprivation quintiles (Ref: Q1 (least deprived))						
Q2	0.000 (-0.000, 0.000)	0.004 (-0.016, 0.025)	0.000 (-0.001, 0.001)	-0.006 (-0.049, 0.037)	-0.000 (-0.001, 0.001)	0.010 (-0.047, 0.067)
Q3	0.000 (-0.000, 0.000)	0.001 (-0.022, 0.023)	0.000 (-0.000, 0.001)	0.014 (-0.031, 0.059)	-0.000 (-0.001, 0.001)	0.009 (-0.050, 0.068)
Q4	0.000** (0.000, 0.001)	0.013 (-0.012, 0.037)	0.001 (-0.000, 0.001)	0.021 (-0.032, 0.075)	0.000 (-0.001, 0.002)	0.034 (-0.030, 0.098)
Q5 (most	0.001***	0.016	0.000	-0.010	-0.000	-0.013

deprived)	(0.000, 0.001)	(-0.013, 0.046)	(-0.001, 0.001)	(-0.067, 0.048)	(-0.002, 0.001)	(-0.088, 0.063)
Income quintiles (Ref: Q1 (lowest income))						
Q2	0.000 (-0.000, 0.000)	0.000 (-0.021, 0.021)	0.000 (-0.000, 0.001)	0.005 (-0.028, 0.038)	0.000 (-0.001, 0.001)	0.008 (-0.033, 0.049)
Q3	0.000 (-0.000, 0.000)	0.025* (-0.001, 0.051)	0.000 (-0.000, 0.001)	0.022 (-0.019, 0.063)	0.000 (-0.001, 0.001)	0.023 (-0.027, 0.074)
Q4	-0.000 (-0.000, 0.000)	0.022 (-0.005, 0.049)	0.000 (-0.000, 0.001)	0.048* (-0.000, 0.096)	-0.000 (-0.001, 0.001)	0.013 (-0.045, 0.070)
Q5 (highest income)	-0.000 (-0.000, 0.000)	0.021 (-0.009, 0.052)	0.000 (-0.001, 0.001)	0.005 (-0.047, 0.058)	-0.000 (-0.001, 0.001)	-0.023 (-0.086, 0.040)
Physician Characteristics						
Age	-0.000 (-0.000, 0.000)	0.002 (-0.004, 0.007)	0.000 (-0.000, 0.000)	0.005 (-0.005, 0.014)	0.000 (-0.000, 0.000)	0.006 (-0.010, 0.021)
Age-squared	0.000 (-0.000, 0.000)	-0.000 (-0.000, 0.000)	-0.000 (-0.000, 0.000)	-0.000 (-0.000, 0.000)	-0.000 (-0.000, 0.000)	-0.000 (-0.000, 0.000)
Female	-0.000	-0.006	-0.001***	-0.009	-0.001***	-0.033

(Ref: Male)			(-0.000, 0.000)	(-0.021, 0.010)	(-0.001, -0.000)	(-0.048, 0.031)	(-0.002, -0.000)	(-0.092, 0.027)
IMG status (Ref: CMG)			-0.001*** (-0.001, -0.000)	-0.005 (-0.024, 0.014)	0.000 (-0.000, 0.001)	0.010 (-0.033, 0.053)	0.001 (-0.000, 0.001)	0.022 (-0.041, 0.084)
Constant	-0.219*** (-0.342, -0.096)	-23.495*** (-36.861, -10.130)	0.165** (0.030, 0.299)	-18.898*** (-31.758, -6.039)	2.004 (-3.149, 7.158)	82.995 (-286.844, 452.835)		
R-squared	0.000	0.003	0.006	0.188	0.004	0.250	0.411	0.503
Number of patients	172,451	1,240	172,451	1,240	172,451	1,240	172,451	1,240
Observations	1,207,157	8,680	1,207,157	8,680	1,207,157	8,680	1,207,157	8,680

DMI, Diabetes Management Incentive; DID, Difference-in-difference; OLS, Ordinary least squares; 95% CI, 95% confidence interval; Ref, Reference; ADGs, Aggregated Diagnosis Groups; IMG, International Medical Graduate; CMG, Canadian Medical Graduate. Robust 95% CI in parentheses.

[a] Only assessed in patients hospitalized at least once for diabetes-related short-term complications as indicated in Table 4.1. In addition, this outcome has been natural-log transformed.

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

Table 4.5: Estimated impact of DMI on hospitalizations for diabetes-related long-term complications

