JOHANNES KEPLER
UNIVERSITY LINZ

DEPARTMENT OF ECONOMICS
JOHANNES KEPLER UNIVERSITY OF LINZ

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by

Katrin ZOCHER, Marina CASAZZA, Matthias BOLZ, Gerald PRUCKNER, Josef HUEMER

Working Paper No. 2509
June 2025

Johannes Kepler University of Linz
Department of Economics
Altenberger Strasse 69
A-4040 Linz - Auhof, Austria
www.econ.jku.at

katrin.zocher@jku.at

The systematic shortcomings of opportunistic screening for diabetic retinopathy *

Katrin Zocher [a], Marina Casazza [b], Matthias Bolz [b], Gerald Pruckner [a], and Josef Huemer [b,c,d]

[a] *Department of Economics, Johannes Kepler University Linz*
[b] *Department of Ophthalmology and Optometry, Kepler University Hospital, Johannes Kepler University Linz*
[c] *NIHR Moorfields Biomedical Research Centre, London, UK*
[d] *Institute of Ophthalmology, University College London, London, UK*

July 31, 2025

Abstract

Aims: Diabetic retinopathy (DR) is a leading cause of vision loss among working-age adults, with early detection and regular screening being critical for prevention. In Austria, DR screening is conducted opportunistically, lacking the systematic approach seen in other countries. This study evaluates the uptake of DR screening, the impact of a diabetes-specific Disease Management Program (DMP), and the potential for systemic regional screening to address gaps.

Method: We conducted a retrospective cohort study to investigate diabetic screening behavior using pseudonymized administrative data from the Austrian Health Insurance Fund in Upper Austria (AHIF-UA) from 2005 to 2021, encompassing 1,439,900 total observations. To isolate the effects of diabetes diagnosis on eye screening participation, we employed a quasi-experimental design that controls for unobserved heterogeneity by comparing individuals with similar diagnosis dates. To determine the causal effect of access to timing of the diabetes diagnosis and DMP enrollment, our study exploits the quasi-random assignment of primary care providers (PCPs) to practices and patients.

Results: Results indicate a statistically significant 5 percentage-point increase in eye care visits right after a diabetes diagnosis. However, overall adherence was low: only 46% of individuals had an ophthalmology visit in the first year, and 16.7% maintained annual visits over three years. Enrollment in the DMP significantly improved screening rates. Patients assigned to a PCP offering the DMP were eight times as likely to enroll, demonstrating access as the primary driver.

* *Correspondence:* Katrin Zocher,Department of Economics, Johannes Kepler University Linz, Altenberger Straße 69, 4040 Linz, Austria; E-Mail: katrin.zocher@jku.at.

Conclusion/Interpretation: The study highlights the limitations of opportunistic screening, with significant disparities in access and adherence. Opportunistic screening for DR in Upper Austria fails to ensure adequate coverage, leaving many individuals at risk of preventable vision loss. While DMP enrollment improves adherence to screening guidelines, the overall impact is limited. The findings underscore the need for systematic screening programs to address disparities and improve outcomes.

JEL Classification: I12, I14, I18, H51
Keywords: diabetic retinopathy, eye health, opportunistic screening

Research in context

What is known about this subject?

- Diabetic retinopathy is the leading cause of vision loss in working-age adults.
- Compliance in countries with opportunistic screening models shows that screening participation is linked to sociodemographic factors.

What is the key question?

- In a country with an opportunistic screening model, what is the causal impact of a diabetes diagnosis on patient screening behavior? Furthermore, what is the causal role of primary care providers and structured Disease Management Programs (DMPs) in influencing patient screening adherence?

What are the new findings?

- This study provides the first causal evidence of a "teachable moment" following a diabetes diagnosis, showing a significant increase in ophthalmologist contacts immediately after diagnosis in an opportunistic screening setting.
- We provide a novel causal analysis of the impact of primary care providers by exploiting the quasi-random assignment of patients to practices. We show that PCPs impact patient enrollment and, consequently, screening participation.
- The study highlights the limitations of an opportunistic system, demonstrating that while DMPs are effective in improving screening rates for enrolled patients, their overall impact on the population is limited due to low enrollment.

How might this impact on clinical practice in foreseeable future?

- This research provides evidence for advocating a shift from the current opportunistic model to a comprehensive, systematic screening program with a centralized patient registry to ensure equitable access and prevent avoidable vision loss.

I. Introduction

Diabetic retinopathy (DR) is the leading cause of vision loss in working-age adults due to microvascular damage caused by diabetes mellitus (DM) [1]. By 2045, DM is projected to affect 700 million people globally, with one-third expected to develop some degree of retinopathy [2, 3, 4]. Early detection through systematic screening is crucial, as timely interventions such as intravitreal injections or laser photocoagulation can preserve vision and improve retinal outcomes [5]. Advances in screening, imaging, and treatment have already improved visual outcomes in many regions [6].

In response to the growing burden of DR, many regions have implemented screening programs. Systematic screening programs are centralized and highly structured, aiming to include all at-risk patients. In contrast, opportunistic screening programs are less structured and typically provide services only when a person comes into contact with a healthcare provider [7]. Many countries, including Iceland, the United Kingdom (UK), Singapore, and Ireland, have successfully implemented nationwide systematic programs [8, 9, 10], while others, such as Denmark, Norway, and Turkey, have done so regionally [7]. For example, the UK Diabetic Eye Screening Programme, introduced in 2003, has been associated with a significant reduction in DR-related blindness among the working-age population [11]. These programs adhere to the principles of effective disease screening outlined by Wilson et al. in 1968, which emphasize the importance of early detection, cost-effective treatment, and accessible testing methods [12].

A body of research from countries with opportunistic screening models highlights a clear link between sociodemographic factors and compliance with DR screening recommendations [13]. Higher screening rates are consistently reported for older patients, those with greater financial stability and educational attainment, and individuals who do not belong to a racial or ethnic minority [13, 14, 15, 16]. However, a critical limitation of this literature is its focus on average screening behavior and correlational associations, which cannot determine whether patients causally adapt their behavior in response to a diabetes diagnosis. We overcome this limitation by employing a quasi-experimental design that controls for unobserved heterogeneity, allowing us to identify the

causal effect of a diabetes diagnosis on eye screening behavior in a region with an opportunistic screening model. Furthermore, our access to longitudinal data enables a detailed analysis of individual screening patterns over time.

Despite PCPs providing a large proportion of care for chronic diseases, the influence of primary care providers (PCPs) on patient screening behaviour is currently understudied. Existing literature [17, 18] often fails to causally link PCP access and practice style to patients' uptake of diabetes-related care, including screening. Our study adds to this literature by exploiting the quasi-random assignment of patients to primary care practices to analyze the causal effect of PCPs' participation in the disease management program on eye screening uptake. We conduct our empirical analysis using a large administrative dataset from Austria, a country that lacks a national diabetic retinopathy screening program. Here, opportunistic screening is provided by general ophthalmologists who encourage individuals with diabetes to attend annual appointments. The absence of a national registry for people with diabetes, however, complicates efforts to monitor and improve screening uptake. According to the National Diabetes Report [19], the prevalence of diabetes based on medical prescriptions is estimated at 5%, corresponding to approximately 308,250 people in Austria. With the third-highest incidence in Upper Austria, our region of focus, the problem is particularly pronounced. Furthermore, an estimated 2-4% of the population (147,000-247,000 individuals) has undiagnosed DM.

The aim of this study is to: (i) investigate the uptake of opportunistic screening for DR in Upper Austria using a large, pseudonymized administrative dataset, (ii) evaluate the impact of an existing diabetes-specific Disease Management Program (DMP), (iii) identify the causal impact of PCP on individual screening uptake, and (iv) assess the potential for a systemic regional screening program. The strength of our empirical approach lies in the combination of a large, representative dataset and a rigorous quasi-experimental design. The use of real-world administrative data ensures our findings accurately reflect actual screening behaviors. This allows for a causal evaluation of the effect of a diabetes diagnosis on screening adherence and the identification of critical access and demographic disparities. By benchmarking these findings against systematic international

standards, our research is positioned to deliver clear, evidence-based recommendations to inform policies aimed at improving the effectiveness and equity of diabetic retinopathy screening.

II. Data and methods

II.A. Data and identification of people with diabetes mellitus

Austria's healthcare system is based on the Bismarckian social insurance model, which guarantees universal access to quality healthcare. Compulsory insurance covers extensive inpatient and outpatient care, as well as pharmaceuticals. People are assigned to a specific insurance fund according to their occupation and residence. We conducted a retrospective analysis using pseudonymized data from the Austrian Health Insurance Fund – Upper Austria (AHIF-UA). Upper Austria is one of Austria's nine federal states and comprises one sixth of the country's population [20]. The AHIF-UA covers private-sector employees and their dependants, accounting for around 75% of Upper Austria's population [21]. The dataset contains quarterly, individual-level information on inpatient hospital stays, including diagnoses (3rd-level ICD-10 codes) and prescribed drugs (4th-level ATC codes), as well as outpatient physician contacts, from 2005 to 2021.

