Online versus In-Person Services: Effects on Patients and Providers *(Preliminary and incomplete)* *

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Abstract

Online delivery of one-to-one services offers potential to save costs while increasing user convenience and equalizing access opportunities. But we know relatively little about online's actual impacts (relative to in-person delivery) on consumers and providers, such as firms and governments. This paper focuses on online delivery of healthcare, and specifically primary care doctor consultations. We use novel data from Sweden and effectively random assignment of patients to nurses with different propensities to refer patients to online versus in-person doctor consultations. We find that online consultations are delivered sooner and are shorter, and yield similar in-meeting outcomes, including rates of diagnosis, prescription, specialist referral, and patient satisfaction. Online consultations are, however, followed by more visits to emergency departments and more in-person primary care consultations. Nevertheless, patients' medium-run outcomes do not differ significantly after online consultations. Adding the costs of increased follow-ups, online visits offer modest overall cost savings to both providers and patients.

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1 Introduction

In a hybrid world, many decisions are made on which services to provide online or in person, and to whom. Such decisions are important for providers, including firms and governments, as well as to workers and users. While online provision offers potential benefits such as potentially lower costs and higher convenience, a concern is that despite technological advances, the anatomy of one-to-one meetings may still differ through a screen. Consequently, switching services online may have implications for important outcomes for providers such as costs, quality and downstream outcomes, as well as for user experiences. However, there is limited evidence from direct head-to-head comparisons of in-person and online customer-facing services. To better inform decision-makers, we need to know more about the trade-offs in the mode of service delivery.

The choice of delivery mode is particularly important in healthcare. For providers[1], online meetings offer potential productivity improvements which are urgently needed due to rising costs in aging societies, while for patients, online offers convenience, around-the-clock access, and time savings. Online services may also reduce gaps in access to high quality healthcare between rural and urban areas, or rich and poor ones (Dahlstrand, 2023). Key to healthcare delivery in many countries are patient consultations with primary care physicians (PCPs), also known as general practitioners (GPs). In this paper we provide evidence on the consequences of switching doctor consultations from in person to online for a variety of patient outcomes and provider costs.

To do so, we assemble new data on individual consultations from Sweden, whose national health insurance covers both public and private providers. The provider that contributes the majority of the data we study is Europe's largest digital healthcare firm. Since 2019, it has provided patients who chose to register with it all their primary care, including both in-person and online doctor consultations. Our data cover both consultation types and are matched to panel data on the patients themselves, including demographics, socioeconomic characteristics, and rich data on health outcomes from the rest of the universal healthcare system.

A challenge in studying online versus in-person care is that we rarely observe similar patients in both modes. Our analysis focuses on patients who are registered at primary care clinics which offer both online and in-person visits, and who request primary care consultations. After these patients briefly meet a nurse online, this nurse decides whether to

[1] By providers, we refer to healthcare providing and paying organizations such as firms, insurance companies, and public healthcare payers and providers.

direct them to a doctor consultation, and if so, whether this consultation should be online or in person. To use the variation arising from the nurses' decision, we begin by estimating OLS regressions of the consequences of nurses directing patients online versus in person, controlling for time and location fixed effects, and in some specifications a rich set of other potential confounders.

A second challenge in studying the consequences of moving services online is that providers and/or users may sort between delivery modes based on factors that are unobservable. Since the sorting of patients across delivery modes (online versus in person) may depend in part on factors that we cannot observe, we also develop an instrumental variable (IV) strategy. Our instrument is the share of patients that each nurse directed online among all other patients directed to any doctor consultation (leave-one-out).

To demonstrate that the instrument is valid, conditional on our controls, we begin by showing that the first stage is large and precisely estimated. To show that the instrument satisfies the independence assumption, we develop an econometric framework that applies to our setting, and demonstrate that: (i) observable characteristics of nurses' full set of patients are uncorrelated with the instrument; (ii) nurses' propensity to direct to any doctor consultation is uncorrelated with their propensity to direct online; and (iii) the characteristics of patients who are directed to doctor consultations are also uncorrelated with the instrument. To demonstrate that the instrument satisfies (average) exclusion and average monotonicity (weaker identification conditions than the standard IV conditions, developed by (Frandsen et al., 2023)), we show that (i) institutional rules tightly circumscribe nurses' actions, limiting their potential to affect patient outcomes other than by directing them to doctors; (ii) nurses' meetings with patients last on average less than five minutes, leaving little time for anything except a brief exchange to inform the directing of patients; (iii) the first stage is large, positive, and precisely estimated for patients with different demographics and health conditions, suggesting that most patients comply with the instrument, Moreover, we perform an additional test : we test that nurses who direct more online are not differentially likely to make rare mistakes (Chan et al., 2022).

Our instrumental variable estimates show that compared to in-person doctor consultations, online ones take place sooner after a patient's request, and are shorter overall, with much shorter patient-facing time but longer administrative time for the doctor to, e.g., write prescriptions and notes after meeting the patient. Perhaps surprisingly given the difference in duration and timing, online consultations have similar in-meeting outcomes, including rates of diagnosis, prescription (and following prescription collection at the pharmacy by the patient), specialist referral, and patient satisfaction.

Extending the analysis to patient outcomes within 30 days after the consultation, we find similar rates of (very rare) avoidable hospitalizations[2] after online consultations. Overall hospitalizations may be higher after online consultations, although these estimates are imprecise. Two significant differences do arise, however: first, online consultations are more likely to be followed by Emergency Department (ED, also known as accident and emergency - A&E) visits within 30 days; and second, they are more likely to be followed by additional primary care consultations within 30 days, most of which are in-person consultations booked by the doctor. We are also able to study patient outcomes over more than 30 days after the consultation (in some cases up to around a year). Importantly, we find no significant differences in the healthcare outcomes between online and in-person consultations in this period.

Compared to our OLS estimates, our IV estimates generally show lower cost savings from online consultations, suggesting that on average sicker patients tend to be triaged to in-person consultations, and IV overcomes this sorting problem to give a more realistic cost comparison. Nevertheless, our findings suggest that online consultations offer a modest cost saving to providers or insurers, even when we account for the costs from subsequent ED visits and primary care consultations. Moreover, since the patients we study are mostly city dwellers, they live closer to ED hospitals and primary care clinics than most Swedes.[3] Consequently, the patients we study may be more likely to seek additional in-person care than the average patient after an online visit. Online consultations also offer time savings for patients on travel and waiting in the medical office, which we also assess and are part of the societal benefits of online consultations. We find that when we count these patient-incurred costs for online vs in person, and include travel and time costs for the in-person follow-ups for patients, online consultations also offer very small expected cost savings for the average patient. Other benefits to patients from online care, such as convenience, around-the clock access, and more equitable healthcare delivery across locations and income groups are harder to quantify ((Dahlstrand, 2023) attempts to quantify the last part), and we do not focus on that in this paper.

The main contribution of this paper is to study the trade-offs between online and in-

[2]Hospitalizations that could have been avoided by timely and adequate primary care. Defined by a list of diagnosis codes attached to hospitalizations. It is the doctor at the hospital that sets the diagnosis and makes the decision about a hospitalization, never the primary care doctor.

[3]This is because we study the patients who registered with the firm's first in-person and online combined clinics, which opened in cities.

person 1:1 service provision.[4] This contributes to the recent literature on the shift to hybrid work, which is an important development in labor markets in the last few years (Barrero et al., 2023; Bloom et al., 2015; Aksoy et al., 2022; Bloom et al., 2022; Goodman et al., 2019; Ertem et al., 2021).[5] Current work on remote or hybrid work has mostly studied settings where the mode (online vs. in person) only changes for the workers (Bloom et al., 2015; Emanuel and Harrington, 2023; Emanuel et al., 2023), but there is no change in mode for the customer or client. Also changing the mode for the client can have important implications both for clients and for the provider organization's outcomes. These settings have, so far, only been studied in the literature on online teaching where students have also been switching mode during Covid-19 (Jack et al., 2023). However, the forced switching of mode during lockdown may have completely different implications than other forms of voluntary online services.[6] Moreover, settings where collaboration or peer effects are central (Emanuel et al., 2023; Agostinelli et al., 2022) will likely find different effects from online work than settings in which there is 1:1 service provision.[7] To the best of our knowledge, we provide the first paper studying the effects of online vs. in person 1:1 services where assignment of mode to clients occurs after sorting in to the service.

A nascent literature in economics focuses on changing access to or price of online healthcare (Zeltzer et al., 2023; Ellegård et al., 2021; Rabideau and Eisenberg, 2022). Our paper differs from these by studying a setting where assignment to online versus in person occurs *after* patients sort into care. This allows us to shed more light on the respective effects of these modes of delivery, free from sorting of different patients (or the same patients with different symptoms) into care when they anticipate either online or in-person consultations, and from provider sorting of patients into modes based on unobservables. The differences between our OLS and IV results indicate that there is sorting (in this case, by the provider organization) of simpler cases to online, emphasizing the need for our type of identification.

Methodologically, we build on the literature using expert propensities as instruments (Kling, 2006; Doyle Jr, 2007; Anwar et al., 2012; Dahl et al., 2014; Aizer and Doyle Jr, 2015;

[4]By 1:1 service provision, we mean meetings between one service provider and one user. Examples are banking/financial advice, tutoring, mental health therapy, legal advice, and healthcare consultations.

[5]Barrero et al. (2023) show that the shift to working from home has continued after the pandemic: 28 percent of paid workdays in the US in mid-2023 are from home (4 times the 2019 rate and ten times the rate in the mid-1990s). They also show that in the industry sector Health care and social assistance, 1.58 days per week were from home in the first half of 2023 for full time work weeks of workers aged 20-64.

[6]We study hybrid (online or in person) healthcare that started before the pandemic and continues after it in the same mixed form. Our sample includes periods before the pandemic, during the pandemic in a country with few restrictions and where in-person visits continued, and during lulls between Covid-19 waves.

[7]Carlana and La Ferrara (2021) have a setting with online 1:1 service provision (online remedial tutoring) and find positive effects from online tutoring, but they do not have an in-person comparison group.

Dobbie et al., 2018; Bhuller et al., 2020; Bakx et al., 2020; Chan et al., 2022; Frandsen et al., 2023). We apply this approach to a different research question, namely assessing the impact of online consultations, and based on the new weaker identification assumptions of Frandsen et al. (2023). Our work is also related to the literature on IV with multi-valued treatments, which are typically either ordered (Angrist and Imbens, 1995; Heckman and Urzua, 2010) or unordered (Lee and Salanié, 2018; Mountjoy, 2022). Our paper differs in focusing on a partially ordered model, where having a doctor consultation ranks above not having one, but the trade-offs between in person and online may differ across patients.

The remainder of our paper is organized as follows. Section 2 presents the background, including the institutional setting we study; Section 3 presents our econometric model; Section 4 explains our data sources and our dataset construction; Section 5 presents our tests of instrument validity and the empirical findings; and Section 6 concludes.

2 Institutional background

Assessing the impact of online consultations relative to in-person ones involves overcoming two main challenges. First, in many settings doctor consultations are either only in person, as in most countries until a few years ago, or only online, as in some countries during the Covid pandemic.[8] To compare online versus in-person, we need to observe patients across both types of delivery modes. Second, in settings with both online and in-person consultations, sorting of patients is a concern. When faced with a change in the relative price or in the convenience of online consultations, for example, different patients may schedule appointments for different symptoms, and healthcare providers may also sort patients across delivery modes based on their own criteria. To make progress, we need a setting that allows us to overcome this selection problem.

Our setting is helpful in addressing both of these issues. To observe patients across both consultation modes, we focus on a large Swedish firm, which provides a model of hybrid primary care which in the post-pandemic world has become very common: some physician consultations are in person and some are online. Different providers around the world have different assignment methods of which meetings are held online versus in person. This type of hybrid primary care was started in the firm we study in 2019, i.e., before the pandemic, and continues after the pandemic. The model applies to patients who chose this firm as

[8]Sweden is an exception among high-income countries, as it maintained a combination of both online and in-person consultations (and many other services) even during the worst phases of the Covid pandemic. Sweden never had a real lockdown.

their primary care provider under the national health insurance.[9] Here we use novel data on online and in person doctor consultations for patients who were registered at four clinics: one that opened in Lund in southern Sweden in September 2019, and three which opened in the Stockholm area (the capital) since September 2020. Our sample includes periods before the pandemic, during the pandemic in a country with few restrictions and where in-person visits continued, and during lulls between Covid-19 waves.