Variables	Model 1: DID Unadjusted Pooled OLS $\hat{\beta}$ (95% CI)		Model 2: DID Adjusted Pooled OLS $\hat{\beta}$ (95% CI)		Model 3: Fixed-Effects DID $\hat{\beta}$ (95% CI)		Model 4: High-dimensional Fixed-Effects DID $\hat{\beta}$ (95% CI)	
	Probability of being hospitalized	Number of hospitalizations[a] (Log-transformed)	Probability of being hospitalized	Number of hospitalizations[a] (Log-transformed)	Probability of being hospitalized	Number of hospitalizations[a] (Log-transformed)	Probability of being hospitalized	Number of hospitalizations[a] (Log-transformed)
DMI	0.001*** (0.000, 0.001)	0.008 (-0.006, 0.022)	0.001*** (0.001, 0.002)	0.013* (-0.001, 0.028)				
Period (Ref: Pre-DMI period)	0.001* (-0.000, 0.002)	0.039*** (0.010, 0.068)	0.001** (0.000, 0.002)	0.039*** (0.014, 0.065)	0.001 (-0.000, 0.002)	0.037*** (0.010, 0.064)	0.001 (-0.001, 0.003)	0.036 (-0.013, 0.085)
DMI*Period (DID Effect)	0.000 (-0.001, 0.001)	-0.012 (-0.039, 0.016)	0.000 (-0.001, 0.001)	-0.007 (-0.032, 0.017)	0.000 (-0.001, 0.001)	-0.005 (-0.029, 0.019)	-0.000 (-0.002, 0.001)	-0.007 (-0.056, 0.042)
τ (time trend)	0.001*** (0.000, 0.001)	0.017*** (0.014, 0.020)	-0.000*** (-0.000, -0.000)	0.007*** (0.004, 0.010)	0.093 (-0.086, 0.272)	0.911 (-3.902, 5.724)		
Patient Characteristics								
Age			-0.000*** (-0.000, -0.000)	0.000 (-0.002, 0.003)				
Age-squared			0.000	-0.000	0.000***	0.000***	0.000	0.001

	(-0.000, 0.000)	(-0.000, 0.000)	(0.000, 0.000)	(0.000, 0.000)	(-0.000, 0.000)	(-0.001, 0.002)
Female (Ref: Male)	-0.003*** (-0.003, -0.003)	-0.020*** (-0.026, -0.015)				
Rural residence (Ref: Urban)	0.003*** (0.001, 0.004)	0.011 (-0.013, 0.035)	0.004*** (0.001, 0.006)	0.049* (-0.004, 0.102)	0.001 (-0.003, 0.005)	0.034 (-0.042, 0.110)
Number of ADGs	0.003*** (0.003, 0.003)	0.029*** (0.028, 0.030)	0.003*** (0.003, 0.003)	0.044*** (0.043, 0.045)	0.003*** (0.003, 0.003)	0.046*** (0.045, 0.048)
Duration of diabetes (years)	0.001*** (0.001, 0.001)	0.000 (-0.001, 0.001)	-0.094 (-0.273, 0.085)	-0.923 (-5.734, 3.887)	-0.094 (-0.292, 0.103)	-1.465 (-6.779, 3.850)
Material deprivation quintiles (Ref: Q1 (least deprived))						
Q2	0.000 (-0.000, 0.001)	-0.003 (-0.013, 0.006)	0.000 (-0.001, 0.001)	0.004 (-0.020, 0.027)	-0.000 (-0.002, 0.001)	0.000 (-0.033, 0.033)
Q3	0.000 (-0.000, 0.001)	-0.003 (-0.014, 0.008)	-0.000 (-0.001, 0.001)	-0.007 (-0.032, 0.018)	0.001 (-0.001, 0.003)	0.008 (-0.027, 0.043)
Q4	0.001*** (0.000, 0.001)	-0.000 (-0.012, 0.011)	-0.001 (-0.002, 0.001)	-0.010 (-0.035, 0.016)	-0.000 (-0.002, 0.001)	-0.013 (-0.050, 0.024)

Q5 (most deprived)	0.001*** (0.001, 0.002)	0.002 (-0.012, 0.017)	0.000 (-0.001, 0.001)	-0.004 (-0.032, 0.024)	0.000 (-0.002, 0.002)	0.002 (-0.039, 0.043)
Income quintiles (Ref: Q1 (lowest income))						
Q2	-0.000* (-0.001, 0.000)	0.009* (-0.000, 0.018)	0.000 (-0.001, 0.001)	0.010 (-0.006, 0.026)	-0.000 (-0.001, 0.001)	0.003 (-0.019, 0.024)
Q3	-0.000 (-0.001, 0.000)	0.012* (-0.001, 0.024)	0.000 (-0.001, 0.001)	0.013 (-0.007, 0.033)	-0.000 (-0.001, 0.001)	0.007 (-0.020, 0.033)
Q4	-0.001*** (-0.002, -0.000)	0.010 (-0.002, 0.023)	0.000 (-0.001, 0.001)	0.020* (-0.003, 0.042)	-0.000 (-0.001, 0.001)	0.011 (-0.019, 0.040)
Q5 (highest income)	-0.001*** (-0.002, -0.001)	0.006 (-0.008, 0.019)	0.000 (-0.001, 0.001)	0.004 (-0.022, 0.030)	-0.001 (-0.002, 0.001)	-0.013 (-0.048, 0.022)
Physician Characteristics						
Age	-0.000 (-0.000, 0.000)	-0.002* (-0.005, 0.000)	-0.000 (-0.000, 0.000)	-0.004 (-0.010, 0.001)	-0.000 (-0.000, 0.000)	-0.006 (-0.016, 0.003)
Age-squared	0.000* (-0.000, 0.000)	0.000* (-0.000, 0.000)	0.000 (-0.000, 0.000)	0.000* (-0.000, 0.000)	0.000 (-0.000, 0.000)	0.000 (-0.000, 0.000)
Female (Ref: Male)	-0.000 (-0.001, 0.000)	-0.011*** (-0.018, -0.004)	-0.000 (-0.001, 0.001)	-0.002 (-0.024, 0.021)	-0.000 (-0.002, 0.001)	0.002 (-0.034, 0.038)