In the absence of a diabetes registry in Austria, we analyzed health care utilization to identify individuals with DM. People were classified as having diabetes based on hospitalization for diabetes, prescription of ATC group A10 drugs, or enrollment in a diabetes-specific DMP (see Table B.1 in the supplementary material for the complete list). People can join the DMP if they have been diagnosed with type 2 DM and if their general practitioner (GP) offers this service. Approximately 44.9 % (47.2 %) of all active AHIF-UA contracted GP practices offered DMP services in 2019 (2021). Column 1 of Table 1 shows the full sample of all insured persons between the first quarter of 2007 and the fourth quarter of 2021. Of the nearly two million individuals observed, about 2.8% received diabetes diagnosis at some point.

We defined the quarter in which a person received their DM diagnosis as the reference point for analyzing the frequency of ophthalmic visits over time, given the critical role of regular eye

Table 1: Individual characteristics by sample

	Sample (2007-2021)		
		Received diabetes service	
	Full	Any time	At diagnosis
	(1)	(2)	(3)
Share of observations with diabetes services in %	5·5	100·0	100·0
Quarterly averages of individual characteristics			
Average Age	40·2	64·4	61·3
	(22·7)	(13·9)	(15·0)
Share of females in %	50·3	45·5	47·7
	(50·0)	(49·9)	(49·9)
Share in urban areas in % [a]	22·1	26·2	26·7
	(41·5)	(44·0)	(44·2)
Average health care expenditures in €	436·8	1,399·4	2,465·8
	(2,280·9)	(4,024·0)	(6,146·3)
Average expenditures ophthalmologists in €	3·6	9·9	8·5
	(15·7)	(27·8)	(24·4)
Share with at least one ophthalmologist contact in %	7·2	16·0	15·4
	(25·8)	(38·8)	(36·1)
Distinct Persons	1,950,234	53,678	53,678
Quarters x Persons	68,802,471	836,675	53,678

Notes: This table presents figures for three different samples: (1) Full sample of all persons and quarters observed. (2) All persons and quarters in which at least one diabetes service was observed. (3) First quarter of all persons who received at least one diabetes service. The full list of diabetes services is given in Table B.1 in the supplementary material. [a] Urban areas are Linz, Wels, and Steyr representing cities with more than 35,000 inhabitants. Standard errors are presented in parenthesis.

examinations in comprehensive DM care. To be included in the sample of people with diabetes, individuals were required to have continuous AHIF-UA insurance coverage for at least two years prior to diagnosis and no prior record of diabetes-related services. The characteristics of the DM people are summarized in Column 2 for the entire study period and in Column 3 for the specific quarter in which the diagnosis occurred.

The mean age at diagnosis is 61.3 years, and 47.7% of the sample are female. Approximately 27% of all individuals live in urban areas. Between 2007 and 2021, 53,678 individuals were identified as having diabetes. We acknowledge that there may have been individuals diagnosed with diabetes who did not receive any of the services on our list. Because the list only includes services for the management of diabetes, the total number of individuals with diabetes is likely to be higher. More than three-quarters of the sample (75.7%) were identified as diabetic based on medication prescriptions. The remaining individuals were identified through enrollment in a DM-specific disease management program (11.9%), hospitalization (3.2%), or a combination of multiple services (9.3%). This sample of people with diabetes was then used to construct the treatment and control groups for the analysis of ophthalmologist contact.

II.B. Empirical framework

To accurately measure the eye screening behavior of people with diabetes and identify the groups with the greatest deficiencies, it is critical to select an appropriate control group. Using individuals without a diagnosis of DM can be problematic because their health needs, behaviors, and risk factors differ significantly from those of people with diabetes, potentially leading to biased comparisons. To address this issue, we compared people of the same gender and age who were diagnosed with DM at different points in time. Specifically, we identified individuals diagnosed earlier and compared them with those diagnosed slightly later. This approach allows us to control for unobserved heterogeneity by assuming that two people diagnosed within a narrow time frame are similar in their unobserved characteristics, given that the timing of diagnosis is not selective.

Individuals in the treatment group were diagnosed with DM at relative quarter 0, defined as

the treatment quarter. Each treatment group individual was paired with at least one control group individual with the same birth year and gender who was diagnosed with diabetes 12 quarters later ($\Delta = 12$). In Section C of the supplementary material, we illustrate the method, discuss the choice of Δ, and present summary statistics for the individuals in the treatment and control groups. For more details on the method, we refer to Fadlon and Nielson [22]. Individuals in the treatment group were dropped if we were unable to match them to an individual in the control group. For the control group, relative quarter 0 (which occurs 12 quarters prior to their diabetes diagnosis) is referred to as the pseudo-treatment quarter. Using a dataset of $N = 1,439,900$ person-quarter observations (of which $N^T = 705,600$ are in the treatment group), we compare outcomes over the 20 relative quarters from -8 to 11 surrounding the (pseudo-) treatment quarter using the following dynamic model:

$$y_{itq} = \alpha_i + \eta_{it} + \gamma DD_{it} + \sum_{k=-8}^{11} \delta_k \mathbb{I}\{q = k\}_q + \sum_{k=-8 \,|\, k\neq -2}^{11} \beta_k \mathbb{I}\{q = k\}_q \times DD_{it} + \varepsilon_{itq}, \qquad (1)$$

where y_{itq} represents the outcome of individual i in calendar quarter t. In the cumulative version of the variable, the number of previous quarters with at least one ophthalmologist contact is counted. The model includes two types of fixed effects: α_i, which represents the individual fixed effect, and η_{it}, which captures the group fixed effect for each unique combination of age, gender and (pseudo-)treatment quarter[1]. The function $\mathbb{I}\{q = k\}_q$ denotes the relative quarter q, and DD_{it} is a binary variable indicating whether the observed individual i is in the treatment group, that is, whether the individual received a diabetes diagnosis in relative quarter $q = 0$ ($DD_{it} = 1$). Standard errors are clustered at the individual level. We chose the relative quarter -2 as the reference quarter to account for potential temporal imprecision in DM diagnosis. The outcome variable y_{itq} is either a binary variable indicating whether an eye care visit was observed in the quarter ($y_{itq} = 1$) or not ($y_{itq} = 0$), or a cumulative binary variable indicating whether a contact was observed in this quarter or in any previous quarter starting from reference quarter -2 ($y_{itq} = 1$) or not ($y_{itq} = 0$).

[1]This variable may change over time for each individual, as people may initially be in the control group and then, $\Delta = 12$ quarters later, in the treatment group.

Table 2: Annual ophthalmology contacts since diagnosis

	Treat						*Control*
	All (1)	Cohen's *d* (2)	DMP (3)	Cohen's *d* (4)	No DMP (5)	Cohen's *d* (6)	All (7)
Number of annual contacts since diagnosis							
Never	0·379		0·230		40·6		0·500
Once in three years	0·271	−0·247	0·287	−0·550	26·8	−0·191	0·255
Twice in three years	0·183	−0·232	0·247	−0·541	17·1	−0·181	0·130
Every year	0·167	−0·150	0·236	−0·361	15·5	−0·117	0·115
Cross-section estimation result of diabetes diagnosis							
Every year	0·045***		0·113***		0·033***		
	(0·003)		(0·006)		(0·003)		
Observations	35,280		5,416		29,864		36,715

Note: The means in columns (1), (3), (5), and (7) show the proportion (between 0 and 1) of people with respective years with ophthalmology contacts in the three years since relative quarter zero for four different subsamples: all individuals in the treatment group; all treated individuals who joined the DMP in relative quarter zero or one; all treated individuals who didn't join the DMP in relative quarter zero or one; all individuals in the control group. Cohen's *d* is reported for at least one contact within the three years, at least two contacts within the three years, and at least one contact each year. Asterisks indicate significance levels: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

III. Results

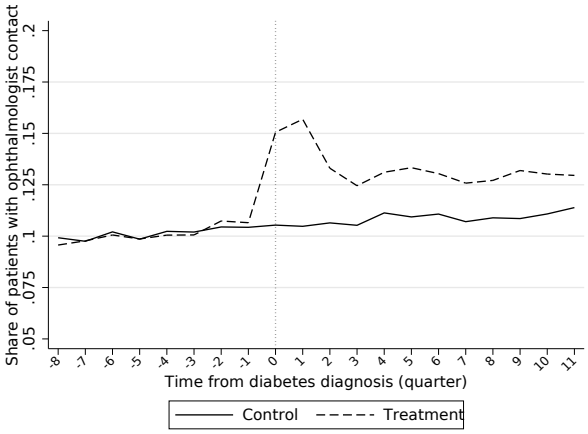
III.A. Main results

Our analysis began with an examination of how frequently people visited an ophthalmologist following a diabetes diagnosis. Figure 1a shows a clear jump in the percentage of individuals who had contact with an eye doctor in the same three-month period they received their diabetes diagnosis. The estimation results (Figure 1b) indicate a statistically significant increase of just over 5 percentage points in the probability of an eye care visit right after a diabetes diagnosis. However, in the two quarters that followed, the percentage of individuals in the treatment group who saw an ophthalmologist dropped noticeably, and it stayed only a little higher than in the comparison group for the rest of the time after diagnosis. Despite the diabetes diagnosis leading to an increase of 11.5 percentage points in the proportion of people with at least one visit to an eye doctor in the first year, only slightly more than 60% of treated individuals had such a visit within three years (Figures 1c and 1d).