To resolve the endogeneity concerns due to patient sorting, we use key aspects of the institutional setting. Figure 1 illustrates the flow of patients who were registered in the hybrid clinics, from the point when patients request a consultation. The patient submits their request via a mobile phone application, at which point an algorithm determines whether a doctor consultation is immediately available, taking into account the symptoms the patient entered and the current waiting time for doctors. In most cases, the algorithm assigns patients directly to an online doctor consultation, but in others the patients are directed to the next available online nurse – these nurses can be based anywhere in the country and meet a mix of patients from the different clinics. Congestion (waiting time for the next doctor) is the most important factor in determining if a case is sent to a nurse, with a smaller role played by the symptoms of the patient. The online nurse then has to make two quick sequential decisions. First, the nurse decides whether to resolve the case without a doctor, or whether a doctor consultation is needed.[10] Second, if the nurse decides that a doctor consultation is needed, the nurse goes on to decide whether to book one in person or online. We discuss in Section 4 the factors that go into the nurses' decisions. In that section, we also explain how this setting allows us to use variation across nurses in the propensity to direct patients across the two doctor consultation delivery modes.

Before we proceed to the model, however, it is useful to note a few more points about the setting. First, doctors are paid a rate for each shift they work (effectively an hourly rate), and they work from home when online and from clinics when in person. Second, the

[9]Primary care provision is publicly funded in Sweden with a mix of public (60%) and private (40%) provision. Patients can choose a clinic, but many patients default to one which is close to their home. For patients who are registered at a certain clinic, the national health insurance pays the clinic for healthcare services primarily through capitation, but also in some administrative regions with some fee for service

[10]We define a "case" as an online meeting between patient i and nurse $j(i)$ and its resulting treatment (either an online or in-person doctor consultation, or no consultation). The nurse cannot prescribe medicine or refer to an outside specialist. If a nurse decides (based on the patient's symptoms) that a doctor consultation is needed, the nurse directs the patient straight away, as it would be inefficient to give advice when the patient is going to meet a doctor soon. Sometimes, the nurse decides that there is no need for a doctor consultation, as the patient's symptoms are not severe or in need of treatment. In those instances, the nurse can provide some advice about self-care and resolve the case.

service is covered by universal health insurance, with small co-pay.[11] Third, the application lets doctor and patient see each other, so it differs from a phone conversation without video. Fourth, we study a broad set of patients with a wide range of ages and conditions who chose a primary care provider with an online option; we discuss their representativeness of the broader population below. Finally, the treatment we study is bundled with the identity of individual doctors who chose to work online versus in person. We note that this would have been the case even if we had randomly assigned patients online versus in person, as long as we had not manipulated the work assignment of doctors. At the same time, as we discuss in the data section, almost all the doctors we study worked at least some of the time online.

3 Data

This section briefly outlines the data sources we use and the way we construct our dataset, leaving the details to the data appendix.

3.1 Data sources

Our starting point is a dataset covering roughly 1.8 million primary care meetings with a large healthcare provider in Sweden during the 24 months spanning 2019-2020. These include doctor consultations and nurse meetings, both in person and online. Most of this large sample are consultations with patients across the country who only used this provider for online consultations, and who were registered with another provider as their in-person primary care provider. We describe below how we parse the data down to patients who have the option of both in person and online care within the same provider. We have matched these with data from Statistics Sweden and the Swedish National Board of Health and Welfare from 2013-2020, covering three main data aspects. First, the matched data cover healthcare provision outside the primary care provider, including inpatient and outpatient care as well as prescriptions and their collection. Second, the data contain demographic information, including age, gender, education, and immigration status. Finally, the data contain socioeconomic information, such as earnings and education. For more information, please see Section A.1.

[11] During the sample period and in the two regions in the sample, patients paid a fee of between SEK 200 (approximately USD 22) and SEK 250 for an in-person doctor consultation, and between SEK 100 and SEK 200 for an online consultation, up to a ceiling of around 1150 SEK per year (approx. 125 USD in 2020 – average exchange rate 0.109 or 9.2). The ceiling applies to all healthcare visit co-pays, so if you go to the ED twice (400 SEK times two) and have two in-person primary care consultations, you have reached the ceiling and pay nothing for the rest of a rolling calendar year.

3.2 Dataset construction

We focus on patient cases which start with a nurse meeting (around 240 000 cases). We define a "case" as an online meeting between patient i and nurse j and its resulting "treatment" (either an online or in-person doctor consultation, or no consultation). As discussed in Section 2, our primary analysis sample comprises cases resulting in a consultation with a doctor, in person or online.

The process of creating the final sample is documented in Appendix Table A1. We impose five conditions on the cases that start with a nurse meeting. The first three ensure a strictly positive probability that the case *could* result in an in-person consultation, i.e., that the patient was "at risk" for an in person consultation. The first of these three conditions removes patients who cannot access in-person care within this provider, i.e. they are not registered with this firm as their primary care provider. The other two remove patients with symptoms (chlamydia, breastfeeding issues, and Covid-19) as well as infants. These patients follow care pathways differing from those outlined in Figure 1.[12] The other two conditions are imposed to limit our sample to cases where we have sufficient statistical power. We refer to the 8,907 resulting cases handled by 62 nurses as the "Nurse meeting sample" in 1 (or "Nurse sample" in brief).

Finally, on the last row in Appendix Table A1, we impose that the case results in either an in-person or online doctor consultation to obtain our primary analysis sample. This leaves us with 4,664 cases, referred to as the "Doctor consultation sample" in Figure 1 (or "Doctor sample" in brief). Within this doctor sample, roughly 57% of doctor consultations were in person, and the rest were online. These consultations were conducted by 400 doctors, of which 338 were only observed having online consultations *within the doctor sample*. Of the remaining 62, 38 were observed both in person and online, and 24 only in person.[13]

Key summary statistics of the doctor sample are reported in Table 1. The definitions of the main variables that we use in the paper are given in Appendix Table A13, and variable construction is further described in Appendix Section A.7. Table 1 shows that that 49% of cases happened before Covid or during a lull between Covid-19 waves. 49% of patients are female and the average age is 35, with ages ranging from 1 to 87. 19% have at least

[12] Chlamydia cases are sent a home test, breastfeeding cases are directed to a breastfeeding consultant rather than a doctor, and covid cases had their own pathways which changed during the pandemic due to changing availability of testing and changing guidelines.

[13] Since the firm's core business is online provision, however, almost all the doctors who work for it have some online experience. Therefore, of the 24 doctors mentioned earlier, at least 17 had worked online at least in 2019-2020. These doctors consulted patients online who were not directed to them by a nurse or patients who had not registered with this firm as their in-person primary care provider.

one important comorbidity in earlier healthcare records (as defined by the comorbidities in the Elixhauser index). 24% are first-generation immigrants from a country outside of Scandinavia and the 15 first joining countries of the European Union, while 39% are first or second generation immigrants from any country outside of Sweden. Finally, 58% have at least some university/college education.

To help assess the representativeness of our main (doctor) sample, Table A2 compares the patients we study (column 1) to the population in the same municipalities (column 2) and to the Swedish population as a whole (column 3). In some aspects (including gender and mean income), our sample is quite representative. The patients we study are, however, more likely to live in cities (a consequence of being registered with primary care centers located in or near cities),[14] slightly younger, more likely to have a university education, more likely to have an immigrant background, and less likely to be married. These differences notwithstanding, our sample has a broad representation of different segments of Swedish society.

4 Model

This section outlines an econometric model of the assignment of patients to online and in-person doctor consultations. The model illustrates the identification problem, namely that there is sorting of patients into consultations based on characteristics that could include unobservables, which confounds the use of OLS to identify the effects of online delivery. The model also justifies our use of nurses' propensities to direct to online doctors in all but the current meeting as instrumental variables, following the literature on expert propensities, and especially the recent work by Frandsen et al. (2023), on which we build.[15]

We differ from existing work by presenting a semi-ordered model of instrumental variables, which breaks nurses' decision into two parts. The first is an ordered decision: a doctor consultation is more intensive than no doctor consultation. The second is an unordered one: while the value of an in-person doctor consultation may typically be higher for sicker patients, some sick patients may find travel to an in-person consultation costly, and prefer an online consultation. This section begins by introducing the model setup, after which we discuss identification and finally explain how we take the model to the data.

[14] Stockholm is a city with around 1 million inhabitants, while Lund is a smaller city with approximately 100 000 inhabitants within commuting distance of a larger city (Malmö).

[15] (Frandsen et al., 2023) introduce the weaker assumptions of average monotonicity and average exclusion to replace the standard assumptions of monotonicity and exclusion in settings with expert propensities. Under these weaker assumptions (with independence and a first stage) they derive a causal LATE interpretation for IV which is similar to the familiar one.

4.1 The model setup

As outlined in Section 2 and Figure 1, we consider patients (included in the sample discussed above) who request primary care consultations using the firm's mobile application, which is the way that the patients who are registered with this provider initiate a primary care contact. We focus on patients who are registered with this provider as their main primary care clinic, whose in-person clinic is open, and who are directed by the firm's algorithm to an online nurse meeting due to temporary congestion. We assume – and later verify – that this assignment to the next available nurse is conditionally random. We focus on patients (indexed by i)[16], who are assigned to nurses (indexed by j), and we define j_i as the nurse assigned to patient i; I_j as the set of patients treated by nurse j, which consists of N_j patients; and I as the set of all patients. Each nurse briefly assesses every patient assigned to them and makes two sequential decisions: first, whether to direct the patient to a doctor consultation, and second, if the nurse does direct the patient to a doctor consultation, whether this doctor consultation should be in person or online.

We assume that each person is characterized by their sickness, θ_i, which is causing them to request a doctor consultation; [17] a vector of observable pre-determined characteristics ψ_i; and a measure of how keen they are to consult with a doctor, ϕ_i. We assume that $\phi_i = \theta_i + g(\psi_i) + \eta_i$, where η_i is mean 0 independent and identically distributed (i.i.d.) noise.

We also assume that the patient has a preference $\tau_i > 0$ for an in-person (compared to an online) doctor consultation, such that $\tau_i = 1$ denotes indifference between in-person and online. The relationship between τ_i and the other patient parameters, including sickness, is flexible, which leads to sorting into online that cannot be controlled for using observable characteristics.

We model the patient's utility as

$$U_i = \begin{cases} \phi_i & D^0_{ij} = 1, D_{ij} = 1 \\ \phi_i \tau_i & D^0_{ij} = 1, D_{ij} = 0 \\ 0 & D^0_{ij} = 0 \end{cases} \tag{1}$$

where D^0_{ij} is an indicator for patient i being directed to any doctor consultation (after meeting nurse j); and D_{ij} is an indicator for patient i being directed to an online doctor

[16] We use the single index i to denote a patient at the point in time when when they use the firm's app to request a doctor consultation to simplify notation and avoid having to carry a time index.

[17] Sickness reflects the patient's "objective" need to see a doctor when they use the firm's app, which does not necessarily correlate strongly with underlying medical conditions, such as comorbidity.

consultation, as opposed to an in-person one (after meeting nurse j). We note that D_{ij} is only defined for patients for whom $D_{ij}^0 = 1$.

We also $\mathbf{Y}_i(d, j)$ as the vector of potential outcomes of patient i meeting nurse j, where d is an indicator for online consultation. The vector of outcomes for patient i who met nurse j can be written as $\mathbf{Y}_{ij} = \mathbf{Y}_i(1, j) D_{ij} + \mathbf{Y}_i(0, j)(1 - D_{ij})$.

Turning to the nurses, we assume that they make the decision of whether to direct a patient to any doctor consultation (versus no consultation) based on patient sickness, but they could potentially make different assessments of patient sickness. We define θ_{ij} as nurse j's assessment of patient i's sickness, where $\theta_{ij} = \theta_i + \eta_{ij}$, and η_{ij} is mean zero i.i.d. noise.