IMG status (Ref: CMG)			-0.001*** (-0.002, -0.001)	0.001 (-0.006, 0.008)	0.000 (-0.001, 0.001)	0.009 (-0.014, 0.031)	0.001 (-0.001, 0.002)	0.023 (-0.013, 0.059)
Constant	-1.194*** (-1.414, -0.974)	-33.985*** (-40.479, -27.492)	0.761*** (0.531, 0.991)	-14.333*** (-20.580, -8.086)	-5.034 (-14.659, 4.590)	-49.935 (-311.540, 211.670)		
R-squared	0.001	0.024	0.017	0.161	0.012	0.218	0.369	0.398
Number of patients	172,451	4,490	172,451	4,490	172,451	4,490	172,451	4,490
Observations	1,207,157	31,430	1,207,157	31,430	1,207,157	31,430	1,207,157	31,430

DMI, Diabetes Management Incentive; DID, Difference-in-difference; OLS, Ordinary least squares; 95% CI, 95% confidence interval; Ref, Reference; ADGs, Aggregated Diagnosis Groups; IMG, International Medical Graduate; CMG, Canadian Medical Graduate. Robust 95% CI in parentheses.

[a] Only assessed in patients hospitalized at least once for diabetes-related long-term complications as indicated in Table 4.1. In addition, this outcome has been natural-log transformed.

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

Table 4.6: Estimated impact of DMI on hospitalization costs for diabetes-related short-term and long-term complications

Variables	Model 1: DID Unadjusted Pooled OLS $\hat{\beta}$ (95% CI)		Model 2: DID Adjusted Pooled OLS $\hat{\beta}$ (95% CI)		Model 3: Fixed-Effects DID $\hat{\beta}$ (95% CI)		Model 4: High-dimensional Fixed-Effects DID $\hat{\beta}$ (95% CI)	
	Short-term[a] (Log-transformed)	Long-term[b] (Log-transformed)	Short-term[a] (Log-transformed)	Long-term[b] (Log-transformed)	Short-term[a] (Log-transformed)	Long-term[b] (Log-transformed)	Short-term[a] (Log-transformed)	Long-term[b] (Log-transformed)
DMI	-0.102 (-0.409, 0.205)	0.082 (-0.078, 0.242)	-0.065 (-0.359, 0.229)	0.144* (-0.022, 0.310)				
Period (Ref: Pre-DMI period)	-0.389 (-0.965, 0.187)	0.454*** (0.123, 0.784)	-0.202 (-0.690, 0.286)	0.460*** (0.165, 0.755)	-0.031 (-0.534, 0.473)	0.453*** (0.146, 0.759)	0.039 (-0.965, 1.043)	0.406 (-0.161, 0.973)
DMI*Period (DID Effect)	0.239 (-0.318, 0.796)	-0.140 (-0.454, 0.174)	0.100 (-0.368, 0.569)	-0.090 (-0.368, 0.188)	0.011 (-0.446, 0.469)	-0.060 (-0.334, 0.214)	-0.165 (-1.193, 0.863)	-0.049 (-0.616, 0.518)
τ (time trend)	0.138*** (0.067, 0.209)	0.212*** (0.174, 0.249)	0.109*** (0.043, 0.175)	0.097*** (0.061, 0.132)	-32.701 (-128.006, 62.604)	-1.036 (-57.136, 55.064)		
Patient Characteristics								
Age			-0.057*** (-0.088, -0.026)	0.016 (-0.005, 0.036)				
Age-squared			0.000**	-0.000*	0.000	0.002***	0.015	0.008

	(0.000, 0.001)	(-0.000, 0.000)	(-0.001, 0.001)	(0.001, 0.002)	(-0.006, 0.036)	(-0.005, 0.020)
Female (Ref: Male)	-0.356*** (-0.485, -0.227)	-0.227*** (-0.287, -0.167)				
Rural residence (Ref: Urban)	-0.234 (-0.879, 0.410)	0.112 (-0.159, 0.383)	-0.010 (-0.873, 0.854)	0.576** (0.010, 1.143)	0.319 (-0.854, 1.492)	0.385 (-0.445, 1.214)
Number of ADGs	0.374*** (0.353, 0.395)	0.339*** (0.329, 0.349)	0.577*** (0.554, 0.599)	0.514*** (0.502, 0.527)	0.598*** (0.571, 0.625)	0.544*** (0.528, 0.559)
Duration of diabetes (years)	-0.033*** (-0.052, -0.014)	-0.002 (-0.012, 0.007)	32.659 (-62.603, 127.920)	0.860 (-55.215, 56.935)	13.211 (-90.877, 117.299)	-6.318 (-68.165, 55.529)
Material deprivation quintiles (Ref: Q1 (least deprived))						
Q2	0.052 (-0.148, 0.253)	-0.051 (-0.160, 0.057)	-0.060 (-0.504, 0.383)	-0.008 (-0.269, 0.253)	0.047 (-0.565, 0.659)	-0.037 (-0.421, 0.348)
Q3	-0.000 (-0.217, 0.216)	-0.043 (-0.162, 0.077)	0.088 (-0.376, 0.551)	-0.041 (-0.321, 0.239)	-0.022 (-0.652, 0.608)	0.141 (-0.270, 0.552)
Q4	0.142 (-0.102, 0.386)	-0.041 (-0.167, 0.085)	0.238 (-0.290, 0.766)	-0.120 (-0.408, 0.168)	0.276 (-0.385, 0.938)	-0.141 (-0.561, 0.279)