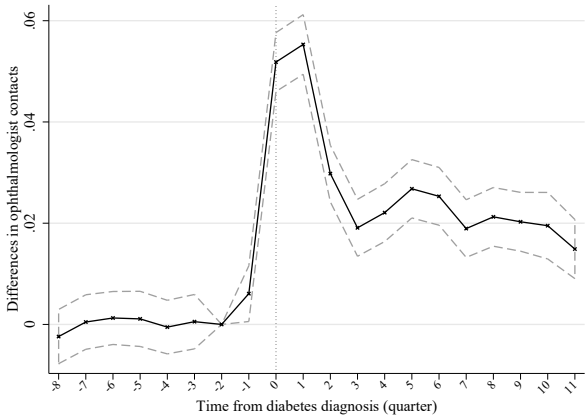
In addition to determining whether individuals accessed eye care services, we also sought to

Figure 1: Ophthalmologist contacts of people with diabetes relative to diagnosis timing

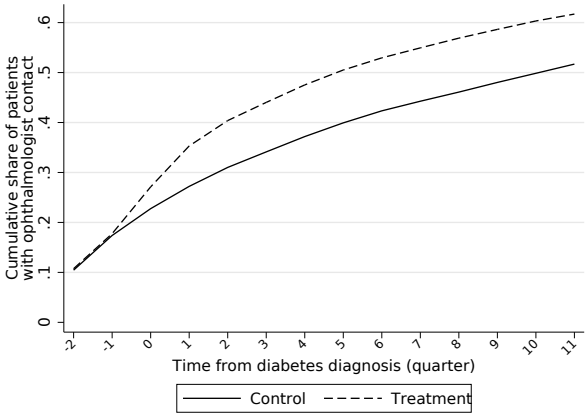
(a) Share of people with ophthalmology contacts



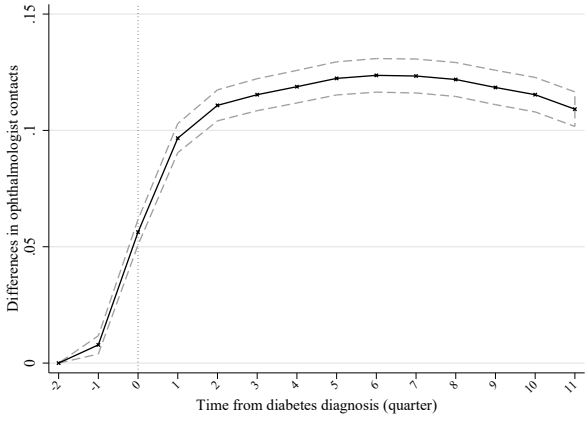
(b) Estimated differences in ophthalmology contacts



(c) Cumulative share of people with ophthalmology contacts



(d) Estimated differences in cumulative ophthalmology contacts



Notes: (a) shows the average percentage of eye care contacts by relative quarter for the treatment and control group. (b) shows the estimated differences and 95% confidence interval in eye care contacts between the treatment and control group in each relative quarter. (c) shows the average cumulative percentage of people with eye care contacts since relative quarter -2 by treatment group. (d) shows the estimated differences and 95% confidence interval in cumulated eye care contacts between the treatment and control group. (c) and (d) are estimation results from Model 1.

evaluate the frequency of these visits. For this reason, we counted how many times each person in our sample saw an eye doctor per year in the three years after their diabetes diagnosis. The results of this count are in Columns (1) and (7) of Table 2. In the three-year post-period, we found that only 16.7% of all people with diabetes saw an ophthalmologist at least once a year, while this was only 11.5% in the comparison group. Column (2) shows Cohen's d, which quantifies the standardized mean difference in annual ophthalmologist visits between the two groups. The small value of -0.150 suggests that the 5.2 percentage point difference in these average numbers, when considered in isolation of other factors, represents a small effect size and might be attributable to the inherent variability within the data. However, when we employed a cross-sectional regression analysis to estimate the impact of the diabetes diagnosis on annual ophthalmology contacts within the three-year post-diagnosis window, while controlling for potential confounders such as the (pseudo) treatment quarter, birth year, and gender, we observed a statistically significant coefficient of 0.045 (corresponding to a 4.5 percentage point increase). Furthermore, the data enabled the estimation of the impact of diabetes diagnosis on specific ophthalmic services relevant to DR screening, retinal examination including funduscopy, tonometry and slit lamp examination as well as skiascopy and stereoscopic vision. The results of these estimations are presented in Table 3. Within three years post-diagnosis, 65% of people in the treatment group underwent retinal examination or funduscopy, compared to the control group which exhibited a 10.5 percentage point lower probability of receiving this service. Estimation of the static version of Model 1 showed that the average quarterly retinal examination increased by 4.3 percentage points after diabetes diagnosis. Consistent with the cumulative eye care contact data presented in Figure 1, these findings suggest the integration of diabetic retinopathy severity assessments during ophthalmological consultations.

Overall, these results suggest that a diabetes diagnosis leads to both an immediate increase in eye care utilization and a small but significant rise in regular annual contacts, indicating improved continuity of care. However, the data also revealed that only a limited fraction of people adhered to consistent annual eye care.

Table 3: Estimation results for eye care examination services

	Retinal examination, funduscopy			*Tonometry and slit lamp*			*Skiascopy, stereoscopic vision, orthoptic status*		
	Mean			Mean			Mean		
	Treat (1)	Control (2)	Coef. (3)	Treat (4)	Control (5)	Coef. (6)	Treat (7)	Control (8)	Coef. (9)
Cumulative service utilization									
until $q = 3$	0·426	0·306	0·114*** (0·003)	0·464	0·344	0·114*** (0·004)	0·376	0·278	0·093*** (0·003)
until $q = 7$	0·538	0·405	0·126*** (0·004)	0·576	0·448	0·122*** (0·004)	0·482	0·375	0·103*** (0·004)
until $q = 11$	0·607	0·485	0·116*** (0·004)	0·643	0·528	0·109*** (0·004)	0·552	0·453	0·094*** (0·004)
Quarterly service utilization†									
$-8 \leq q \leq -1$	0·083	0·077		0·101	0·094		0·069	0·065	
$0 \leq q \leq 11$	0·120	0·090		0·138	0·106		0·097	0·075	
$DD \times Post$			0·024*** (0·001)			0·025*** (0·001)			0·019*** (0·001)
Observations			1,007,930			1,007,930			1,007,930

Note: Columns (1), (2), (4), (5), (7), and (8) show the average cumulative service use for the treatment and control groups up to relative quarters 3, 7 and 11. The estimated differences between the treatment and control group for retinal examination and funduscopy are shown in Column (3) and for tonometry and examination with slit lamp are shown in Column (6) and for skiascopy and stereoscopic vision are shown in Column (9). † The average quarterly effect is estimated by the static version of Model (1). Asterisks indicate significance levels: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

III.B. Heterogeneity

III.B.1. Enrollment in disease management program

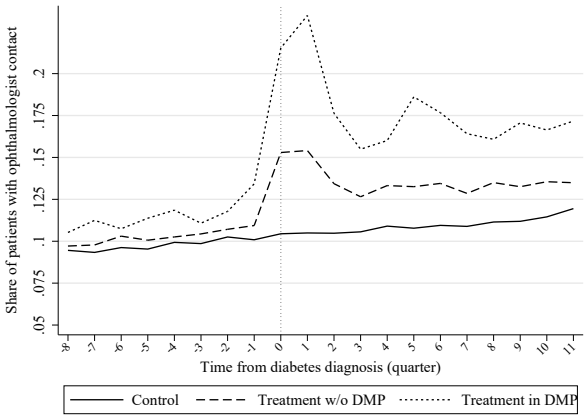
To explore potential variations in the impact of the diabetes diagnosis, we categorized the treatment group based on their enrollment in the DMP. People with DMP service documentation in their medical records during the quarter of diagnosis (relative quarter 0) or the subsequent quarter (relative quarter 1) were classified as "enrolled". Those without such documentation were classified as "not enrolled". Figure 2 presents the findings of this subgroup analysis. Within the treatment group, DMP enrollment was associated with a significantly larger increase in eye care contacts post-diabetes diagnosis compared to non-enrollment. Within the first year post-diagnosis, approximately 63% of DMP participants had at least one eye care contact, increasing to nearly 80% after three years. In contrast, only 62% of not-enrolled had an eye care contact within the same three-year period.