Nurses differ in their assessment of the value of online doctor consultations relative to in-person ones. When choosing the mode of a doctor consultation, a nurse also takes into account the patient's preference for in person. Specifically, we define ρ_j as the tendency of nurse j to direct patients online, where $\rho_j > 0$. ρ_j varies across nurses, so that $\rho_j \neq \rho_{j'}$ for some j, j'.

We define the utility of nurse j, who meets patient i, as

$$\widetilde{U}_j = \begin{cases} 1_{\theta_{ij}>0} & D_{ij}^0 = 1, D_{ij} = 1 \\ \frac{\tau_i}{\rho_j} 1_{\theta_{ij}>0} & D_{ij}^0 = 1, D_{ij} = 0 \\ 1_{\theta_{ij}\leq 0} & D_{ij}^0 = 0. \end{cases} \tag{2}$$

Since the nurses decide the treatment status of patients, patient i will have an online consultation ($D_{ij}^0 = 1, D_{ij} = 1$) when $\theta_{ij} > 0$ and $\tau_i \leq \rho_j$; an in-person doctor consultation ($D_{ij}^0 = 1, D_{ij} = 0$) when $\theta_{ij} > 0$ and $\tau_i > \rho_j$; and no doctor consultation ($D_{ij}^0 = 0$) when $\theta_{ij} \leq 0$.[18]

4.2 Identification in the model

Panel (a) of Appendix Figure A1 illustrates the treatment of patient i when nurses make no mistakes about the sickness of the patient ($Var(\eta_{ij}) = 0$). In this case, only patients with $\theta_i > 0$ receive a doctor consultation. Among those who consult doctors, there may be three types of patients. Patients with very strong preferences for in person ($\tau_i > \max(\rho_j)$) always consult in person, and those with very strong preferences for online ($\tau_i \leq \min(\rho_j)$) always consult online. Patients whose preferences for online versus in person are intermediate ($(\min(\rho_j) < \tau_i \leq \max(\rho_j))$ are compliers – the mode of consultation is determined by the

[18]Without loss of generality, we assume that nurses break ties between online and in-person consultations by assigning patients online.

nurse to whom they are (conditionally) randomly assigned. Panel (b) of Appendix Figure A1 shows that when nurses make mistakes ($Var(\eta_{ij}) \neq 0$) the situation is similar, except that some patients who should have consulted a doctor based on θ_i do not, while some who should not, do have a consultation.

We define the propensity of nurse j to direct online (conditional on directing to any doctor) if the nurse had met the full population of patients as $\pi_j^{pop} \equiv \frac{\sum_{i' \in I} D_{i'j}}{\sum_{i' \in I} D^0_{i'j}}$ and a similar propensity among the patients that nurse j actually met as $\pi_j \equiv \frac{\sum_{i' \in I_j} D_{i'j}}{\sum_{i' \in I_j} D^0_{i'j}}$.[19] We similarly define the instrument as nurse j's propensity to direct online, leaving out patient i's meeting: $\pi_i \equiv \frac{\sum_{i' \in I_j; i' \neq i} D_{i'j}}{\sum_{i' \in I_j; i' \neq i} D^0_{i'j}}$.

To use π_i as an instrument for D_{ij}, we specify conditions under which the identification assumptions outlined by Frandsen et al. (2023) are satisfied. First, to satisfy the first stage, we require (sufficient) variation across nurses in ρ_j.

Second, to satisfy independence in the doctor consultation sample we rely on the (conditional) random assignment of patients to nurses and the orthogonality of nurse errors in the first decision (η_{ij}) to nurse propensities to online. This allows us to write:

Lemma 1. $\pi_i \perp \left\{ \mathbf{Y}_i(d, j_i), D_{ij_i} | D^0_{ij_i} = 1 \right\}$

Proof. $\rho_{j_i} \perp \theta_i, \eta_{ij_i}, \{\mathbf{Y}_i(d, j_i), D_{ij_i}\} \Rightarrow \pi_i \perp \theta_i, \eta_{ij_i}, \{\mathbf{Y}_i(d, j_i), D_{ij_i}\}$
$\Rightarrow \pi_i \perp \{\mathbf{Y}_i(d, j_i), D_{ij_i} | \theta_i + \eta_{ij_i} > 0\}$ □

Third, our assumptions on nurse tendencies and decisions imply (strict) monotonicity within the doctor sample: $\forall j' \neq j$, either $D_{ij} \geqslant D_{ij'}$ for all i, or $D_{ij} \leq D_{ij'}$ for all i, which in turn implies average monotonicity.

Finally, we assume that the instrument satisfies average exclusion:
$E[\sum_{j=1...J} \lambda_j (\pi_j^{pop} - \pi)\gamma_{ij}] = 0$, where $\lambda_j \equiv Pr(j_i = j)$, $\pi \equiv \sum_{j=1...J} \lambda_j \pi_j^{pop}$, and $\gamma_{ij} \equiv Y_i(d, j) - \overline{Y}_i(d)$ is nurse j's direct contribution to patient i's potential outcome.

4.3 Taking the model to the data

To verify the model's applicability, we begin by estimating first stage regressions of D_i on π_i in the doctors' sample

$$D_i = \beta_0 + \beta_1 \pi_i + \mathbf{Controls}_i^{'} \beta_2 + \epsilon_{1i} \tag{3}$$

[19] "Population" refers here to the fixed population of the doctor sample.

Here and in the regressions below we also add a set of controls, the vector $\textbf{Controls}_i$, which includes a set of fixed effects for: four-hour time blocks; days of week; years × months; and the primary care clinic at which the patient is registered. The other controls we gradually add are a set of demographic controls; an indicator for prior patient comorbidity; and fixed effects for patients' ICD (diagnosis) code groups, as determined by the nurse (groups of the International Classification of Diseases (ICD, version 10) codes).[20] Appendix Table A3 shows a large and precisely estimated first stage, indicating a high compliance rate both without and with the controls.[21]

To examine independence, we proceed in three steps. First, to test the (conditional) random assignment of patients to nurses, we regress π_i on ψ_i in the nurses' sample and report the p-value from a joint F-test for patient characteristics ψ_i. Panel A in Appendix Table A4 shows that the instrument is uncorrelated with patient characteristics in this sample. Still, the controls are useful, because they address that patients (nurses) with different characteristics might be differentially likely to request a doctor consultation (work) at particular times. In practice, this balancing test passes in all specification, irrespective of the controls.

Second, to test the assumption that nurses with different propensities to refer online are not systematically different in their propensity to refer to any doctor, we regress the nurse-level propensity (not the leave-one-out instrument) π_j on nurse j's propensity to assign to any doctor, $\frac{1}{N_j}\sum_{i' \in I_j} D^0_{i'j}$. The estimates in Panel B of Appendix Table A4, show no significant correlation.[22]

Finally, to test whether the instrument is orthogonal to the characteristics of patients in the doctors' sample, we regress π_i on ψ_i in the doctors' sample, and report the p-value on a joint F-test for ψ_i. The results in Panel C of Appendix Table A4 show balance in the doctors' sample.

To establish average exclusion and average monotonicity, we present four pieces of evidence. First, there are institutional rules, which circumscribe nurses' decisions in our setting;

[20] These controls are all fully pre-determined, except the nurse ICD groups. We use the ICD groups as proxies for patient's current symptom. We have a variable reflecting patient symptom, but it is more coarse and more often missing.

[21] Following Abadie et al. (2023) we use robust standard errors (s.e.) throughout our regression specifications. To ease comparisons to the existing literature using expert propensities, however, we also report the first stage using standard errors clustered by nurse, which we show are very similar to the robust s.e. in our setting.

[22] This finding helps address a potential concern that low propensity to online reflects excessive caution on the part of less-skilled nurses who might also refer more cases to doctors, along lines similar to those in Chan et al. (2022)

for example, nurses cannot prescribe medications or refer to outside specialists. Thus, nurses are unlikely to affect patient outcomes through channels other than through directing them to doctor consultations.

Second, in Panel A of Appendix Table A5 we report the distribution of durations of patient-facing time in nurse meetings. These are short, with a mean of less than five minutes and a median of four minutes. [23] This leaves little time for anything other than a brief conversation about the patient's symptoms and potentially about some self-care if no doctor consultation is deemed necessary.

Third, to verify that we observe no first stage reversals, we regress D_{ij} on π_i in subsamples of the doctors' sample. As Appendix Table A6 shows, there is high compliance for different sets of patients, broken down by age, sex, income, education, and other predetermined characteristics.

Finally, in the spirit of Chan et al. (2022), we check if nurses who direct more online are differentially likely to make rare mistakes. To do so, we define as a mistake an instance in which the nurse did not direct a patient to a doctor consultation, but the patient was actually sick as evidenced by turning up in any emergency care (ED or hospitalization) within ten days after meeting the nurse. We then regress π_j on the share of mistakes of nurse j and find no significant correlation, as Panel B of Appendix Table A5 shows.

After reporting all the checks above, we proceed to use the doctors' sample to estimate our main specification

$$Y_i = \beta_3 + \beta_4 D_{ij} + \mathbf{Controls}_i^{'} \beta_5 + \epsilon_{2i}, \tag{4}$$

where Y_i are individual outcome components of $\mathbf{Y}_i$. Since D_i is potentially endogenous (e.g., if patients with different health problems or other differences that matter for outcomes receive online rather than in-person consultations), we also estimate specifications where we instrument for D_i using π_i. The differences between the OLS and IV estimates may inform us whether, on average, sicker patients tend to sort into online or in-person consultations.

5 Empirical findings

We begin this section by discussing evidence on the validity of the model discussed in Section 4. We then discuss our main findings on the similarities and differences between online and in-person in (i) the duration and timing of consultation, (ii) in-meeting outcomes, and (iii)

[23] For comparison, the same table shows that the patient-facing time of the doctor consultations with the same patients is much longer.

patient outcomes after the consultation. For patient outcomes after the consultation, we look at outcomes in the month after, as well as separately in more than a month after. We also illustrate how key outcomes look in the weeks before and after the nurse meeting graphically. We discuss doctor sorting between online and in-person work. We present evidence on the extent to which patients with different demographics view online consultations as a replacement for in-person consultations. Finally, we show evidence on the cost trade-offs for the providers and the patients.

5.1 Instrument validity

Appendix Figure A2 shows the variation in our instrumental variable, which is the nurse propensity to direct patients online, leaving out the current meeting. Most of the 62 nurses in our sample direct patients more frequently to in-person consultations, but some direct more often online, resulting in a mean in-person consultation rate of around 57 percent in the doctors' sample.

We use this variation in the instrument to examine the identification assumptions. As Appendix Table A3 shows, the first stage estimate falls slightly from 0.78 without controls to 0.7 when we include the main set of fixed effects (time of day, day of week, month $\times$ year, and clinic), to address the possibility of nurse and patient sorting across times and locations. Reassuringly, when we add further controls (patient demographics, comorbidity indicator, and fixed effects for the nurse-set diagnosis codes, the first stage coefficient remains large (0.66) and stable. The first stage is also precisely estimated when we use either robust s.e. (following Abadie et al., 2023) or s.e. clustered by nurse (following earlier papers on expert propensities). The F-statistic for the first stage is over 100, so we are not concerned about weak instruments problems, at least for outcomes that we can measure for all or most patients.

Next, we turn to our three tests of the independence assumption. Panel A of Appendix Table A4 tests balance of the instrument on patient characteristics in the nurses' sample. The p-values are consistent with our assumption that patients and nurses are randomly matched, especially after we include our standard controls for time and location (of the clinic that the patient is registered with). Panel B tests balance of nurse propensity to direct online on nurse propensity to direct to *any* doctor (vs. suggesting no doctor visit) in the nurses' sample. The estimates are not only statistically insignificant, but also small in magnitude. Finally, Panel C tests balance of the instrument on patient characteristics in the doctors' sample. Reassuringly, we cannot reject that patient characteristics are balanced among patients directed to doctor consultations, especially with our standard controls for time and location.