Q5 (most deprived)	0.118 (-0.163, 0.399)	-0.023 (-0.167, 0.121)	-0.117 (-0.718, 0.485)	-0.042 (-0.360, 0.275)	-0.204 (-0.978, 0.570)	0.080 (-0.390, 0.551)
Income quintiles (Ref: Q1 (lowest income))						
Q2	0.003 (-0.207, 0.213)	0.083* (-0.014, 0.180)	0.025 (-0.321, 0.372)	0.099 (-0.082, 0.279)	0.032 (-0.409, 0.472)	0.036 (-0.210, 0.282)
Q3	0.244* (-0.009, 0.498)	0.085 (-0.031, 0.200)	0.188 (-0.250, 0.626)	0.093 (-0.128, 0.314)	0.181 (-0.360, 0.723)	0.063 (-0.246, 0.371)
Q4	0.209 (-0.057, 0.475)	0.076 (-0.055, 0.206)	0.390 (-0.096, 0.877)	0.204 (-0.048, 0.455)	-0.058 (-0.647, 0.531)	0.128 (-0.215, 0.471)
Q5 (highest income)	0.184 (-0.108, 0.476)	0.020 (-0.124, 0.165)	-0.003 (-0.538, 0.532)	0.004 (-0.292, 0.300)	-0.279 (-0.955, 0.396)	-0.202 (-0.607, 0.203)
Physician Characteristics						
Age	0.030 (-0.025, 0.086)	-0.017 (-0.045, 0.011)	0.062 (-0.039, 0.162)	-0.041 (-0.101, 0.020)	0.079 (-0.082, 0.240)	-0.051 (-0.156, 0.055)
Age-squared	-0.000 (-0.001, 0.000)	0.000 (-0.000, 0.000)	-0.001 (-0.001, 0.000)	0.000 (-0.000, 0.001)	-0.001 (-0.002, 0.001)	0.000 (-0.001, 0.001)
Female (Ref: Male)	-0.042 (-0.190, 0.105)	-0.116*** (-0.194, -0.037)	-0.175 (-0.568, 0.218)	-0.024 (-0.277, 0.230)	-0.416 (-1.006, 0.173)	-0.007 (-0.418, 0.404)

IMG status (Ref: CMG)			-0.032 (-0.212, 0.147)	-0.002 (-0.082, 0.078)	0.108 (-0.371, 0.586)	0.111 (-0.143, 0.365)	0.237 (-0.486, 0.960)	0.291 (-0.129, 0.711)
Constant	-275.611*** (-417.578, -133.645)	-423.127*** (-497.756, -348.499)	-218.310*** (-350.524, -86.097)	-195.143*** (-266.321, -123.966)	1,372.792 (-2,641.304, 5,386.888)	50.005 (-2,999.308, 3,099.317)		
R-squared	0.004	0.027	0.189	0.164	0.264	0.226	0.469	0.390
Number of patients	1,240	4,490	1,240	4,490	1,240	4,490	1,240	4,490
Observations	8,680	31,430	8,680	31,430	8,680	31,430	8,680	31,430

DMI, Diabetes Management Incentive; DID, Difference-in-difference; OLS, Ordinary least squares; 95% CI, 95% confidence interval; Ref, Reference; ADGs, Aggregated Diagnosis Groups; IMG, International Medical Graduate; CMG, Canadian Medical Graduate. Robust 95% CI in parentheses.

[a] Only assessed in patients hospitalized at least once for diabetes-related short-term complications as indicated in Table 4.1. In addition, this outcome has been natural-log transformed.

[b] Only assessed in patients hospitalized at least once for diabetes-related long-term complications as indicated in Table 4.1. In addition, this outcome has been natural-log transformed.

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

Table 4.7: Estimated impact of DMI on MRS

Variables	Model 1: DID Unadjusted Pooled OLS $\hat{\beta}$ (95% CI)	Model 2: DID Adjusted Pooled OLS $\hat{\beta}$ (95% CI)	Model 3: Fixed-Effects DID $\hat{\beta}$ (95% CI)	Model 4: High-dimensional Fixed-Effects DID $\hat{\beta}$ (95% CI)
DMI	-1.054*** (-1.290, -0.818)	0.196*** (0.117, 0.274)		
Period (Ref: Pre-DMI period)	-0.077 (-0.176, 0.022)	0.004 (-0.080, 0.087)	-0.010 (-0.096, 0.077)	-0.145* (-0.305, 0.014)
DMI*Period (DID Effect)	0.024 (-0.074, 0.121)	0.036 (-0.045, 0.118)	0.033 (-0.048, 0.115)	0.060 (-0.103, 0.223)
τ (time trend)	1.355*** (1.343, 1.366)	0.116*** (0.105, 0.128)	-0.896 (-14.992, 13.201)	
Patient Characteristics				
Age		0.839*** (0.827, 0.852)		
Age-squared		0.002*** (0.002, 0.002)	0.004*** (0.004, 0.005)	0.020*** (0.016, 0.024)
Female (Ref: Male)		-4.198*** (-4.241, -4.156)		
Rural residence (Ref: Urban)		0.839*** (0.668, 1.010)	0.313*** (0.109, 0.516)	0.204 (-0.074, 0.481)
Number of ADGs		1.614*** (1.607, 1.622)	1.551*** (1.543, 1.558)	1.519*** (1.508, 1.529)
Duration of diabetes (years)		0.031*** (0.026, 0.037)	1.571 (-12.520, 15.662)	-17.730** (-34.057, -1.404)
Material deprivation quintiles (Ref: Q1 (least deprived))				