Furthermore, individuals in the treatment group who participated in a DMP shortly after their DM diagnosis showed substantially higher rates of annual ophthalmologist visits. Almost 24% of these individuals had an annual eye care visit in the three years following their DM diagnosis, compared to only 15.5% of individuals with DM who did not enroll in the program (Columns 3, 5, and 7 in Table 2). We also calculated Cohen's d to assess the effect size of each DMP participation status relative to the control group. These calculations (Columns 4 and 6 in Table 2) revealed considerable differences in effect size, with a larger effect observed for individuals who enrolled in the DMP compared to those who did not. Consistent with these observations, our cross-sectional regression results indicated a statistically significant positive difference in annual eye care contacts for both DMP participant and non-participant subgroups compared to the control group. Importantly, the magnitude of this positive effect was notably larger among people who enrolled in the DMP. Taken together, the results indicate a beneficial effect of coordinated care programs on eye screening rates for people with DM in Austria.

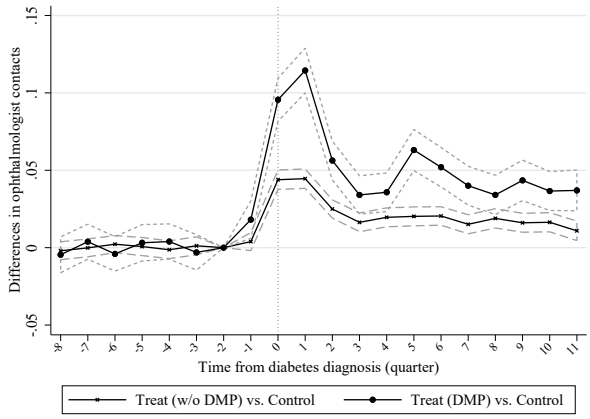
However, only 15.4% of individuals in the treatment group enrolled in the DMP in the quarter of

Figure 2: Heterogeneity analysis

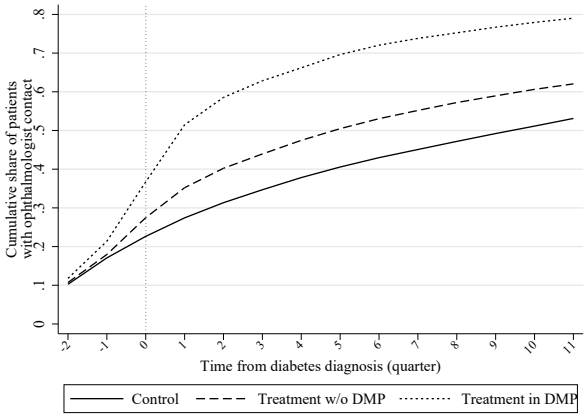
(a) Share of people with ophthalmology contacts in %



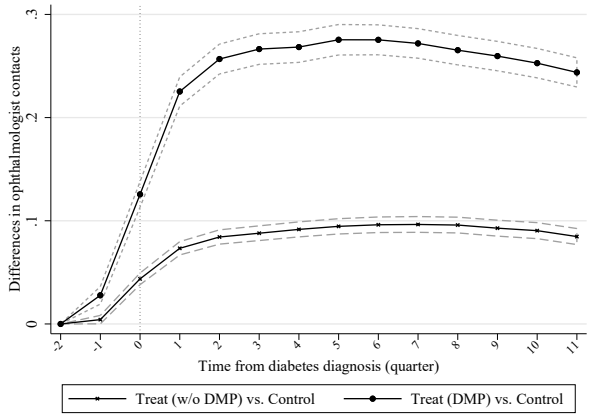
(b) Estimated differences in ophthalmology contacts



(c) Cumulative share of people with ophthalmology contacts



(d) Estimated differences in cumulative ophthalmology contacts



Notes: In all figures, the people in the treatment group were split by their enrollment in the disease management program (DMP) in relative quarter 0 or 1. (a) shows the average percentage of eye care contacts by relative quarter and treatment group. (b) shows the estimated differences and 95% confidence interval in eye care contacts between the treatment and control group in each relative quarter. (c) shows the average cumulative percentage of people with eye care contacts since relative quarter -2 by treatment group. (d) shows the estimated differences and 95% confidence interval in cumulative eye care contacts between the treatment and control group. (b) and (d) are estimation results from Equation 1.

their DM diagnosis or the subsequent quarter ($q = 0$ or $q = 1$), and only 20.5% enrolled at any point within the three years following their diagnosis. In an additional analysis[2], we found causal evidence that access to physicians offering DMP services was the primary driver of program enrollment. Individuals diagnosed with DM were significantly more likely to enroll in the DMP if their primary care provider (PCP) offered the service ($OR = 8.1$, $p < 0.01$) and therefore also more likey to have an ophthalmologist contact ($OR = 1.3$, $p < 0.1$). We found no differences in the likelihood or timing of a diabetes diagnosis based on whether the PCP offers DMP services. Furthermore, DMP enrollment was negatively associated with a migration background and positively associated with older age.

To account for potential unobserved heterogeneity between individuals with and without access to a DMP, we performed a sensitivity analysis. We repeated the estimation of the effect of a diabetes diagnosis on eye care visits, but restricted the sample to only those individuals in the treatment and control groups who eventually enrolled in the DMP. As expected, the resulting effect sizes for cumulative eye care contacts were slightly smaller but consistent with our main findings (see Figure A.1 in the supplementary material versus Figure 2 in the article).[3]

IV. Discussion

The aim of this study was to provide real-world data on participation in opportunistic screening for DR in Upper Austria, where 75% of the population is covered by the AHIF-UA. Current estimates of DM prevalence rely on small registries, fragmented data, and surveys [23], with higher prevalence in eastern Austria [24]. Our analysis estimates the prevalence of diagnosed DM at 5.5%. National strategies aim to investigate undiagnosed diabetes and evaluate care standards [25].

Diabetes guidelines recommend annual DR screening after diagnosis [26, 27], and individuals are encouraged to join a DMP for better diabetes management [27]. However, our results show that only 46% of people with diabetes in Upper Austria visited an ophthalmologist in the first year

[2]Description and detailed results can be found in the supplementary material, Section D.

[3]Table B.2 in the supplementary material shows the estimation results by individual characteristics.

Table 4: Extrapolated DR cases in Upper Austria

	Gloucestershire		Upper Austria		Upper Austria	
Reference	DR Actual numbers		DR Extrapolated		DR Extrapolated	
Time orizon	1.1.2012 - 3.12.2016		1.1.2012 - 3.12.2016		2021	
Individuals with diabetes	43,236		67,272		57,238	
Diabetes identifier	Register		Services (Table B.1)		Services (Table B.1)	
DR Screening	35,873		55,836		47,508	
Screening attendance	83.0%		83.0%		83.0%	
DR						
No sign	23,245	64.8%	36,182	64.8%	30,785	64.8%
Mild NPDR	10,447	29.1%	16,248	29.1%	13,825	29.1%
Moderate/severe NPDR	1,280	3.6%	2,010	3.6%	1,710	3.6%
PDR	901	2.5%	1,396	2.5%	1,188	2.5%

Note: The numbers from Gloucestershire were taken from Scanlon P. [28]. The calculations for Upper Austria are based on the data described in Section II. NDRP is nonproliferative diabetic retinopathy and PDR is proliferative diabetic retinopathy.

after diagnosis, and just 16.7% had annual visits in the following three years. A diabetes diagnosis increased the likelihood of an ophthalmology visit in the first year by only 11.5 percentage points, driven by younger cohorts, men, and migrants with initially low baseline contact rates. Three years post-diagnosis, only 62.1% had at least one ophthalmology visit, and just 23.6% of DMP participants had annual visits. This highlights disparities in DR screening and underdiagnosis. To assess the extent of the disparity in Upper Austria, we compared our data with published data from the UK Diabetic Retinopathy Screening Service [28].

The UK National Health Service offers the world's largest systematic screening service for DR [11]. Established in 2003, the programme provides annual two 45-degree field mydriatic digital photographic screenings to all people with DM aged 12 or older, screening approximately 2,500,000 people annually with a target uptake of 80% of the diabetic population [29]. The county of Gloucestershire, in rural west England, has a population comparable to Upper Austria in age and ethnicity. According to The Office of National Statistics, Gloucestershire's population was 600,000 in 2021. As part of this programme, 35,873 people with DM attend screening appointments and are referred to a single ophthalmology service if necessary [28]. They achieved an attendance rate of 83% of the local population. At the first visit after DM diagnosis, 64% (23,245) had no signs of DR, 10,447 (29.1%) had mild nonproliferative diabetic retinopathy (NPDR), 1,280 (3.6%) had moderate to severe NPDR, and 901 (2.5%) had proliferative diabetic retinopathy (PDR).