In Appendix Table A5 we show results pertaining to the average exclusion assumption (Frandsen et al., 2023). Panel A shows that the mean patient-facing time for nurses is less than five minutes, and the median is four minutes. Such a short meeting may allow a nurse to enquire about the patient's condition and decide whether the patient should consult a doctor and if so – whether this consultation should be online. However, it leaves little time for the nurse to affect patient outcomes in other ways than through their assignment to a consultation with a doctor, either in person or online. Panel A also shows that nurse meetings are typically much shorter than doctor consultations: the mean patient-facing time is about four times shorter, and the median is about three times shorter.[24]

Next, we examine the assumption of average monotonicity. Appendix Table A6 follows Frandsen et al. (2023) and Bhuller et al. (2020) by reporting the first stage for different subsamples. As the table shows, the first stage is large and statistically significant when we break down patients by their gender, age, education, income, immigrant status, comorbidity status, whether they specified "general health" in their symptoms form (rather than filling out a specific symptom), and whether they requested the consultation during periods of low or no Covid (versus the first or second Covid wave). This suggests that most patient groups are compliers, responding to the nurse's tendency towards online versus in-person consultations. This is important, since it means that our compliers are broadly representative, at least within the population of patients we study. We return to the point of generalizability below, when we discuss the external validity of our estimates with regards to costs.

Panel B of Appendix Table A5 examines an aspect of the average monotonicity assumption, relating to rare mistakes that nurses make. Similarly to Chan et al. (2022), we measure these mistakes as instances when a patient whom a nurse *did not* direct to a doctor consultation is hospitalized or observed in the ED within 10 days of meeting the nurse.[25] Even these instances, which are rare (on average nurses have a mistake share of 6%, and 5% of patients experience these events), do not necessarily imply a mistake on the nurse's part, as the health problem may have arisen after the nurse meeting. Nevertheless, our estimates

[24] To ensure comparability of the nurse and doctor meeting durations, Panel A of the table restricts the sample to patients for whom the patient-facing duration is observed for both, although this restriction does not matter much in practice.

[25] Chan et al. (2022) study radiologists' diagnosis of pneumonia, where their decision to diagnose or not is strictly ordered, so less skilled radiologists may be more cautious and over-diagnose. Our setting is different, since we consider the decision to direct to online or in-person consultations, which are not necessarily ordered. We separately consider the nurses' decision whether to direct patients to any doctor in our discussion above, and the mistake we measure pertains to that decision rather than to the online vs. in person decision.

suggest that nurses who direct more online do not significantly differ in the fraction of rare mistakes they make. The estimate is again not only statistically insignificant, but also small in magnitude.

5.2 Effects of online versus in-person doctor consultations

5.2.1 Duration and timing of consultations

Table 2 reports our first set of results regarding the differences in duration and timing between online and in-person consultations. In Panel A of Table 2 we show one clear advantage of online consultations: they take place much sooner after the patient's request – typically on the same day. In contrast, in-person consultations are typically held 2-3 days after the nurse meeting, reflecting the need to find availability among the smaller set of doctors working in the nearby clinic, as well as the need to schedule for travelling.

Panel B shows that the total consultation time is much shorter online according to all the specifications we estimate. This may be one of the reasons why online consultations in themselves are cheaper than in-person (we will investigate post-consultation costs below). Two patterns in these results are worth mentioning, since they recur in many of the other outcomes below. First, the inclusion of different sets of controls affects the estimates little, and second, OLS and IV differ, and there is a systematic pattern to this difference. The OLS estimates suggest that online meetings are about two-thirds shorter, while the IV estimates suggest that they are only one-third as short. These findings are consistent with patients with (on average) less severe symptoms sorting (or being sorted) into online consultations (assuming that more difficult cases take longer time). Our set of controls, although detailed, cannot address this sorting. However, the IV estimates overcome this sorting, and they suggest smaller cost savings online than the OLS results would imply – in this case in terms of time saved. As we discuss below, several of our other findings are also consistent with this interpretation.

Panels C and D of Table 2 break down the total doctor consultation time into patient-facing and administrative parts. Online meetings have significantly shorter patient-facing time but longer administrative time. A possible interpretation of this finding is that when meeting a patient in person, the doctor fills in any notes or forms while the patient is in the room, whereas online meetings end sooner and the doctor fills in some forms by themselves after the meeting. Another possible interpretation (they are not mutually exclusive) is that doctors need some time to consult notes and/or recuperate after consulting patients. Online, this is recorded separately as administrative time, whereas in person this time may be bundled with patient-facing time.

5.2.2 Within-consultation outcomes: diagnoses, prescriptions, referrals

Table 3 examines key within-consultation outcomes. It shows that online and in-person doctor consultations are broadly similar across a range of immediate outcomes. The OLS estimates in Panel A show that the rate of meaningful diagnosis is higher online, while the IV estimates show more negative but imprecise estimates.[26] Panel B shows that online consultations are either more likely (OLS) or equally likely (IV) to yield a prescription.

Panel C of Table 3 shows that the rates of patient prescription collection are similar for online and inperson consultations. This measure is interesting, since it can be seen as a measure of patient adherence (Neiman et al., 2018), but is often difficult to measure in data. Nonetheless, these estimates should be taken with caution, since they rely on a subsample of patients (those who receive a prescription), which means we are both conditioning on an outcome and relying on a weaker first stage.

Panel D shows that specialist referrals are either less common online (OLS) or equally common (IV), again consistent with the above-mentioned sorting pattern.[27]

Panel E shows the satisfaction of patients following online consultations. These estimates are available only for patients who scored the meeting, which is more commonly done online (see Appendix Table A7), most likely because patients are more systematically reminded to score consultations online than in person. Consequently, the estimates in this panel (like those in Panel C) condition on an outcome, and should therefore be treated with caution. Nevertheless, the estimates here are again consistent with the similarity of in-person and online in terms of their in-consultation outcomes – we see no significant difference. In sum, meaningful diagnosis, prescription, adherence, referral, and patient satisfaction are all similar.

5.2.3 Post-consultation outcomes

In contrast to the similarity of in-consultation outcomes for in person and online consultations, we see some differences between the two delivery modes in the short-run (within a month) post-consultation outcomes (Table 4). We focus on extensive-margin short-run

[26] A meaningful diagnosis is one that does not fall in the symptomatic or procedure categories of the Swedish ICD 10 diagnosis classification (which are R or Z diagnoses).

[27] Due to differences across regions, patients are only observed being referred to specialists in Stockholm and not in Lund, so we run this regression on the Stockholm sample only.

outcomes, since if a person has used a follow-up service, any subsequent outcomes may in part be the result of that follow-up.

No difference between online and in person is present when it comes to the rare (and negative) outcome of avoidable hospitalizations, where patients are hospitalized for reasons that primary care could plausibly have treated or prevented, but did not do or succeed in (U.S. Agency for Healthcare Research and Quality, 2023). Neither the OLS nor the IV estimates in Panel A of Table 4 show any significant difference in this measure between online and in-person consultations. We note that this outcome is very rare, so the confidence intervals of the estimates are wide compared to the mean of the outcome, suggesting that we may be under-powered to detect significant differences.

Panel B examines overall hospitalizations. All the estimates are statistically insignificant, although the IV estimates are large compared to the mean of the outcome, and in some cases marginally significant. As discussed above, and as we shall also see in the next outcomes, the difference between OLS and IV is consistent with the latter solving a selection problem. We will return to hospitalizations in Section 5.2.5.

In Panel C we see significant differences in Emergency Department visits after online compared to in-person consultations. Online consultations are more likely to be followed by Emergency Department (ED) visits in both OLS and IV, and the IV estimates are large. Our interpretation is that an online consultation is more likely to result in the patient or the doctor – or both – concluding that the patient should see another doctor in person, at least as a precaution. In some cases, ED could, at least in the patient's perspective, be the easiest way to achieve this.

In Panel D, both OLS and IV show that following an online consultation, the patient is more likely to have another primary care consultation within 30 days (still within the same provider, where patients are registered and should receive their primary care). The estimates are all large and statistically significant, and the IV estimates suggest that about 63% of the online consultations (compared to about 37% of the in-person consultations) are followed by another primary care visit within 30 days.

5.2.4 Robustness of post-consultation outcomes

In Appendix Table A8 we repeat the analysis in Table 4, but this time starting the 30-day count from the nurse meeting, since this avoids a gap in observing patients between the nurse and doctor meeting, which (as we discuss above) is larger for in-person consultations.

The estimates in Appendix Table A8 are broadly similar to those in Table 4.

5.2.5 Patient outcomes in the weeks before and after the nurse meeting

In Figure 2, we show IV estimates in the weeks before and after the nurse meeting, which has two main advantages. First, we bring in data from prior to the current case, and show that there are no differences in previous PCP meetings, ED visits etc. in the ten weeks before the nurse meeting, between patients who were assigned by the nurse to an online (vs. an in person) doctor consultation. Second, we illustrate the time pattern of what happens after the nurse meeting. In this figure, we define as 0 the week starting on the day when the patient had the nurse meeting (more equivalent to Appendix Table A8 than Table 4). We do this since for the time pattern, it may be relevant to keep the longer delay between the nurse meeting and the in-person doctor consultation in mind. The point estimates in the sub-figures come from 21 separate regressions, with the outcome variable measured in the respective week. Otherwise it is our main IV specification with the full set of controls, as in Column 8 of Table 4.

Having noticed that we see no difference between the patients later assigned to online vs in person in the weeks before the nurse meeting in the four panels, we notice that in the week of the event, we see a significant increase in PCP visits for patients who are directed online (Panel a).[28] Panel (b) shows that the coefficient on in-person doctor consultations is almost identical, and this too happens directly in the same week, and then goes to zero quickly. Panel (c) shows ED visits, which also are higher for online-doctor patients in the same week as the initial nurse meeting, and then quickly go to zero, while ED visits are less precise than PCP visits. In Panel (d), we see a small (in percentage point terms) increase in hospitalizations, only the week after the nurse meeting (week 1, not week 0 as above), which is just about significant at conventional levels, although as discussed earlier, the overall 30 day estimate on hospitalizations is not significant at conventional levels.

5.2.6 Breakdown of primary care follow-ups

Appendix Table A9 looks more closely at the increased primary care follow-ups after online consultations. The table shows that this is mostly due to more revisits that are initiated by a doctor (not the patient), and that these are essentially all in-person consultations and not online ones. The table also suggests that there may be a slightly higher probability

[28] The outcome variable in panels a and b excludes the online or in person doctor meeting defined as our treatment and the nurse meeting directing to that meeting.

of a patient-initiated primary care follow-up visit, although the estimates are smaller and imprecise. Taken together the results in this table suggest that doctors working online are often cautious, and book a follow-up in-person consultation. At the same time, it is possible that some of the follow-up visits reflect patient requests for doctors to inspect unrelated health issues. In a longer in-person consultation, there may be time to discuss several health issues, while in the shorter online consultation, there may be time only for one.

5.2.7 Medium run post-consultation outcomes

In Appendix Table A10 we re-estimate the regressions reported in Table 4, except that we consider "medium run" outcomes – those from over 30 days until the end of our sample. The period over which we observe patients varies, with some (who met a nurse in late 2019) observed for over a year while others (who met a nurse in late 2020) are observed for a much shorter duration. Still, our results suggest no significant differences in these medium-run outcomes between in-person and online consultations.

5.3 Doctor productivity and the sorting of doctors to online

So far we have seen that doctors working online held shorter consultations, and only part of this productivity advantage was due to sorting of patients. To further investigate differences in doctor productivity online vs in person (in terms of consultations per hour), we study doctors' shifts in these two different delivery modes. Here we use the sample of doctor "shifts" which encompasses the much larger sample of non-registered patients as well as registered ones.[29] Shifts are defined as starting with the start time of the first consultation and ending with the end of the last consultation within 24 hours of a calendar day. In-person and online shifts are on average similarly long (approximately 5 hours).