Q2		-0.037 (-0.099, 0.025)	-0.088** (-0.173, -0.002)	-0.019 (-0.134, 0.095)
Q3		0.089** (0.021, 0.158)	-0.073 (-0.165, 0.020)	-0.039 (-0.161, 0.083)
Q4		0.109*** (0.033, 0.185)	-0.187*** (-0.289, -0.084)	-0.145** (-0.284, -0.006)
Q5 (most deprived)		0.289*** (0.199, 0.378)	-0.200*** (-0.319, -0.082)	-0.145* (-0.301, 0.010)
Income quintiles (Ref: Q1 (lowest income))				
Q2		-0.127*** (-0.191, -0.063)	-0.086** (-0.153, -0.020)	-0.066 (-0.150, 0.018)
Q3		-0.204*** (-0.277, -0.132)	-0.088** (-0.167, -0.010)	-0.096* (-0.195, 0.003)
Q4		-0.256*** (-0.335, -0.177)	-0.069 (-0.156, 0.019)	-0.111** (-0.220, -0.001)
Q5 (highest income)		-0.335*** (-0.422, -0.248)	-0.083 (-0.183, 0.017)	-0.096 (-0.224, 0.031)
Physician Characteristics				
Age		-0.016* (-0.034, 0.001)	0.026** (0.005, 0.046)	0.045*** (0.012, 0.078)
Age-squared		0.000*** (0.000, 0.000)	-0.000* (-0.000, 0.000)	-0.000** (-0.001, -0.000)
Female (Ref: Male)		-0.120*** (-0.169, -0.071)	-0.042 (-0.125, 0.040)	-0.028 (-0.140, 0.084)
IMG status (Ref: CMG)		-0.587*** (-0.637, -0.537)	-0.303*** (-0.388, -0.219)	-0.294*** (-0.413, -0.174)
Constant	-2,667.129***	-250.712***	64.462	

	(-2,690.107, -2,644.151)	(-273.577, -227.846)	(-692.529, 821.452)	
R-squared	0.027	0.834	0.396	0.927
Number of patients	172,451	172,451	172,451	172,451
Observations	1,207,157	1,207,157	1,207,157	1,207,157

DMI, Diabetes Management Incentive; MRS, Mortality Risk Score; DID, Difference-in-difference; OLS, Ordinary least squares; 95% CI, 95% confidence interval; Ref, Reference; ADGs, Aggregated Diagnosis Groups; IMG, International Medical Graduate; CMG, Canadian Medical Graduate.
Robust 95% CI in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Table 4.8: Estimated impact of DMI on the probability of being hospitalized for diabetes-related complications, and on MRS in the two subgroups

Outcome Variables	Model 1: DID Unadjusted Pooled OLS $\hat{\beta}_3$ (95% CI)		Model 2: DID Adjusted Pooled OLS[a] $\hat{\beta}_3$ (95% CI)		Model 3: Fixed-Effects DID[a] $\hat{\beta}_3$ (95% CI)		Model 4: High-dimensional Fixed-Effects DID[a] $\hat{\beta}_3$ (95% CI)	
Subgroup Analysis #1: Comorbidity (Comparing patients with below versus at or above median number of ADGs at baseline)								
	<4 ADGs at baseline	≥ 4 ADGs at baseline	<4 ADGs at baseline	≥ 4 ADGs at baseline	<4 ADGs at baseline	≥ 4 ADGs at baseline	<4 ADGs at baseline	≥ 4 ADGs at baseline
Hospitalized for short-term complications								
(Binary)	-0.000 (-0.001, 0.000)	0.000 (-0.000, 0.001)	-0.000 (-0.001, 0.000)	0.000 (-0.000, 0.001)	-0.000 (-0.001, 0.001)	0.000 (-0.000, 0.001)	-0.000 (-0.001, 0.001)	0.000 (-0.001, 0.002)
Hospitalized for long-term complications								
(Binary)	0.000 (-0.001, 0.001)	0.000 (-0.001, 0.001)	0.000 (-0.001, 0.001)	0.000 (-0.001, 0.001)	0.000 (-0.001, 0.001)	0.000 (-0.001, 0.002)	-0.001 (-0.003, 0.001)	0.000 (-0.002, 0.002)
MRS	0.049 (-0.098, 0.197)	-0.014 (-0.142, 0.113)	-0.019 (-0.138, 0.099)	0.085 (-0.023, 0.194)	-0.009 (-0.128, 0.110)	0.072 (-0.036, 0.180)	0.054 (-0.177, 0.284)	0.054 (-0.157, 0.264)
Subgroup Analysis #2: Sex (Comparing males versus females)								
	Males	Females	Males	Females	Males	Females	Males	Females

Hospitalized for short-term complications								
(Binary)	0.001* (-0.000, 0.001)	-0.000 (-0.001, 0.000)	0.001** (0.000, 0.001)	-0.000 (-0.001, 0.000)	0.000 (-0.000, 0.001)	-0.000 (-0.001, 0.000)	0.000 (-0.001, 0.002)	0.000 (-0.001, 0.001)
Hospitalized for long-term complications								
(Binary)	-0.000 (-0.001, 0.001)	0.001 (-0.000, 0.002)	-0.000 (-0.001, 0.001)	0.001 (-0.000, 0.002)	-0.000 (-0.001, 0.001)	0.001 (-0.000, 0.002)	-0.001 (-0.004, 0.001)	0.001 (-0.001, 0.003)
MRS	0.038 (-0.097, 0.174)	0.014 (-0.126, 0.154)	0.050 (-0.062, 0.161)	0.019 (-0.099, 0.138)	0.048 (-0.064, 0.159)	0.019 (-0.100, 0.137)	0.181 (-0.035, 0.396)	-0.079 (-0.290, 0.132)

DMI, Diabetes Management Incentive; MRS, Mortality Risk Score; DID, Difference-in-difference; OLS, Ordinary least squares; 95% CI, 95% confidence interval; ADGs, Aggregated Diagnosis Groups.