Applying these figures to the population of Upper Austria, and assuming the same screening participation and DR prevalence among the 57,238 diabetes individuals in 2021, an estimated 47,508 people would require screening. Among those screened, this would result in an estimated 13,825 individuals with signs of mild DR, 1,710 with moderate to severe DR, and 1,188 with vision-threatening PDR (Table 4). In 2021, 41.3% (around 24,000) of individuals with diabetes mellitus had an ophthalmology consultation. To reach the target of 47,500, an estimated 23,500 more consultations would be needed. The average per capita cost for ophthalmological care in 2021 was € 53. Maintaining this cost per consultation, these additional 23,500 consultations would result in an extra expenditure of close to € 1.24 million, which is cost-effective when the investment prevents individuals from progressing to severe vision impairment or blindness, thereby averting significant, long-term societal costs related to lost productivity, increased need for social support, and reduced quality of life. Specifically, the cost-effectiveness of this € 1.24 million investment becomes clearer when considering the 2,898 individuals expected to be newly diagnosed with moderate-to-severe or vision-threatening DR (1,710 + 1,188). The initial expenditure amounts to an investment of approximately € 428 per high-risk individual (€ 1.24 million / 2,898). This cost is likely to be offset by preventing the need for even a small number of expensive interventions (e.g., anti-VEGF injections or laser surgery) or by averting the long-term societal costs of vision loss in this group.

IV.A. Systematic screening in Upper Austria

General ophthalmologists deliver primary public eye care in Upper Austria, with individuals also having access to private care. In 2024, 57 provided public care, in addition to 69 private practitioners. Seven secondary hospital eye care centers are regionally distributed, and a tertiary center is in Linz.

The long-established primary care units are strategically distributed, providing conservative care with state-of-the-art imaging. In 2024, we conducted a telephone survey of ophthalmologists in UA (73% response rate; n=92). Results indicate that 98.9% offer optical coherence tomography (OCT),

and 83.7% offer colour fundus photography (CFP). Systematic screening could be facilitated by a network of ophthalmologists and local screening sites. A central reading centre with AI-assisted graders has been shown to be a cost-effective solution [30, 7].

Our analysis demonstrated that PCPs in the DMP did not expedite diabetes detection. However, DMP enrollment was associated with a significantly higher likelihood of regular eye screening. These findings suggest that while DMP training for PCPs does not affect early diagnosis, it significantly influences adherence to care guidelines. Given the cost of widespread DMP training, a diabetes registry with regular reminders and screening invitations may be a cost-effective strategy to achieve similar adherence.

V. Conclusions

In this study, we highlight the shortcomings of opportunistic screening for DR in a Bismarckian public health system by analyzing insurance data covering the majority of the insured population. The diagnosis of diabetes leads to only a small increase in screening appointments and also shows the potential of DMP to improve screening attendance. To highlight this, we compared our results with published screening data from the UK NHS Diabetic Eye Screening Program (DESP). Therefore, establishing a systematic screening program that integrates the primary care sector is a critical step toward the early detection of DR. Such a program would not only prevent unnecessary vision loss but also contribute to a higher standard of integrated diabetes management.

Ethics approval

Ethics approval was granted by the local ethics committee in June 2024 (EK Nr: 1358/2024)

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Data availability

The study utilized data from the Austrian Health Insurance Fund – Upper Austria (AHIF-UA). The authors do not have permission to share data, as it includes sensitive or confidential information.

Authors' contribution

In alphabetical order:

Matthias Bolz: Interpretation of the results, Revised the manuscript

Marina Casazza (shared first author): Writing the manuscript, Conceptualization, Interpretation of the results

Josef Huemer (shared last author): Managed project, Conceptualization, Writing the manuscript, Interpretation of the results

Gerald J. Pruckner (shared last author): Data collection from external sources, conceptualization, manuscript editing, Interpretation of the results

Katrin Zocher (shared first author): Methodology, Formal analysis, Interpretation of the results, Data curation, Writing the manuscript

Declaration of competing interest

The authors declare that they have no known competing interests or personal relationships that could have appeared to influence the work reported in this paper. The authors did not receive funding for this work.

Declaration of generative AI

During the preparation of this work the authors used Academic AI (ChatGPT 4o) and DeepL (deepl.com) to check for grammatical and spelling errors in the text and to rephrase sentences. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

Supplementary Material

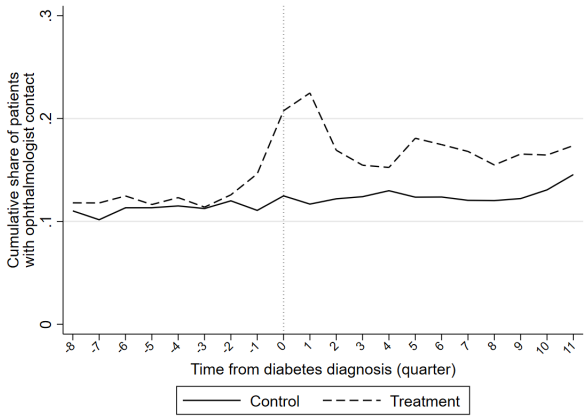
This appendix contains supplementary materials for the paper *"The systematic shortcomings of opportunistic screening for diabetic retinopathy"* by Katrin Zocher, Marina Casazza, Matthias Bolz, Gerald J. Pruckner, and Josef Huemer.

Contents

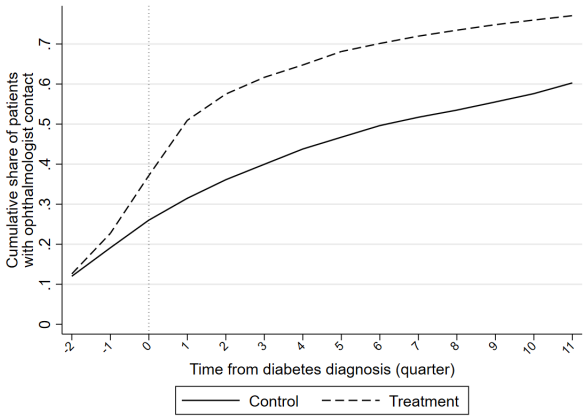
A. Additional figures

Figure A.1: Results forpeople with DMP as diabetes identifier

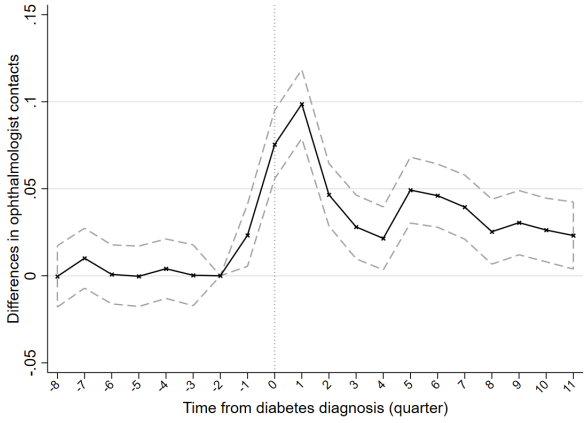
(a) Share of people with ophthalmology contacts



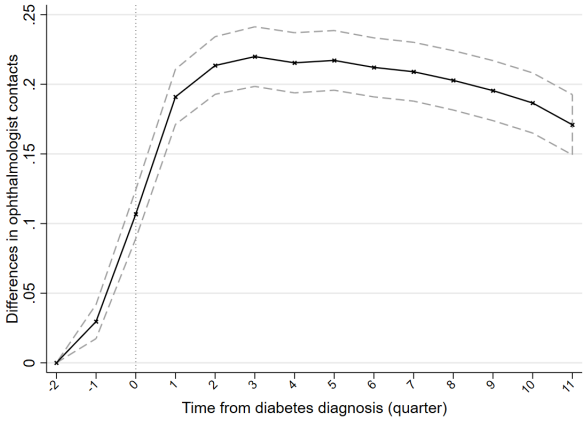
(b) Cumulative share of people with ophthalmology contacts



(c) Differences in ophthalmology contacts



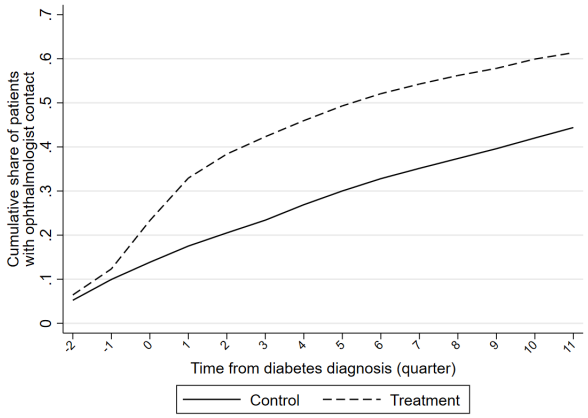
(d) Differences in cumulative ophthalmology contacts



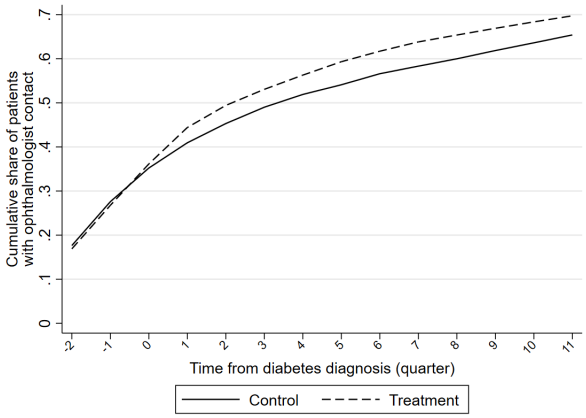
Notes: The sample consists of only people whose diabetes diagnosis is based on the participation in DMP. (a) shows the average percentage of people with eye care contacts by relative quarter and treatment group. (b) shows the cumulative share of individuals with eye care contacts since relative quarter -2 by treatment group. (c) shows the estimated differences in eye care contacts contacts between the treatment and control group in each relative quarter. (d) shows the estimated differences in cumulated eye care contacts between the treatment and control group. (c) and (d) are estimation results from equation 1.