Columns (1) and (2) of Table 5 show that when we account for the full shift duration, doctors working online are roughly twice as productive (in terms of patients per hour) as those working in person, although this setting cannot account for patient sorting. The shift data does, however, afford sufficient variation to study doctor sorting. As the difference between columns (2) and (3) shows, more productive doctors do indeed sort online, but only about 13 percent of the online productivity gains are explained by doctor sorting. Columns (4)-(6) repeat the analysis excluding any breaks between patients, and the results are broadly

[29] Patients who are registered have one of the company's clinics as their primary care provider, and are "at risk" for both in-person and online consultations with the provider. Patients who are not registered have another PCP, and use this service only for online consultations.

similar. These results hold despite the fact that doctors are paid per hour both online and in person, and not per patient.

5.4 Patient heterogeneity in viewing online visits as substitute for in-person care

Finally, we consider the extent to which patients with different characteristics view online as a substitute for in-person consultations. Table 6 shows this for a sample of non-registered patients (i.e. patients who had a different in-person primary care provider than this firm), which is much larger than that of registered patients, and allows for heterogeneity analysis. These patients use the service only for online consultations. Here we use a question that was asked only to online patients – did they consider their online consultation a replacement for an in-person consultation? An important caveat here is that just under half the patients who were asked answered this question, and it is possible that those who answered were more positively disposed towards online. Still, as the table shows, about 95 percent of those who answered said that online was a substitute for in-person. Those who were less likely to consider online a replacement were predominantly older patients in their 70s or over 80 years old, and to a lesser extent first-generation immigrants who were neither from Scandinavia or from the first 15 countries in the European Union.

5.5 Cost analysis

We now consider the difference in costs for providers and patients between online and in-person consultations. When we think about provider costs, we consider a provider or payer who takes all the patients' healthcare costs into account, including ED visits, such as an insurance company, health maintenance organization, or a public healthcare provider and insurer.[30] As Table 7 shows, when we ignore follow-ups, online meetings are four times cheaper than in person.[31] This large cost advantage could reflect the productivity improvements discussed above, as well as reduced overhead costs from operating clinics and other

[30] This is also relevant in the setting we study, as the payment model is capitation and in some cases has cost penalties for ED visits. The primary care provider company is paid through capitation for the patients studied in this paper in Region Scania, and so faces a cost from additional primary care follow-ups within the service. In Region Stockholm, they are paid through a combination of capitation and some fee for service, so it is less clear what the incentives are for additional primary care visits. In Region Stockholm, the primary care provider faces a penalty if a large share of their patients have ED visits, while they get a bonus if a low share has ED visits. In Region Scania, that was not the case in the study period, but was started in 2022.

[31] The costs for both online and in-person are best estimates of what the public health insurance pays for each, and come with some uncertainty. The online cost we use is a cost set by regulation for out-of-region online visits. The in-person cost is an average of what an in-person consultation costs or is reimbursed with. See the notes of Table 7, Appendix Table A12 and Appendix Section A.7.3 for more details.

staff costs.The cost advantage of online consultations is reduced, however, when we account for the higher incidence of follow-ups in primary care and the Emergency Department (ED). Once those follow-up rates are accounted for, online consultations are only about 20 percent cheaper.

A similar result applies to patient costs. When we account for patient co-pay, the time costs of the duration of the consultations and travel and waiting costs, as well as the travel costs – without follow-ups – consultations online are about 3 times cheaper than in person. However, accounting for the same costs related to a higher share of follow-up visits in primary care and ED almost erases the cost advantage of online consultations (9% cheaper than in person). Nevertheless, as discussed above, online patients still benefit from seeing doctors sooner, which is not taken into account in these calculations. Still, to achieve greater cost savings for both providers and patients, reducing revisits without sacrificing healthcare quality remains an important challenge.

5.6 Generalization of the costs and benefits of online consultations

There are potentially other benefits of online doctor visits that are hard to price, such as the convenience for patients of attending a medical appointment from their home, not having to travel and wait when sickest, the ease of scheduling when there is no travel time and when online visits are available with extended opening hours, and short waiting times after an initial request.[32] 51% of online doctor consultation in the doctor sample take place outside of regular medical office hours (i.e. outside 8am-5pm on weekdays), compared to 28% out-of-hours for in-person consultations. Another benefit of online consultations that we have not priced is avoiding potential contagion (both from the patient at hand and to the patient at hand) in the waiting room or medical office, or during travelling (Neprash et al., 2021).

Moreover, it is possible that our comparison is harsh on online for the following reasons:

5.6.1 Sickness of patients

The patients in our sample have gone through nurse triage, and the nurse has decided that they should see a doctor (in our model based on having nurse-perceived sickness θ_{ij} over a certain threshold). This means that the sample patients are likely sicker than the average patient contacting primary care. Some primary care systems allow patients to see a doctor

[32] We do not take into account the time between when the nurse meeting happened and the doctor consultation in the cost calculation. It is much longer for online, but the patient can do other things during the 2-3 days when he or she waits for the in-person visit, so the cost of this waiting time is not easily calculated.

straight away, while others have a nurse triage before. Our results are more reflective of the trade-off between online and in person in the second case, when there has been nurse triage. This means that the results regarding outcomes of online, such as in-person primary care follow ups, and our cost comparison, while internally valid, could be seen as a harsh comparison against online care if trying to generalize to any patient contacting primary care. We show in Appendix Table A11 that the patients in the nurse-triaged sample (which we use for identification reasons) who have seen an online doctor have a considerably higher share of in-person doctor follow-ups, than patients who are also registered with a clinic in the same system, but see a doctor online straight away after contacting primary care, without nurse triage.

5.6.2 Distance to in-person care

The patients in our sample all live in urban areas, since the four clinics in our sample are located in the cities or suburbs of Stockholm and the area of Lund/Malmö. This means that the distance to both primary care clinics and to hospitals with Emergency Departments are likely shorter than on average in the country.[33] Patients who live further away from an ED may be less likely to follow up with an ED visit than the patients in our sample, as in Vaz et al. (2014). This would affect the cost of online more than in person, since there are more ED visits after online consultations. This could indicate that our comparison is harsh against online.

6 Conclusion

Online delivery is now possible for many services, such as banking/financial advice, tutoring/teaching, therapy, and healthcare. Within healthcare, systems around the world are struggling to find the right mix of online and in-person consultations after the pandemic. The trade-off between online and in-person services can be related to the typically lower price of online consultations, which is important in a situation with tighter finances for healthcare providers and systems. It can also be related to preferences about work mode among doctors, and patient preferences for having a more convenient consultation and not travelling when sick. However, it is crucial that we also understand patient health outcomes

[33] The average distance between municipality centroid and ED hospital is 32 kilometers in the entire country. A weighted average of the distances in the municipalities where the doctor sample patients live, it is 3 kilometers. The most common municipalities of patients in the sample have at least one hospital with an ED.

and the overall costs that result from online compared to in-person consultations. To the best of our knowledge, we provide the first paper studying the effects of online vs. in person 1:1 services in a setting where clients have already opted to receive the service (i.e. without sorting into the service or not based on whether it will be in person or online).

This is also, to the best of our knowledge, the first paper to study the anatomy of such meetings, in terms of how they are scheduled and how long they last for. We find that online consultations take place sooner and are considerably shorter than in-person ones. The shorter waiting times can help explain the popularity of online consultations among patients. The shorter duration can help explain why the sticker price of online meetings is cheaper than in-person, on top of reasons such as lower overhead due to less office space when doctors work from home.

Despite online meetings being shorter than in-person meetings, we find that the in-meeting outcomes such as diagnosis, prescription, specialist referral and patient satisfaction are largely similar to in-person meetings.

It is also crucial to measure what happens after the meeting. We find that online meetings are succeeded (in the month following the consultation) by considerably more in-person follow-ups, both in the same primary care service and in the hospital Emergency Department. The larger share of in-person follow-ups in primary care are mostly initiated by the doctor, and hence seems to reflect cautiousness among doctors about fully completing a case without an in-person consultation. The ED visits can be initiated by the patient, and could suggest that some patients are not fully treated after online, or that patients are cautious after online and use the ED as an in-person check.

Other outcomes during the 30 days after the initial consultation are not significantly different between online and in-person. Our estimates suggest that in the very short-run (a week after), there may be a small increase in hospitalizations after online consultations (though large relative to the base) but our main estimates for hospitalizations are imprecise at conventional levels. No outcomes in the longer run (post 30 days after the consultations) differ between online and in-person care, so it seems that there are no differential medium-term health or healthcare consequences from online visits.

Given the higher share of primary care and ED follow-ups after online consultations, an initial 4 times total cost difference between online and in-person consultations is reduced, leaving online meetings (counting additional follow-ups) just a little (around 20%) cheaper than in-person consultations for providers who take the full cost responsibility of patients' follow up meetings and ED visits, such as insurance companies, HMOs or public health insurance agencies. For patients, the cost of online visits is also initially much lower when counting both co-pay, travel costs and time costs for the in-office waiting time and meeting time. When similar costs for expected follow ups are counted, the costs become more similar between in person and online. However, we have not counted other potential cost savings for patients, such as that of limiting contagion when not travelling to and visiting a doctor's office, and the ease of scheduling and short waiting times from nurse meeting to doctor consultation in the online setting. We have also noted that our comparison may be harsh on online given that the patients we include may be sicker than the average patient contacting primary care, since a nurse has triaged them into having a doctor consultation. A second reason is that the sample of patients live closer to EDs and in-person primary care than the average patient in Sweden, and thus may be more likely to follow up in person.

We have also been able to study doctor sorting between in-person and online work, and find that slightly more productive (in terms of patients per hour) doctors sort to online. This is one of the first measures of such sorting, and interestingly goes the opposite direction as contemporaneous work by Emanuel and Harrington (2023) who study sorting of call center workers to remote vs in-person work.

A pattern that we see in several results is that OLS suggests that online meetings are even shorter or have lower specialist referrals, compared to IV. We interpret this as evidence of the sorting problem, that nurses may sort more severe cases to in person – which is what our IV method is designed to deal with. Future work may investigate whether nurses' current sorting is optimal, or whether it can be improved so that less patients who need in-person follow-ups are sorted to online.

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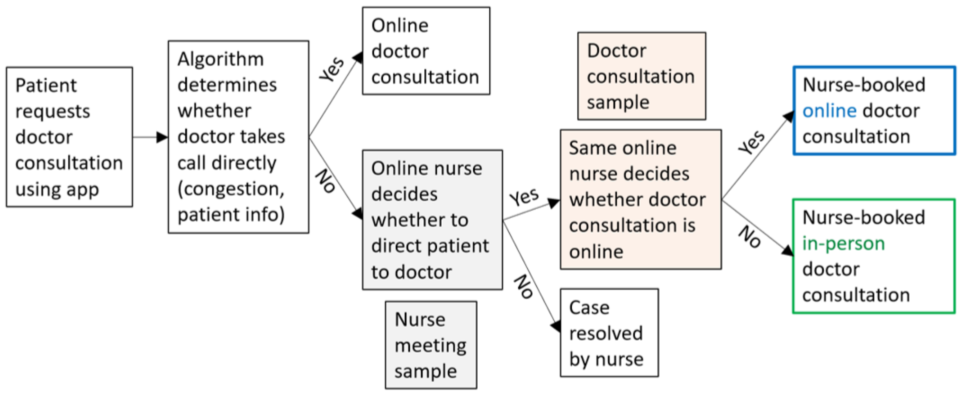
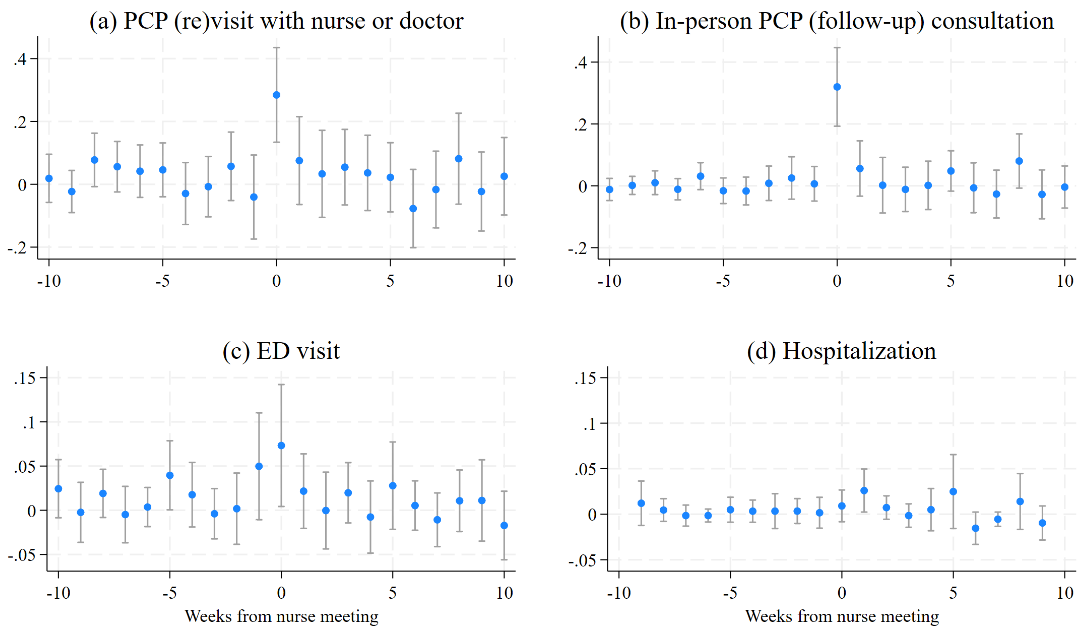
7 Main tables and figures