[a] Models 2-4 controlled for patient characteristics (age, age-squared, sex, rural residence, number of Aggregated Diagnosis Groups, duration of diabetes, material deprivation, neighborhood income quintiles), and physician characteristics (age, age-squared, sex, International Medical Graduate status).

Robust 95% CI in parentheses.

** $p<0.05$, * $p<0.1$

Note: Each of the two subgroup analyses were performed separately using Models 1-4 each. Full regression results are available upon request.

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Appendices

Appendix A4.1: ICD-10 Codes for Diabetes-related Hospitalizations

Table 4.9: The ICD-10 codes for hospitalizations for diabetes-related short-term and long-term complications

Diabetes-related complications	ICD-10 codes	Description of complications included
Diabetes-related short-term complications	E10.0, E10.1, E10.11, E10.12, E11.0, E11.1, E11.11, E11.12, E13.0, E13.1, E13.11, E13.12, E14.0, E14.1, E14.11, E14.12	Type 1, type 2, other specified, or unspecified diabetes mellitus with: Hyperglycemic hyperosmolar coma, hypoglycemic coma, insulin coma, ketoacidosis, or mixed ketoacidosis
Diabetes-related long-term complications	E10.2, E10.3, E10.4, E10.5, E10.6, E10.7, E11.2, E11.3, E11.4, E11.5, E11.6, E11.7, E13.2, E13.3, E13.4, E13.5, E13.6, E13.7, E14.2, E14.3, E14.4, E14.5, E14.6, E14.7	Type 1, type 2, other specified, or unspecified diabetes mellitus with: Renal, ophthalmic, neurologic, circulatory, or multiple complications

ICD-10, 10th revision of the International Classification of Diseases
Source: Petrosyan *et al*., 2017[5]; OECD, 2008[56]; OECD, 2009[57]

Appendix A4.2: Hospitalizations, Hospitalization Costs, and MRS Compared at Baseline and Final Year

Table 4.10: Diabetes-related hospitalizations, hospitalization costs, and MRS compared between comparison and DMI group at baseline and final fiscal year

Variables	2002			2008		
	Comparison group (n = 15,559)	**DMI group** (n = 156,892)	***p*-value**	**Comparison group** (n = 15,559)	**DMI group** (n = 156,892)	***p*-value**
Diabetes-related hospitalizations and hospitalization costs						
Short-term complications						
Patients hospitalized, n (%)						
0	15,539 (99.87%)	156,701 (99.88%)	0.82	15,536 (99.85%)	156,614 (99.82%)	0.40
1	20 (0.13%)	191 (0.12%)		23 (0.15%)	278 (0.18%)	
Number of hospitalizations[a*], Rank sum	60,115.5	709,304.5	0.27	58,266	711,154	0.82
Hospitalization costs[a*] ($ CAD), Rank sum	60,487	708,933	0.20	58,002.5	711,417.5	0.91
Long-term complications						
Patients hospitalized, n (%)						
0	15,530 (99.81%)	156,486 (99.74%)	0.09	15,461 (99.37%)	155,797 (99.30%)	0.33
1	29 (0.19)	406 (0.26%)		98 (0.63%)	1,095 (0.70%)	
Number of hospitalizations[b*], Rank sum	750,181	9,332,114	0.45	777,405	9,304,890	0.30

Hospitalization costs[b*] ($ CAD), Rank sum	749,544.5	9,332,750.5	0.42	779,059.5	9,303,235.5	0.26
Mortality risk						
MRS, mean (SD)	45.09 (14.94)	44.03 (15.56)	<0.001	53.15 (16.60)	52.11 (17.28)	<0.001

MRS, Mortality Risk Score; DMI, Diabetes Management Incentive; $ CAD, Canadian dollars; SD, standard deviation

[a] Only assessed in patients hospitalized at least once for diabetes-related short-term complications as indicated in Table 4.1.

[b] Only assessed in patients hospitalized at least once for diabetes-related long-term complications as indicated in Table 4.1.

* Wilcoxon Rank sum test was used to assess if the medians for the variables differed between the two groups.

Appendix A4.3: Linear Probability Model versus Logit Model

Table 4.11: The estimated impact of DMI on the probability of being hospitalized for diabetes-related short-term complications compared between the Linear Probability Model (LPM) versus a Logit model