Figure A.2: Ophthalmology contacts by age cohorts

(a) Cumulative share of people with ophthalmology contacts: 40-49 years



(b) Cumulative share of people with ophthalmology contacts: 70-7 9 years



Notes: The figure shows cumulative share of people with ophthalmology contacts since relative quarter -2 for the treatment and control group of (a) 40-49 years of age and (b) 70-79 years of age.

B. Additional tables

Table B.1: Services and diagnosis used to identify diabetes diagnosis

List of Services	Chosen services for diabetes identification
Hospital stays principal diagnosis (ICD-10)	
Diabetes mellitus type 1 (E10)	X
Diabetes mellitus type 2 (E11)	X
Diabetes mellitus in connection with malnutrition (E12)	X
Other specified diabetes mellitus (E13)	X
Unspecified diabetes mellitus (E14)	X
Hospital stays additional (not principal) diagnosis (ICD-10)†	
Diabetes mellitus type 1 (E10)	
Diabetes mellitus type 2 (E11)	
Diabetes mellitus in connection with malnutrition (E12)	
Other specified diabetes mellitus (E13)	
Unspecified diabetes mellitus (E14)	
Prescribed drugs (ATC Code A10)	X
Medical Aid	
Measuring devices and blood glucose test strips	
Blood lancets	
Blood clotting strips	
Insulin dosing device	
Plastic syringes	
Urine strips	
Lancing device	
Physician services	
Diabetes related disease management program	X
HbA1c determination‡	
Creatinine determination‡	

Note: † Additional diagnoses are often only suspected diagnoses, i.e. diagnoses for which individuals are tested in hospital. Therefore, they do not necessarily identify individuals with diabetes. Principal diagnoses, on the other hand, are those for which individuals received treatment. ‡ Although we know whether these services were provided, we do not know the outcome of the tests. We therefore exclude these services from the diabetes identifier.

Table B.2: Cumulative ophthalmology contacts by individual characteristics

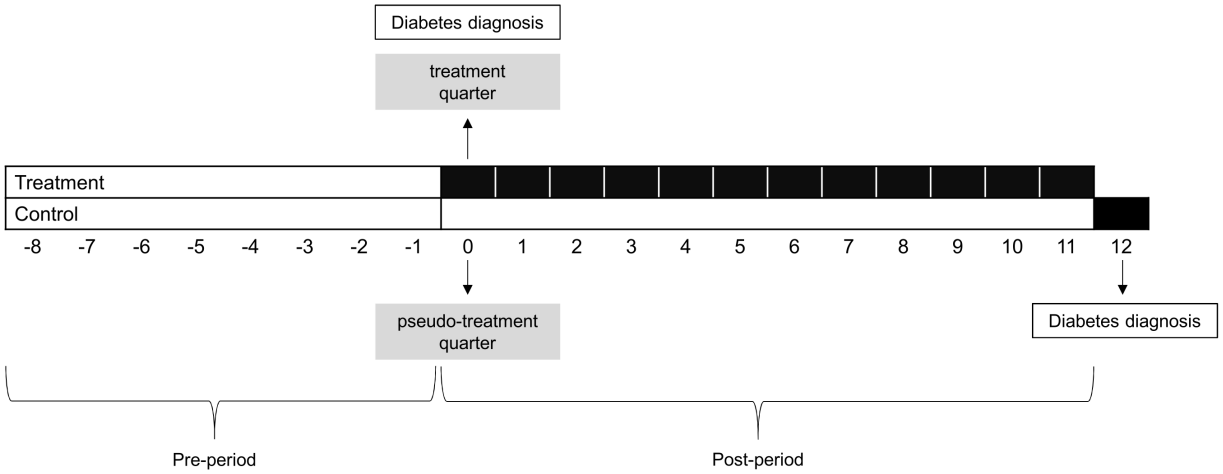
	Age group at diagnosis							
	40-49		50-59		60-69		70-79	
	Mean (1)	Coef. (2)	Mean (3)	Coef. (4)	Mean (5)	Coef. (6)	Mean (7)	Coef. (8)
Quarter since diagnosis								
3^{rd} quarter	0.432	0·187*** (0·010)	0.435	0·154*** (0·006)	0.482	0·111*** (0·007)	0.533	0·052*** (0·008)
7^{th} quarter	0.552	0·197*** (0·011)	0.551	0·158*** (0·007)	0.602	0·119*** (0·007)	0.642	0·067*** (0·008)
11^{th} quarter	0.618	0·169*** (0·011)	0.624	0·144*** (0·007)	0.671	0·105*** (0·007)	0.701	0·053*** (0·008)
Distinct persons	7,071		14,330		16,084		11,075	
	Gender				*Migration*			
	Female		Male		No migrant		Migrant	
	Mean (9)	Coef. (10)	Mean (11)	Coef. (12)	Mean (13)	Coef. (14)	Mean (15)	Coef. (16)
Quarter since diagnosis								
3^{rd} quarter	0.451	0·091*** (0·005)	0.366	0·136*** (0·005)	0.424	0·112*** (0·004)	0.302	0·128*** (0·009)
7^{th} quarter	0.564	0·098*** (0·006)	0.470	0·145*** (0·005)	0.532	0·121*** (0·004)	0.408	0·136*** (0·010)
11^{th} quarter	0.636	0·083*** (0·006)	0.544	0·131*** (0·005)	0.604	0·106*** (0·005)	0.488	0·121*** (0·010)
Distinct persons	23,293		25,703		41,921		7,075	

Notes: The table shows the cumulative share of people with at least one ophthalmology contact until the 3^{rd}, 7^{th}, and 11^{th} relative quarter after the diabetes diagnosis in $q = 0$ for different age cohorts and by gender and migration background. It also displays the estimated differences between the treatment and control groups within each subsample, according to equation 1. Standard errors are clustered at group level and shown in parentheses.

C. Description of the empirical approach and discussion of Δ

The utilized method (illustrated in Figure C.1) is based on the assumption that people of the same age and gender who are diagnosed with diabetes at the same time t have, on average, similar health behaviors. This condition might hold even if the persons are diagnosed with diabetes some quarters apart rather than in the same quarter. Δ is defined as the number of quarters between diagnoses. It is implicitly assumed that it is random which person is diagnosed first (= treatment group) and which person is diagnosed later (= control group). Additionally, it must be ensured that the effect of the diagnosis is the same for both the treatment and control groups, meaning there is no heterogeneity of the effect over time.

Figure C.1: Illustration of the identification strategy

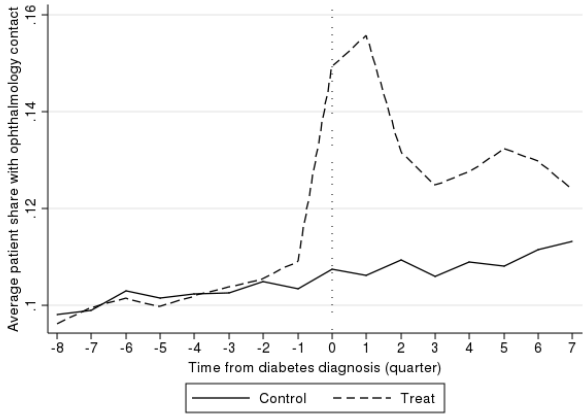


Choosing Δ is therefore a non-trivial task. On one hand, the post-diagnosis period should be as long as possible to capture long-term effects. On the other hand, a lengthy post-period introduces a substantial gap between the initial diagnoses of the treatment and control groups, which may compromise the assumption of randomness in the diagnosis timing. Figure C.2 illustrates the average ophthalmology contact rates and the estimated differences between the treatment and control groups, according to an adjusted Model 1, for various (additional) values of Δ. The results are consistent across all figures: no significant differences were observed between the treatment and control groups during the pre-period. However, after the treatment group received the diabetes diagnosis, contact rates increased significantly. For the main analysis, we selected $\Delta = 12$, as eight quarters provided an insufficient post-period, while 16 quarters resulted in a reduced number of observations.