Figure 1. Assignment of registered patients to in-person versus online



Note: This paper shows the flows of patients registered with the healthcare company. The cases in the box with gray background are defined as the "Nurse meeting sample" (or "Nurse sample" for short). The cases in the box with orange background are defined as the "Doctor meeting sample" (or "Doctor sample" for short). We define a “case” as an online meeting between patient i and nurse j_i and its resulting treatment (either an online or in-person doctor consultation, or no consultation).

Figure 2. Patient outcomes in the weeks before and after the nurse meeting



Note: In each of the four panels of this figure, we show IV estimates and 95 percent confidence intervals of the effect of an online doctor consultation relative to an in-person doctor consultation. Each panel shows estimates from 21 separate regressions, where the outcome is the online coefficient for a separate week; for example, "week 0" shows the effect in the week starting with the patient's nurse meeting, "week 1" is for the following week and "week -1" for the preceding week. The estimates are from our main IV specification with our full set of controls (fixed effects, demographics, an indicator for whether a patient has a comorbidity, and indicators for the letter grouping of the ICD code the nurse marked the patient). Note that for panels (a) and (b), the PCP (re)visit and in-person PCP (follow-up) consultation refer to any visit/consultation that the patient has in the respective time period excluding the online/in-person treatment consultation the nurse directed the patient to. The presented confidence intervals are for the 95% level.

Table 1. Key variable summary statistics

	Mean	SD	Min	Max	Observations
Consultation was online	0.43	0.49	0	1	4664
Instrument (π_i)	0.43	0.12	0.24	1	4664
Nurse propensity to direct to any doctor	0.54	0.092	0.28	0.85	4664
Nurse "mistake" share	0.063	0.035	0	0.17	4664
Patients with a comorbidity	0.19	0.40	0	1	4664
Has some university education	0.58	0.49	0	1	3396
Income (thousands of SEK)	316.4	295.6	0	5301	3990
1st gen. immigrant (non-EU15/Scandi.)	0.24	0.43	0	1	4663
1st or 2nd generation immigrant	0.39	0.49	0	1	4663
Other physical health issue	0.30	0.46	0	1	4664
Period before Covid-19 and during Covid-19 lull	0.49	0.50	0	1	4664
Patient female	0.49	0.50	0	1	4664
Patient age	35.0	13.8	1	87	4664

Note: This table presents summary statistics of some key variables in the doctor sample (N=4664). The propensity of a nurse to redirect to online is our instrument (π_i). The nurse propensity to direct to any doctor is the share of meetings that the nurse directed to a doctor (vs no doctor). The nurse "mistake" share is the share of the nurses patients (within our sample) which were observed in ED or hospitalized within 10 days of the meeting. The income is reported in thousands of SEK and defined for patients above 20 years old. The median income in our sample is 287,300 SEK. We use data from 2018 for income and university education. "1st gen. Immigrant (non-EU15/Scandi.)" is an indicator for people who were born outside the EU15 countries and Scandinavia. EU15 refers to the time back when the EU had only 15 members. "1st or 2nd generation Immigrant" is an indicator for people who were either born outside Sweden or whose parents were both born outside Sweden. "Other physical health issue" is a label suggesting the patient should see an in-person doctor, given by the algorithm that takes patient symptoms as inputs. The low Covid-19 spread indicates consultations that are before 11th of March 2020 and between the 6th of July 2020 until the 24th of October 2020.

Table 2. Timing and duration of doctor consultations

	OLS				IV			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
A: Days between nurse meetings and doctor consultation								
Consultation was online	-2.30	-2.28	-2.31	-2.35	-3.15	-2.75	-2.74	-2.79
	(0.065)	(0.066)	(0.068)	(0.069)	(0.34)	(0.40)	(0.42)	(0.43)
Fixed Effects		✓	✓	✓		✓	✓	✓
Demographics			✓	✓			✓	✓
Any comorbidity			✓	✓			✓	✓
Nurse-set ICD group				✓				✓
Observations	4664	4664	4531	4518	4664	4664	4531	4518
First-stage K-P F-statistic					198	145	138	133
Baseline mean	2.4	2.4	2.5	2.5	2.4	2.4	2.5	2.5
B: Total consultation duration (in minutes)								
Consultation was online	-25.8	-25.7	-25.6	-26.0	-12.6	-14.0	-15.0	-14.9
	(0.62)	(0.62)	(0.63)	(0.66)	(3.52)	(4.01)	(3.99)	(4.14)
Fixed Effects		✓	✓	✓		✓	✓	✓
Demographics			✓	✓			✓	✓
Any comorbidity			✓	✓			✓	✓
Nurse-set ICD group				✓				✓
Observations	4512	4512	4384	4371	4512	4512	4384	4371
First-stage K-P F-statistic					194	141	133	130
Baseline mean	39.8	39.8	39.7	39.7	39.8	39.8	39.7	39.7
C: Patient-facing part of the consultation (in minutes)								
Consultation was online	-26.8	-26.7	-26.8	-27.0	-22.6	-23.2	-22.8	-22.6
	(0.44)	(0.44)	(0.46)	(0.48)	(2.17)	(2.42)	(2.49)	(2.57)
Fixed Effects		✓	✓	✓		✓	✓	✓
Demographics			✓	✓			✓	✓
Any comorbidity			✓	✓			✓	✓
Nurse-set ICD group				✓				✓
Observations	4343	4343	4223	4211	4343	4343	4223	4211
First-stage K-P F-statistic					200	147	137	134
Baseline mean	32.3	32.3	32.2	32.2	32.3	32.3	32.2	32.2
D: Administrative part of the consultation (in minutes)								
Consultation was online	1.32	1.38	1.42	1.30	6.32	6.49	6.42	6.31
	(0.34)	(0.34)	(0.35)	(0.35)	(1.94)	(2.21)	(2.27)	(2.34)
Fixed Effects		✓	✓	✓		✓	✓	✓
Demographics			✓	✓			✓	✓
Any comorbidity			✓	✓			✓	✓
Nurse-set ICD group				✓				✓
Observations	4332	4332	4213	4201	4332	4332	4213	4201
First-stage K-P F-statistic					198	145	136	133
Baseline mean	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2

Note: This table reports regressions using the doctor sample (see text for discussion). The instrument in the IV specifications is the propensity to online π_i. Fixed effects include Year*Month, 4 hour blocks, day of the week and where the patient was listed. For a description of the control variables we use, please see main text. The First-stage K-P F-statistic is the Kleibergen-Paap F-statistic. Robust standard errors are in parentheses.

Table 3. Within-consultation outcomes

	OLS				IV			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
A: Doctor set an informative diagnosis								
Consultation was online	0.035	0.037	0.038	0.028	-0.12	-0.14	-0.15	-0.12
	(0.013)	(0.014)	(0.014)	(0.014)	(0.075)	(0.087)	(0.090)	(0.087)
Observations	4664	4664	4531	4518	4664	4664	4531	4518
First-stage K-P F-statistic					198	145	138	133
Baseline mean	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68
B: Patient received a prescription								
Consultation was online	0.15	0.15	0.15	0.15	-0.011	0.017	0.027	0.063
	(0.013)	(0.013)	(0.014)	(0.014)	(0.070)	(0.079)	(0.082)	(0.083)
Observations	4664	4664	4531	4518	4664	4664	4531	4518
First-stage K-P F-statistic					198	145	138	133
Baseline mean	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
C: Patient collected prescription within 30 days (conditional on getting a prescription)								
Consultation was online	-0.0017	-0.0020	0.0028	0.0054	-0.027	-0.0074	0.029	0.040
	(0.017)	(0.020)	(0.020)	(0.021)	(0.13)	(0.19)	(0.18)	(0.19)
Observations	1073	1073	1042	1039	1073	1073	1042	1039
First-stage K-P F-statistic					27	16	17	17
Baseline mean	0.92	0.92	0.91	0.91	0.92	0.92	0.91	0.91
D: Doctor gave a specialist referral (Stockholm only)								
Consultation was online	-0.092	-0.093	-0.093	-0.096	-0.035	-0.016	-0.0037	-0.018
	(0.010)	(0.010)	(0.011)	(0.011)	(0.057)	(0.068)	(0.069)	(0.068)
Observations	2419	2419	2336	2327	2419	2419	2336	2327
First-stage K-P F-statistic					82	60	58	64
Baseline mean	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
E: Patient satisfaction score (5 is best)								
Consultation was online	-0.012	-0.022	-0.023	-0.038	-0.074	-0.21	-0.21	-0.23
	(0.042)	(0.044)	(0.046)	(0.049)	(0.26)	(0.32)	(0.34)	(0.33)
Observations	1466	1466	1430	1424	1466	1466	1430	1424
First-stage K-P F-statistic					53	34	29	31
Baseline mean	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7

Note: This table reports coefficients from regressions using the doctor sample (see text for discussion). The instrument in the IV specifications is the propensity to online π_i. For a description of the variables, please see the main text and appendix. The baseline mean is the mean of the dependent variable for in-person doctor consultations. The First-stage K-P F-statistic is the Kleibergen-Paap F-statistic. Robust standard errors are in parentheses.

Table 4. Patient outcomes in the 30 days after the doctor consultation

	OLS				IV			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
A: Avoidable hospitalizations within 30 days								
Consultation was online	-0.00011	-0.00016	-0.00030	-0.00040	0.0021	0.0020	0.0018	0.0023
	(0.0011)	(0.0010)	(0.0011)	(0.0011)	(0.0035)	(0.0054)	(0.0059)	(0.0055)
Fixed Effects		✓	✓	✓		✓	✓	✓
Demographics			✓	✓			✓	✓
Any comorbidity			✓	✓			✓	✓
Nurse-set ICD group				✓				✓
Observations	4004	4004	3895	3882	4004	4004	3895	3882
First-stage K-P F-statistic					148	102	95	90
Baseline mean	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
B: Any hospitalization within 30 days								
Consultation was online	0.0024	0.0024	0.0022	0.0022	0.035	0.040	0.044	0.046
	(0.0031)	(0.0030)	(0.0032)	(0.0033)	(0.018)	(0.021)	(0.023)	(0.024)
Fixed Effects		✓	✓	✓		✓	✓	✓
Demographics			✓	✓			✓	✓
Any comorbidity			✓	✓			✓	✓
Nurse-set ICD group				✓				✓
Observations	4004	4004	3895	3882	4004	4004	3895	3882
First-stage K-P F-statistic					148	102	95	90
Baseline mean	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008
C: Any Emergency Department visit within 30 days								
Consultation was online	0.017	0.014	0.014	0.016	0.12	0.11	0.13	0.13
	(0.0070)	(0.0070)	(0.0072)	(0.0078)	(0.044)	(0.054)	(0.057)	(0.059)
Fixed Effects		✓	✓	✓		✓	✓	✓
Demographics			✓	✓			✓	✓
Any comorbidity			✓	✓			✓	✓
Nurse-set ICD group				✓				✓
Observations	4004	4004	3895	3882	4004	4004	3895	3882
First-stage K-P F-statistic					148	102	95	90
Baseline mean	0.040	0.040	0.041	0.041	0.040	0.040	0.041	0.041
D: New visit to primary care provider within 30 days								
Consultation was online	0.081	0.085	0.091	0.097	0.13	0.21	0.24	0.26
	(0.016)	(0.016)	(0.016)	(0.017)	(0.089)	(0.11)	(0.11)	(0.11)
Fixed Effects		✓	✓	✓		✓	✓	✓
Demographics			✓	✓			✓	✓
Any comorbidity			✓	✓			✓	✓
Nurse-set ICD group				✓				✓
Observations	4004	4004	3895	3882	4004	4004	3895	3882
First-stage K-P F-statistic					148	102	95	90
Baseline mean	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37

Note: This table reports coefficients from regressions using the doctor sample (see text for discussion). The instrument in the IV specifications is the propensity to online π_i. For a description of the variables, please see the main text and appendix. There are 37 hospitalizations, 5 avoidable hospitalizations, and 189 Emergency Department visits after the doctor consultation. The baseline mean is the mean of the dependent variable for in-person doctor consultations. The First-stage K-P F-statistic is the Kleibergen-Paap F-statistic. Robust standard errors are in parentheses.