Variables	Model 1: DID Unadjusted Pooled OLS (LPM)	DID Unadjusted Pooled Logit Model	Model 2: DID Adjusted Pooled OLS (LPM)	DID Adjusted Pooled Logit Model
	Average Marginal Effect[a] (95% CI)	Average Marginal Effect[a] (95% CI)	Average Marginal Effect[a] (95% CI)	Average Marginal Effect[a] (95% CI)
DMI	0.000* (-0.000, 0.001)	0.000* (-0.000, 0.001)	0.000 (-0.000, 0.001)	0.000 (-0.000, 0.000)
Period (Ref: Pre-DMI period)	-0.000 (-0.000, 0.000)	-0.000 (-0.000, 0.000)	-0.000 (-0.000, 0.000)	-0.000 (-0.000, 0.000)
DMI*Period (DID Effect)	0.000 (-0.000, 0.001)	0.000 (-0.000, 0.001)	0.000 (-0.000, 0.001)	0.000 (-0.000, 0.001)
τ (time trend)	0.000*** (0.000, 0.000)	0.000*** (0.000, 0.000)	-0.000** (-0.000, -0.000)	-0.000** (-0.000, -0.000)
Patient Characteristics				
Age			-0.001*** (-0.001, -0.001)	-0.000*** (-0.000, -0.000)
Age-squared			0.000*** (0.000, 0.000)	0.000*** (0.000, 0.000)
Female (Ref: Male)			-0.000*** (-0.001, -0.000)	-0.001*** (-0.001, -0.000)
Rural residence (Ref: Urban)			0.000 (-0.001, 0.001)	-0.000 (-0.001, 0.000)

Number of ADGs	0.001*** (0.001, 0.001)	0.000*** (0.000, 0.001)
Duration of diabetes (years)	0.000*** (0.000, 0.000)	0.000*** (0.000, 0.000)
Material deprivation quintiles (Ref: Q1 (least deprived))		
Q2	0.000 (-0.000, 0.000)	0.000 (-0.000, 0.001)
Q3	0.000 (-0.000, 0.000)	0.000 (-0.000, 0.001)
Q4	0.000** (0.000, 0.001)	0.000* (-0.000, 0.001)
Q5 (most deprived)	0.001*** (0.000, 0.001)	0.001** (0.000, 0.001)
Income quintiles (Ref: Q1 (lowest income))		
Q2	0.000 (-0.000, 0.000)	0.000 (-0.000, 0.000)
Q3	0.000 (-0.000, 0.000)	0.000 (-0.000, 0.001)
Q4	-0.000 (-0.000, 0.000)	0.000 (-0.000, 0.000)
Q5 (highest income)	-0.000 (-0.000, 0.000)	0.000 (-0.000, 0.000)
Physician Characteristics		
Age	-0.000 (-0.000, 0.000)	-0.000 (-0.000, 0.000)
Age-squared	0.000 (-0.000, 0.000)	0.000 (-0.000, 0.000)

Female (Ref: Male)			-0.000 (-0.000, 0.000)	-0.000 (-0.000, 0.000)
IMG status (Ref: CMG)			-0.001*** (-0.001, -0.000)	-0.000*** (-0.001, -0.000)
Number of patients	172,451	172,451	172,451	172,451
Observations	1,207,157	1,207,157	1,207,157	1,207,157

DMI, Diabetes Management Incentive; DID, Difference-in-difference; OLS, Ordinary least squares; LPM, Linear Probability Model; 95% CI, 95% confidence interval; Ref, Reference; ADGs, Aggregated Diagnosis Groups; IMG, International Medical Graduate; CMG, Canadian Medical Graduate.

[a] Average marginal effect indicates the effect of the variable on the probability of being hospitalized for diabetes-related short-term complications. The estimated coefficient ($\hat{\beta}$) in the LPM can be directly interpreted as the average marginal effect, however, this cannot be done for the logit model. For the logit model, the average marginal effect is calculated by first determining the derivative of the equation for the logistic regression with respect to a specific variable of interest given by the model.[68,70] Following this, the observed values in the data were used to calculate the average marginal effect. The average marginal effect was calculated using the margins command in Stata 15.1.

Robust 95% CI in parentheses.

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

Chapter 5

5 Conclusions and Future Research

5.1 Summary and Conclusions

Diabetes management provided at primary care is key in improving the health of diabetic patients. Effective disease management provided by family physicians (FPs) can potentially reduce the risk of hospitalizations, hospitalization costs, and mortality.[1–3] Therefore, financial incentives (i.e. pay-for-performance (P4P) incentives) for FPs were introduced in several countries to improve management of diabetes at primary care. Previous literature found that financial incentives tend to increase diabetes-related services provided to patients[4–7]; however, some studies report otherwise.[8,9] To date, the impact of these incentives on hospitalizations, hospitalization costs, and mortality is unclear. Furthermore, it is unknown if the introduction of the Diabetes Management Incentive (DMI), introduced in Ontario, is associated with increased diabetes-related services and decreased diabetes-related hospitalizations, associated costs, and mortality risk in diabetic patients. Therefore, in this thesis, a literature review was first conducted examining the impact of financial incentives for diabetes care on diabetes-related hospitalizations, diabetes-related hospitalization costs, and mortality to understand and summarize the results of the previous literature. Following this, the impact of DMI on diabetes-related services, diabetes-related hospitalizations, associated hospitalization costs, and mortality risk was examined in patients diagnosed with diabetes in Ontario. This was assessed by comparing patients enrolled to FPs eligible for DMI to patients who were affiliated with a FP practicing in the traditional fee-for-service (FFS) model (not eligible for DMI).

In Chapter 2, a literature review assessing the impact of financial incentives for diabetes care on diabetes-related hospitalizations, hospitalization costs, and mortality was performed. This review found that existing studies evaluating this relationship had inconsistent findings. The majority of the studies found the incentives were associated with reduced hospitalizations, nevertheless, a handful of studies also found that there was

no effect, and one study found an increase in emergency visits for diabetes. Findings were inconsistent for diabetes-related hospitalization costs and mortality as well. In addition, there was a high degree of heterogeneity found among the included studies in terms of their study population, study setting, study design, nature of the financial incentives, and the outcomes measured.