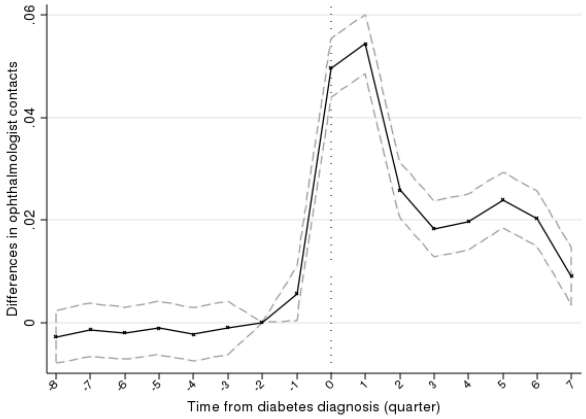
The assumptions underlying the model, such as individual similarity, are not directly testable. To approximate the plausibility of these assumptions for the $\Delta = 12$ sample, we analyzed healthcare expenditures and services before the diabetes diagnosis. These expenditures should be similar or,

Figure C.2: Different values of Δ

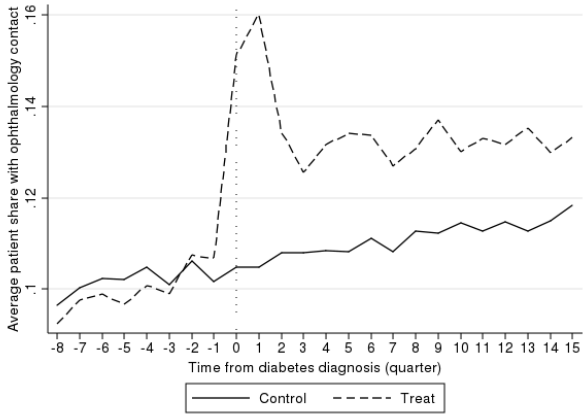
(a) Ophthalmology contact rates (Δ = 8)



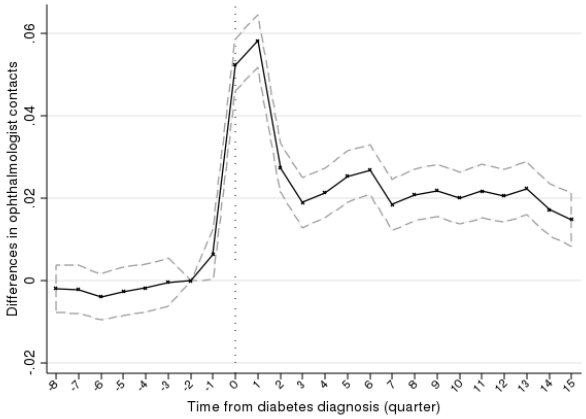
(b) Differences in ophthalmology contacts (Δ = 8)



(c) Ophthalmology contact rates (Δ = 16)

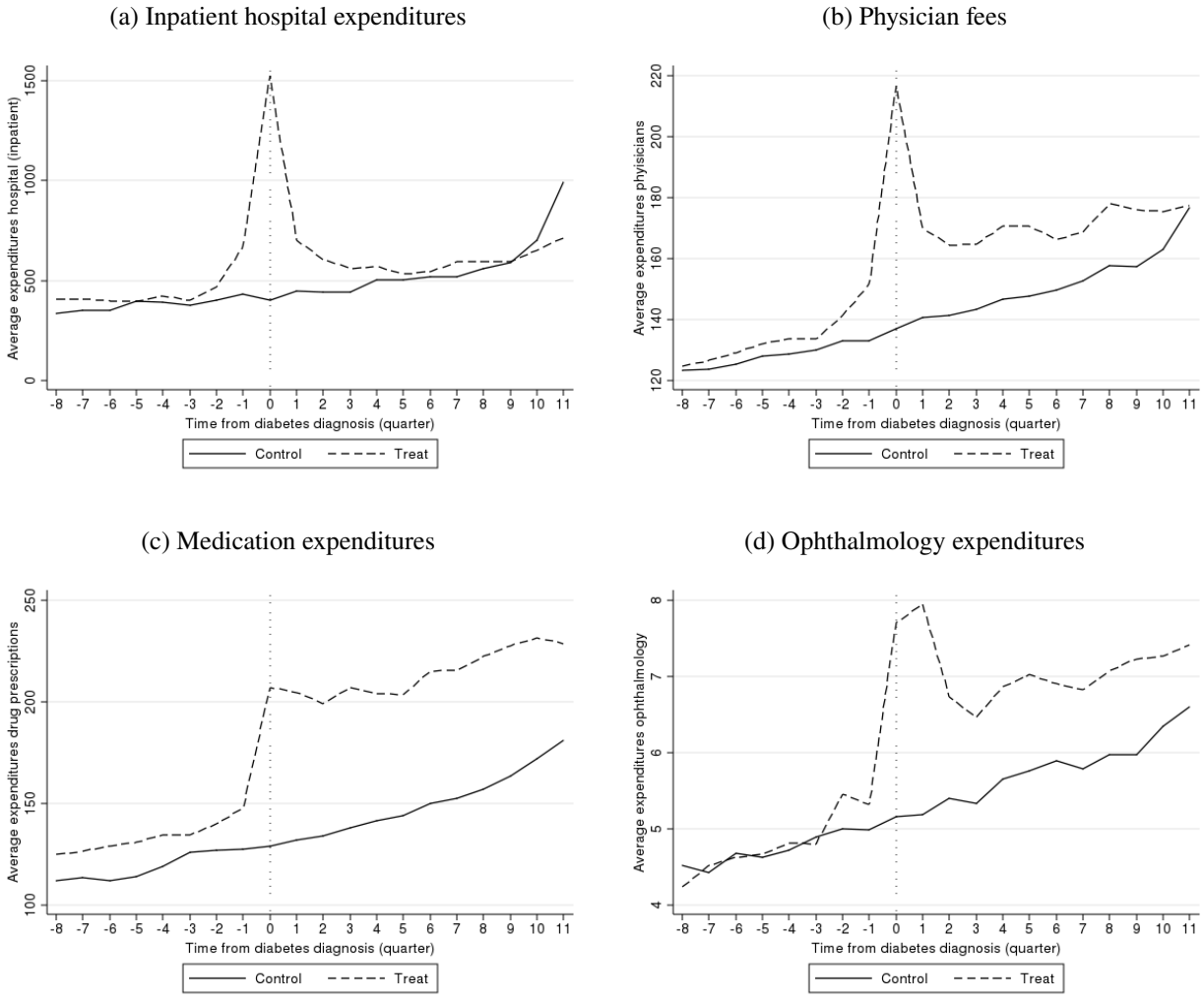


(d) Differences in ophthalmology contacts (Δ = 16)



Notes: The figure shows average ophthalmology contact rates and estimated differences between the treatment and control group for the Δ = 8 (in (a) and (b)) and for the Δ = 16 (in (c) and (d)) sample.

Figure C.3: Health care expenditures

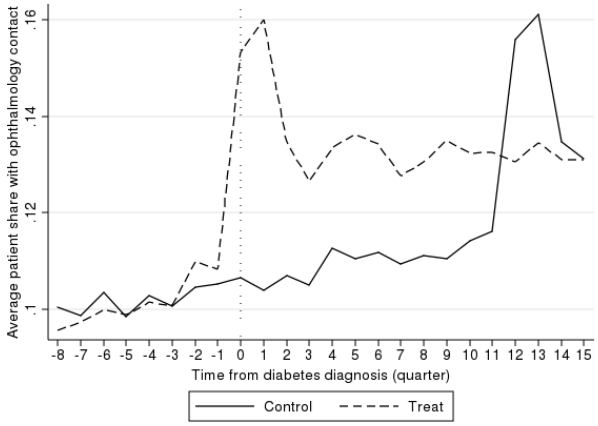


Notes: The figure shows group-specific average health care expenditures for the $\Delta = 12$ sample.

in the case of a difference-in-differences estimator, follow the same trend. Figure C.3 indicates that health care expenditures (hospitals, physicians, drugs, ophthalmology) were comparable between the treatment and control groups during the pre-period. Thus, we assumed that, in the absence of diabetes diagnoses, the expenditures would have developed similarly in both groups.

Figure C.4 illustrates the average ophthalmological contact rates, including the quarters following the diabetes diagnosis of the control group. The contact rates increased similarly in both the treatment and control groups after diagnosis, indicating that the diagnosis had a comparable effect on both groups.

Figure C.4: Ophthalmology contact rates $\Delta = 12$



Notes: The figure shows the average ophthalmology contact rates. The time horizon includes quarters after the diabetes diagnosis of the control group.