Table 5. Doctor consultations per hour

	Shift incl. all breaks			Shift excl. all breaks		
	(1)	(2)	(3)	(4)	(5)	(6)
Shift was online	1.88	1.94	1.68	2.34	2.47	2.00
	(0.078)	(0.078)	(0.12)	(0.084)	(0.084)	(0.15)
Time fixed effects		✓	✓		✓	✓
Doctor fixed effects			✓			✓
Observations	78413	78413	78413	78413	78413	78413
Baseline mean	1.81	1.81	1.81	2.88	2.88	2.88

Note: This table reports coefficients from regressions using the doctor shift sample. This sample consists of registered and non-registered patient meetings (excluding prescription renewals, tests ordered, psychologist consultations and nurse meetings) collapsed to doctor*day level. A shift starts with the start of the first consultation and ends with the end of the last consultation. Breaks are times in between the consultations. For the construction of the shift variables, please see the Appendix Section A.7.2. Time fixed effects include Year*Month and day of the week fixed effects. The baseline mean is the mean of the dependent variable for in-person doctor shifts. Robust standard errors are in parentheses.

Table 6. Patient answer to whether the online consultation was a replacement to in-person, for larger sample

Has a comorbidity	-0.004					-0.003
	(0.0008)					(0.0008)
In employment (ages 16-74)		0.02				
		(0.001)				
Age 10-19			-0.004			0.0007
			(0.0010)			(0.001)
Age 20-29			-0.004			0.004
			(0.0009)			(0.002)
Age 30-39			-0.002			0.009
			(0.0009)			(0.002)
Age 40-49			-0.003			0.007
			(0.001)			(0.002)
Age 50-59			-0.01			-0.0002
			(0.002)			(0.002)
Age 60-69			-0.02			-0.01
			(0.003)			(0.003)
Age 70-79			-0.04			-0.03
			(0.006)			(0.006)
Age 80+			-0.07			-0.07
			(0.02)			(0.02)
In education				-0.0002		0.002
				(0.0008)		(0.002)
Primary school education				-0.01		-0.008
				(0.001)		(0.001)
Short high-school				-0.02		-0.01
				(0.002)		(0.002)
University (less than 3 years)				-0.004		-0.003
				(0.001)		(0.001)
University (3 years or more)				-0.005		-0.005
				(0.001)		(0.001)
Second gen. immigrant					-0.01	-0.01
					(0.001)	(0.001)
Immigrant (EU15/Scandi.)					-0.01	-0.009
					(0.002)	(0.002)
Immigrant (non-EU15/Scandi.)					-0.03	-0.03
					(0.001)	(0.001)
Observations	456498	262893	437297	434144	437023	433878
Baseline mean	0.95	0.95	0.95	0.95	0.95	0.95

Note: This table is based on a larger sample of only online doctor consultations (as the survey question was only asked in online consultations), consisting of patients who are not registered at one of the firm's in-person clinics, and who are directed straight to an online doctor (not a nurse) when requesting an appointment. It shows estimates of a survey, which asked patients whether the online consultation replaced an in-person consultation. Positive answers to the question are coded as 1, "Don't know" responses as 0.5, and negative responses as 0. Consultations related to Chlamydia or Covid-19 are dropped. The baseline for the age bins is children aged 0 - 9, and for the education variables, the baseline is high-school education. The baseline mean is the mean of the dependent variable for in-person doctor consultations. "Immigrant" refers to patients born outside the EU15 countries and Scandinavia. EU15 refers to the time back when the EU had only 15 members. Robust standard errors are in parentheses.

Table 7. Cost table for providers and patients (in SEK)

	In-person	Online	Table
A. Provider cost			
Cost of doctor consultation w/o in-person follow-up	2002	500	
Expected Follow-up cost of in-person primary care	140	661	Table A9, Panel B
Expected Follow-up cost of in-person ED	164	683	Table 4, Panel C
Total provider cost incl. follow-up cost times fraction of follow-ups	2306	1844	
B. Patient cost			
Co-pay/Patient fee in primary care (Average)	159	106	
Expected Patient-facing consultation time	156	46	Table 2, Panel C
Expected Waiting time for the doctor	145	74	
Expected Two-way commuting costs to the GP (Travel/Parking time/Fuel costs)	220	0	
Expected Parking fee (Primary care, during the day)	5	0	Table 2, Panel C
Expected Public transport fee (Single ticket, One-way)	7	0	
Patient cost without in-person follow-up	692	226	
Expected Follow-up cost of in-person primary care	48	228	Table A9, Panel B
Expected Follow-up cost of in-person ED	68	284	Table 4, Panel C
Total patient cost incl. follow-up cost times fraction of follow-ups	808	738	

Note: This table reports cost estimates in SEK (= 0.11 USD, average for 2020). The "Table" column indicates that the cost calculation used estimates from column 8 of a specific table. Follow-ups are either in-person revisits to primary care or Emergency Department (ED) visits, both within 30 days. The provider costs for follow-ups are weighted by the probability that the treatment happens. The sources and years for provider costs are listed in Appendix Table A12. For more information on the cost table, see Section A.7.3. The patient time cost estimates are the product of patient time spent in (or getting to and from) a consultation, multiplied by the mean hourly wage of white-collar workers in Sweden (290 SEK/hour in March 2023). The fee for paying patients is 225 SEK in-person (the mean of 250 SEK for Stockholm and 200 SEK for Scania) and 150 SEK online (the mean of 100 SEK for Stockholm and 200 SEK for Scania) in 2023. The fee per patient is multiplied by the fraction of paying patients (70.58% of our sample). The mean patient-facing consultation time for in-person PCP visits is 32.2 minutes; for online 9.5 minutes. The waiting time in the doctor's office for in-person is an educated guess of 30 minutes (Ekman 2018) and 15.31 minutes for online (based on our data). The commuting costs to a PCP include travel time weighted by transport/parking time both ways – to the doctor and back - multiplied by the average hourly wage. Transport includes commuting by car (incl. fuel costs), public transport (incl. ticket), biking and walking. We calculate the costs based on the probability of commuting type (Rosberg & Enström 2019). The average time to a PCP is 23.42 minutes two-way after including frequencies of commuting. We assume 5 minutes of parking/walking to the doctor's office before and after the consultation. For follow-ups, we multiply the costs by the probability that the follow-up occurs. The ED fees for Stockholm and Scania are 400 SEK for both and were multiplied by the fraction of paying patients. We assume that patients only drive by car to an ED. The commuting costs to an ED take the average travel time to an ED multiplied by the average hourly wage and include parking time and fuel costs. The mean travel time by car to an ED is 31.06 minutes two-way. The median stay time of a patient in an ED is 3.18 hours. The two-way commuting costs are around 420 SEK, and the ED time costs are 957 SEK.

Appendix tables and figures

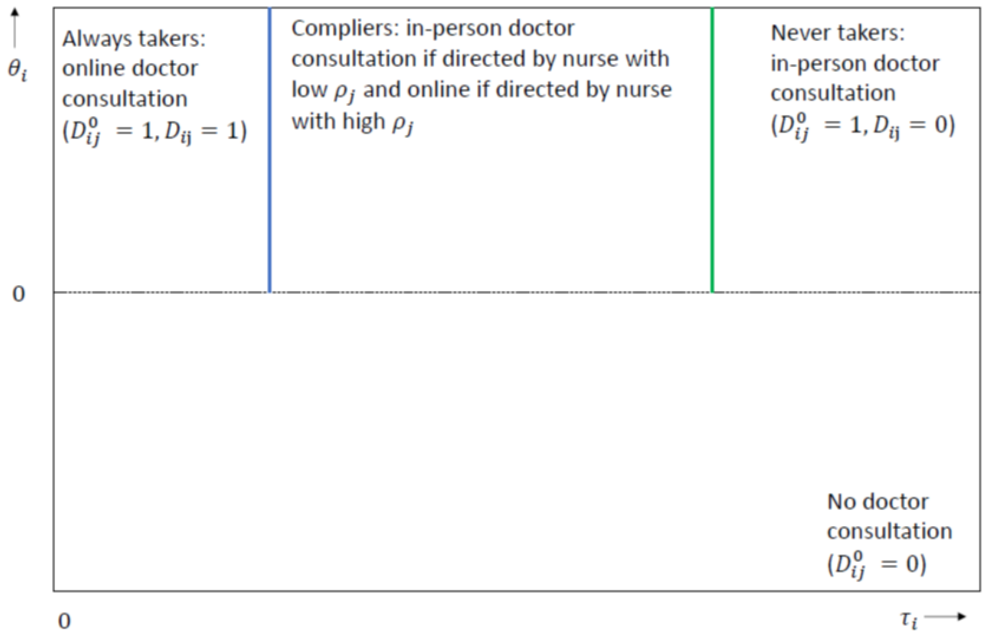
Table A1. Sample restrictions

	Directed in-person	Directed online	Not directed	Total
Cases (each is an episode where a patient is handled by an online nurse)	4460	50987	185674	241121
	(1.8)	(21.1)	(77.0)	(100.0)
+ Kept only cases with registered patients whose clinics are open	2993	2592	8535	14120
	(21.2)	(18.4)	(60.4)	(100.0)
+ Removed cases related to chlamydia, breastfeeding, or Covid-19	2945	2375	5112	10432
	(28.2)	(22.8)	(49.0)	(100.0)
+ Removed cases with infants	2931	2327	4957	10215
	(28.7)	(22.8)	(48.5)	(100.0)
+ Removed cases associated with clinics with very few observations	2924	2246	4773	9943
	(29.4)	(22.6)	(48.0)	(100.0)
+ Removed cases with nurses who have directed fewer than 20 patients to a doctor (nurse sample)	2670	1994	4243	8907
	(30.0)	(22.4)	(47.6)	(100.0)
+ Cases directed to a doctor (doctor sample)	2670	1994		4664
	(57.2)	(42.8)		(100.0)

Note: This table shows the number of cases (observations) as we impose our sample restrictions for our analysis sample. The columns show the different pathways of the case; if the nurse directs the patient, they can either be directed to an in-person or online consultation. In parentheses, we show the percentage split between the pathways. Each row in the table adds another restriction. The first row shows the total number of cases, defined as a care episode where an online nurse handles a patient. We first restrict to cases with patients registered at one of the primary care provider's in-person care clinics, where the clinic was open for consultations. This requirement ensures that patients have a greater than zero probability of being directed by the nurse to both an online or in-person doctor consultation. A clinic is defined as open for consultations based on when the first nurse directed a patient there for an in-person consultation. We then removed cases where the patient indicated that their symptom was related to chlamydia, breastfeeding, or Covid-19. This is because patients with these symptoms follow special care paths. For the same reason, we remove cases with children younger than one-year-old (see appendix). We also remove cases associated with clinics with very few observations. This leaves us with cases associated with four clinics in Stockholm and Lund. Lastly, we only consider cases where the nurse has had at least 20 cases after imposing the previous restrictions. With this restriction, we have defined what we call the "nurse sample". If we further focus only on cases the nurse directed to a doctor, we are left with 4664 cases (observations), which we call the "doctor sample".