In Chapter 3, the impact of the DMI on diabetes-related services in patients with diabetes in Ontario was examined. The diabetes-related services were measured using the Diabetic Management Assessment (DMA) fee code, which is billed by FPs for providing diabetes-related services to their diabetic patients.[9–11] This outcome measure was defined as a dichotomous variable which measured whether or not the patient had three or more DMA fee codes billed by their physician during each fiscal year. Results from this chapter suggested that the introduction of DMI increased the provision of diabetes-related services in Ontario. The effect of DMI is an increase in the probability of having three or more DMA fee codes billed by patient's physician by 2.1 percentage points, after controlling for patient- and physician-level characteristics, patient fixed-effects, and patient-specific time trend. Subgroup analyses were also performed and findings revealed that the effect of DMI on diabetes-related services to be similar across the comorbidity groups, however, the effect of DMI was slightly larger in males than in females.

In Chapter 4, the impact of DMI on diabetes-related hospitalizations, diabetes-related hospitalization costs, and mortality risk in diabetic patients in Ontario was examined. The hospitalizations and associated costs were categorized into two categories: (i) diabetes-related short-term complications, and (ii) diabetes-related long-term complications. The diagnosis codes that identified each type of complication were based on the Organization for Economic Co-operation and Development (OECD) Healthcare Quality Indicator (HCQI) Project.[12–16] The hospitalization costs were calculated using the ICES costing macro discussed in Chapter 4, and the mortality risk was measured using the Mortality Risk Score (MRS), which estimated the patient's risk of all-cause death within one year. The MRS was computed using the algorithm proposed by Austin & Walraven (2011).[17] Results from this analysis revealed that DMI had no statistically significant effect on hospitalization and hospitalization cost for diabetes-related short-term and long-term

complications, and on MRS. Patient- and physician-level characteristics, individual fixed-effects, and patient-specific time trend were controlled for. Subgroup analyses by comorbidity, and sex were also performed to explore the impact of DMI on some of the outcomes. Findings showed that DMI has no effect on the probability of being hospitalized for diabetes-related short-term and long-term complications, and on MRS in all subgroups.

Overall, the introduction of DMI was associated with an increase in the provision of diabetes-related services in Ontario, however, it had no effect on the patient outcomes (measured by hospitalizations, and the risk of mortality), and hospitalization costs. There are some possible explanations as to why DMI had no effect on these outcomes in this study. First, the study period is not sufficiently long enough. It is possible that a longer period post-DMI may be required to see improvements in these long-term patient outcomes and cost savings. Second, although DMI was associated with an increase in the provision of diabetes-related services, the magnitude of this effect was actually very small. Therefore, no effects were observed on the patient outcomes and hospitalization costs. Third, the low uptake of DMI as discussed in Chapters 3 and 4 may be another possible explanation. This implies that not a lot of patients were getting the complete diabetes management during the study period. Finally, there are other factors outside of the primary care settings, such as the ranges of specialist and multidisciplinary care the patient received, patient's self-management of the disease at home and if they were referred to or had access to diabetes education centres, could have affected the outcomes but were not accounted for in this paper.

Findings from this study are relevant to policy makers as it informs them the effect of the DMI on the diabetes-related services provided, patient outcomes, and hospitalization costs. As for the policy implications, a suggestion would be that the policy makers should not scrap the DMI. Although no improvements were observed in the diabetes-related hospitalizations, associated hospitalization costs, and the mortality risk; the DMI did increase the provision of diabetes-related services in diabetic patients. If DMI is scrapped, it may affect the severe diabetic patients who are in high need of the diabetes-related services, and would compromise their health. Instead, further research is required

to understand the potential benefits of this incentive. The impact of this incentive on other patient-relevant outcomes (e.g. quality of life, patient satisfaction with care, user experience, lifestyle changes) is unknown. Therefore, additional research should be performed to gain a better understanding of the DMI, and to determine what areas in the DMI needs to be focused on to observe improvements in patients' health and healthcare system costs.

5.2 Future Research

Future research can further investigate the impact of DMI through several ways. The impact of this incentive on diabetes-related services, hospitalizations, hospitalization costs, and mortality risk were only examined until March 2009 in this study; therefore, future studies can investigate the impacts on patient outcomes and costs beyond 2009. Through this, the study period post-DMI will be much longer, and improvements in the patient outcomes and hospitalization costs, if any, can be more likely seen. Additionally, future research in this area should keep note that all FPs were eligible to bill the DMI (including FPs practicing in the traditional FFS) as of April 1, 2009.[18,19] Second, future research can also explore the effect of DMI on patients' lifestyle changes, satisfaction with care, quality of life, and treatment compliance. Third, it is also important to assess if there are any potential harms associated with the implementation of DMI such as any health disparities in the patient population, if certain groups of patients are being avoided, or if it affects FPs' motivations to provide care that is incentivized instead of the best care to address the patients' needs. Future research can also explore the effectiveness of other P4P incentives outside of the DMI (e.g. Heart Failure Management incentive, incentives for cancer screening) in Ontario. Similar methodologies from this study can be used to understand the effectiveness of these incentives in improving patient's health and/or healthcare system costs. On the whole, further research in the area of DMI and P4P incentives can educate us more about the impact of these incentives, and assist with revising the DMI to improve its desired outcomes.

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