D. Impact of individual characteristics and disease management program access on disease management program participation

To investigate the role of primary care providers (PCPs) in diabetes detection and the provision of Disease Management Program (DMP) services, we used the data and methodological framework of Pruckner et al. [31]. This additional analysis focused on primary care practices which underwent a change in providers, predominantly due to PCP retirement and subsequent practice takeover. The replacement process for these PCP positions in Upper Austria generated a quasi-random assignment of succeeding PCPs to individuals, as the availability of DMP services under the new provider is largely exogenous from the individual's perspective. Utilizing this quasi-random setting, our cross-sectional analysis examined whether PCPs with a DMP certificate were more likely to (1) detect diabetes, (2) achieve earlier detection, (3) order creatinine and HbA1c tests more frequently, and (4) offer DMP services to people with DM, compared to PCPs without such certification. In addition, we analyze the whether (5) probability of an ophthalmologist contact varies among patients. The empirical analysis focused on individuals with no recorded diabetes-related service use in the two years preceding PCP replacement, and we analyzed their service use in the subsequent two years. This approach allowed us to isolate the impact of PCPs' DMP certification on individual diabetes-related healthcare outcomes.

Specifically, we estimated the following model on individual level for outcomes (1), (3), (4)

$$P(Y_i = 1 | \, DMP, X) = \frac{e^{\beta \, DMP_i + \mathbf{X}_i' \gamma}}{1 + e^{\beta \, DMP_i + \mathbf{X}_i' \gamma}} \tag{A1}$$

and for outcome (2)

$$Y_i = \alpha + \beta \, DMP_i + \mathbf{X}_i' \gamma + \varepsilon_i \tag{A2}$$

, where DMP is an indicator variable denoting whether the succeeding PCP of individual i has a type 2 diabetes mellitus DMP certificate ($DMP = 1$) or not ($DMP = 0$). The vector of control variables, $\mathbf{X}$, includes migrant status, gender, education level, age cohort, and the year of practice transfer to the succeeding PCP. Standard errors are clustered at the practice level to account for potential within-practice correlation.

Although the quality of successor PCPs appears independent of the exiting PCPs and individual characteristics, the voluntary application for specific positions suggests a degree of self-selection. To address this potential endogeneity and enable a causal interpretation of DMP access, we need to demonstrate that the acquisition of a DMP certificate was not correlated with PCPs' choices of practice. Therefore, we regress the DMP certificate indicator on practice level outcomes. The results are provided in Table D.1.

Table D.1: PCP selection on position and individual characteristics

	(a) Potential income			*(b) Practice attractiveness*		
	Revenue in €	In-house pharmacy 0/1	Urban 0/1	Soft transition 0/1	No. rounds	No. applicants
	(1)	(2)	(3)	(4)	(5)	(6)
DMP certificate	5,248·6*	−0·169**	−0·005	−0·093	−0·046	−0·060
	(3,122·4)	(0·080)	(0·092)	(0·092)	(0·282)	(0·314)
Successor age at takeover	509·9	−0·031**	0·004	−0·027**	0·026	−0·004
	(425·7)	(0·012)	(0·012)	(0·013)	(0·026)	(0·038)
Successor experience	−303·0	0·020*	0·006	0·023*	−0·007	0·058
	(432·1)	(0·011)	(0·012)	(0·013)	(0·030)	(0·038)
Pre-mean	41,428·5	0·271	0·313	0·641	1·534	2·160
R^2	0·227	0·135	0·053	0·116	0·094	0·301
N	131	118	131	131	118	131

	(c) Patient characteristics			*(d) Average fees*		
	Older than 65 share	Female patients share	Diabetes share	PCP fees in €	Specialist fees in €	Drug prescription in €
	(1)	(2)	(3)	(4)	(5)	(6)
DMP certificate	−0·007	−0·006	0·000	1·105	−0·071	4·580
	(0·013)	(0·005)	(0·003)	(2·207)	(2·786)	(4·749)
Successor age at takeover	0·003	−0·001	0·001	0·781*	−0·037	0·205
	(0·002)	(0·001)	(0·001)	(0·426)	(0·407)	(0·678)
Successor experience	−0·001	0·001	−0·001	−0·727	0·442	−0·016
	(0·002)	(0·001)	(0·001)	(0·473)	(0·442)	(0·720)
Pre-mean	0·284	0·545	0·059	52·830	86·316	124·511
R^2	0·128	0·149	0·091	0·309	0·266	0·177
N	131	131	131	131	131	131

Notes: All outcomes are measured during the two years before the replacement. Revenue is calculated as the quarterly average based on the two years before the replacement. In-house pharmacy is equal to 1 if an in-house pharmacy exists at the practice, and 0 otherwise. Urban is equal to 1 if the practice is in a city with a population larger than 10,000 people. Soft transition is equal to 1 if the exiting and new PCP work together for one quarter after the replacement. Number of rounds indicates the number of calls before a successor was found. Number of applicants indicates how many PCPs applied to a given position. Patient shares are calculated as the quarterly average based on all patients who had contact with the practice in the two years before the replacement. Patients with diabetes is the share of patients who received any of the listed services (not only the marked ones) in Table B.1. Outpatient expenditures indicate the average quarterly fees per patient in the two years prior to the replacement. PCP and specialist fees are all expenditures at (private and contracted) PCPs and specialists. Prescriptions include all medications prescribed by a doctor. Robust standard errors are shown in parentheses. Asterisks indicate significance levels: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Successor PCPs holding a DMP certificate exhibited a lower likelihood of moving to practices with in-house pharmacies but a higher likelihood of moving to practices with greater revenues. Given these results, we additionally controlled for both variables in Models A1 and A2. Regarding patient characteristics, notably the proportion of patients with diagnosed diabetes (*Patient types*, column 3), no significant differences were observed among successor PCPs with and without a DMP certificate.

Table D.2 summarizes the estimation results of Models A1 and A2. Column (1) reveals a higher incidence of diabetes among migrants, those with lower education levels, and older individuals. Interestingly, the likelihood and timing of a diabetes diagnosis were not significantly affected by whether the successor PCP held a DMP certificate. However, patients of PCPs holding a DMP certificate had significantly higher odds of participating in DMP services ($OR = 8.1$, $p < 0.01$), indicating a strong association between physician recommendation and individual DMP enrollment and in the following participation in DR screening.

Table D.2: Access to DMP on diabetes related outcomes

	Diabetes diagnosis *Odds ratio* (1)	Time till diagnosis *Nr. Quarters* (2)	Testing *Odds ratio* *(3)*	DMP participation *Odds ratio* *(4)*	Ophthalmology *Odds ratio* *(5)*
PCP with DMP certificate	1·070	0·837	2·733	8·108***	1·267*
	(0·107)	(0·138)	(1·807)	(3·109)	(0·153)
Female	0·871***	1·239*	0·948	0·997	1·278**
	(0·044)	(0·159)	(0·104)	(0·133)	(0·160)
Migrant	1·501***	1·071	0·357***	0·382***	0·484***
	(0·153)	(0·282)	(0·142)	(0·140)	(0·103)
Education (Reference: Compulsory school)					
Apprenticeship	0·934	1·276	0·812**	1·172	1·280*
	(0·059)	(0·203)	(0·072)	(0·180)	(0·175)
Secondary school	0·869**	1·033	0·581***	1·457	1·176
	(0·060)	(0·205)	(0·061)	(0·337)	(0·216)
College, University	0·628***	0·614	0·735	1·129	0·790
	(0·068)	(0·185)	(0·158)	(0·339)	(0·206)
Age cohort (Reference: Age < 50)					
50 ≤ Age < 60	2·492***	0·907	2·517***	2·838***	2·261***
	(0·237)	(0·211)	(0·396)	(0·800)	(0·438)
60 ≤ Age < 70	4·306***	0·976	3·437***	1·856**	2·750***
	(0·380)	(0·216)	(0·728)	(0·499)	(0·541)
Age ≥ 70	4·652***	0·682*	5·417***	1·725*	2·880***
	(0·443)	(0·145)	(0·968)	(0·497)	(0·522)
In-house pharmacy	1·168	0·629**	0·922	0·296*	0·737**
	(0·125)	(0·115)	(0·949)	(0·193)	(0·111)
Pre-exit practice revenues	1·000	1·000	1·000	1·000	1·000***
	(0·000)	(0·000)	(0·000)	(0·000)	(0·000)
Mean	0·020	3·871	0·006	0·004	0·408
R^2		0·031			
Pseudo R^2	0·039		0·159	0·220	0·059
N	66,398	1,370	66,398	1,443	1,443

Note: Estimations results of models A1 and A2 are shown. The four outcomes are: (1) diabetes diagnosis (binary indicator for diagnosis within two years post-replacement), (2) time to diagnosis (quarters from replacement until DM diagnosis), (3) testing (binary indicator for creatinine or HbA1c test within two years post-replacement), and (4) DMP participation (binary indicator for receiving DMP services within two years post-replacement). Column (5) summarizes the results for probability of ophthalmology contact (indicator variable). The samples in column (2) and (4) consist of only individuals who got a DM diagnosis within two years post-replacement. Asterisks indicate significance levels: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.