Figure A1. Sorting of patients in model

(a) Without nurse mistakes



(b) With nurse mistakes

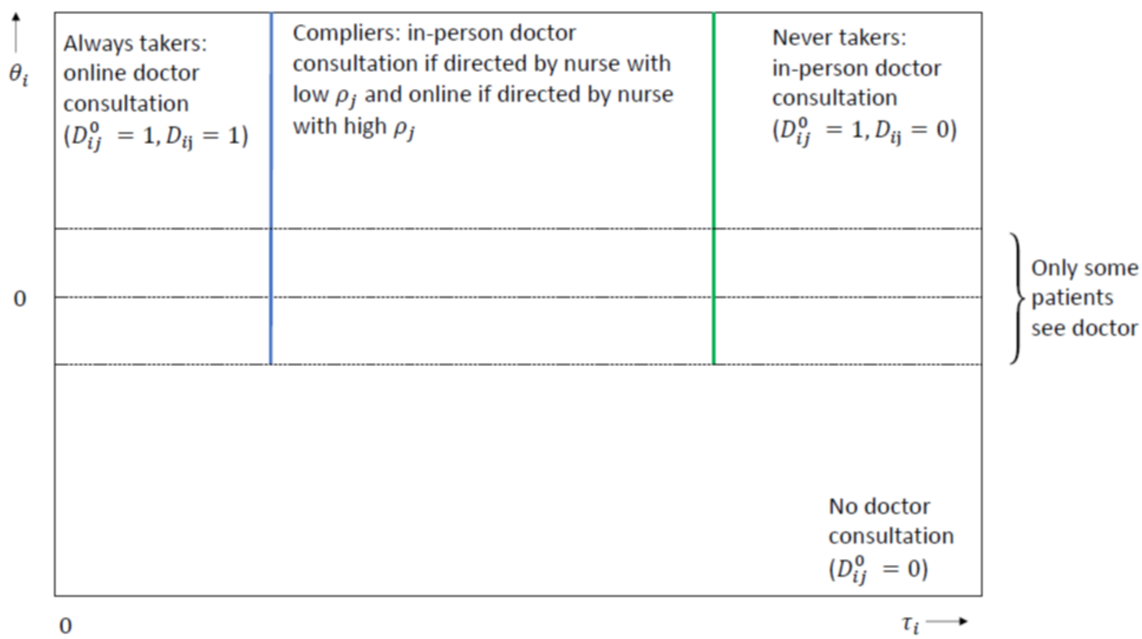
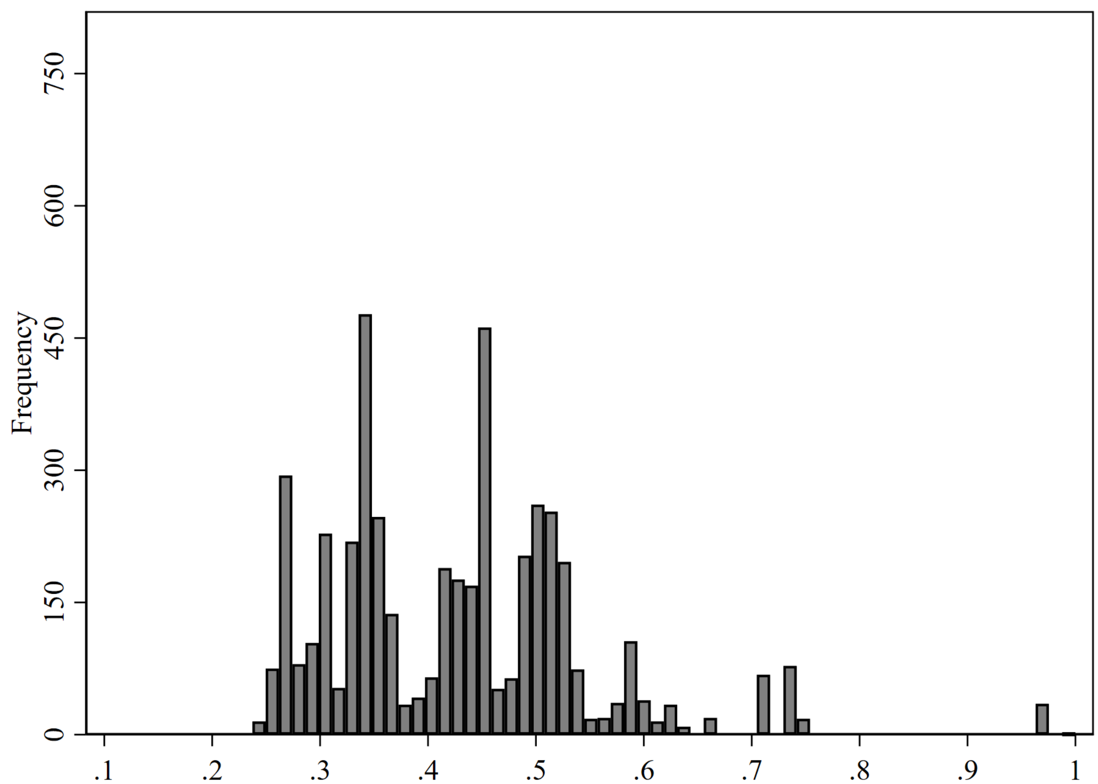


Figure A2. Distribution of the instrument



Note: This figure shows the distribution of the instrument π_i, the nurse's leave-one-out propensity to direct doctor consultations online, in the doctor sample.

Table A2. Sample patient representativeness of municipality and national population

	Doctor sample mean	Municipality mean	National mean
Female	0.49	0.50	0.50
Age	35.0	39.3	41.3
University education	0.58	0.49	0.39
Married	0.30	0.40	0.42
1st or 2nd generation immigrant	0.39	0.35	0.26
Big city municipality	0.85	0.85	0.32
Income	334.4	353.7	328.9

Note: This table compares patients in our sample to the full Swedish population. The "Sample mean" column reports unweighted means of the doctor sample observations (N=4664) for which each variable is defined. The "Municipality mean" takes municipality-level means in 2019 and averages them using the share of each of the 96 municipalities in the doctor sample as weights. The "National mean" is the mean for Sweden in 2019. "University education" is reported for people age 23 and above; "Married" is reported for people over the age of 18; "1st or 2nd generation Immigrant" is an indicator for people who were either born outside Sweden or whose parents were both born outside Sweden. "Big city municipality" is an indicator for municipalities with big cities, including Stockholm and Lund. "Income" includes annual earnings from wages and self-employment in thousands of SEK and is reported for people over the age of 20. More information can be found in section A.6.

Table A3. First Stage Results

LHS variable: Online consultation				
Nurse propensity for online referrals	0.78	0.70	0.69	0.66
	(0.055)	(0.058)	(0.059)	(0.058)
	[0.053]	[0.057]	[0.058]	[0.056]
Fixed Effects		✓	✓	✓
Demographics			✓	✓
Has a comorbidity			✓	✓
Nurse-set ICD group				✓
Observations	4664	4664	4531	4518
F-stat	198	145	138	133
Clustered F-stat	214	153	142	140
Baseline mean	0.43	0.43	0.43	0.43

Note: This table reports coefficients from regressions using the doctor sample. The F-statistic is the Kleibergen-Paap rk Wald F statistic. The baseline mean is the mean of the dependent variable for in-person doctor consultations. Robust standard errors are in parentheses and standard errors clustered by nurse are in brackets.

Table A4. Instrument independence

A. Balance of instrument on patient characteristics in nurses' sample

Demographics	✓	✓	✓	✓	✓	✓
Has a comorbidity			✓	✓	✓	✓
Nurse-set ICD group					✓	✓
Fixed Effects		✓		✓		✓
Joint test p-value	0.54	0.72	0.59	0.77	0.45	0.88
Observations	8639	8639	8639	8639	8609	8609

B: Balance of propensity to direct online on nurse propensity to direct to any doctor

Std. Propensity to direct to doctor	0.020	0.0088
	(0.024)	(0.020)
Weighted by num. meetings:	Redirected	Total
Observations	62	62
Baseline mean	0.43	0.43

C: Balance of instrument on patient characteristics in doctors' sample

Demographics	✓	✓	✓	✓	✓	✓
Has a comorbidity			✓	✓	✓	✓
Nurse-set ICD group					✓	✓
Fixed Effects		✓		✓		✓
Joint test p-value	0.38	0.32	0.46	0.39	0.16	0.25
Observations	4531	4531	4531	4531	4518	4518

Note: Panels A and B show instrument balance tests using the nurse and doctor samples. The p-values for the joint tests always control for the fixed effects when these are included (excluding time variables and center indicators. In Panel B, we collapse the nurse sample to the nurse level. The estimates in Panel B show the correlations between the nurses' propensity to direct patients to online doctor consultations with the propensity to redirect to any doctor (in-person or online). We present two different weighting schemes on the estimates: (1) The total number of meetings observed by the nurse, and (2) The total number of patients a nurse has redirected to a doctor. Both schemes are conditional on our sample restrictions. The baseline mean is the mean of the dependent variable for in-person doctor consultations. Robust standard errors are in parentheses.

Table A5. Average exclusion table

A. Nurse meetings are short (and shorter than doctor consultations)

		Quartiles			
	Mean	Q_{25}	Q_{50}	Q_{75}	Count
Nurse patient-facing time	4.7	2.5	4	6.1	4267
Doctor patient-facing time	20.0	4.2	12.6	30.1	4267

B. Nurse mistake share uncorrelated with instrument

Std. Nurse 'mistake' share	-0.012	-0.014
	(0.026)	(0.022)
Weighted by num. meetings:	Redirected	Total
Observations	62	62
Baseline mean	0.43	0.43

Note: This table is based on the nurse sample with a total of 62 nurses and shows tests of the average exclusion assumption. In Panel A, we show the large difference in meeting duration between doctor consultations and nurse meetings, measured in minutes. In Panel B, we collapse the sample to the doctor level. The estimates in Panel B show the correlations between the nurses' propensity to direct patients to online doctor's consultations with the nurse "mistake" share. We define a nurse mistake as an instance where the nurse did not refer a patient to a doctor consultation, but the patient appeared in the ED or was hospitalized within ten days of the nurse meeting. The mistake share is standardized. We present two different weighting schemes in Panel B: (1) The total number of meetings observed by the nurse (Total), and (2) The total number of patients a nurse has redirected to a doctor (Redirected). Both schemes are conditional on our sample restrictions. Robust standard errors are in parentheses

Table A6. Average Monotonicity

	Patient female	Patient male	Age $>$ median	Age $\leq$ median
Propensity for online	0.73	0.67	0.67	0.72
	(0.085)	(0.081)	(0.083)	(0.082)
Fixed Effects	✓	✓	✓	✓
Observations	2299	2365	2246	2418
First-stage K-P F-statistic	74	68	67	77
Baseline mean	0.45	0.40	0.42	0.43

	Uni. education	No Uni. education	Income $>$ median	Income $\leq$ median
Propensity for online	0.72	0.66	0.79	0.59
	(0.090)	(0.11)	(0.085)	(0.091)
Fixed Effects	✓	✓	✓	✓
Observations	1975	1421	2055	2057
First-stage K-P F-statistic	63	39	88	41
Baseline mean	0.39	0.45	0.40	0.43

	Immigrant (non-EU15/Scandi.)	All other	Any comorbidity	No comorbidities
Propensity for online	0.76	0.69	0.82	0.67
	(0.12)	(0.068)	(0.14)	(0.065)
Fixed Effects	✓	✓	✓	✓
Observations	1140	3523	908	3756
First-stage K-P F-statistic	43	103	37	109
Baseline mean	0.41	0.43	0.46	0.42

	"Other physical health issue"	Not "Other physical health issue"	Low covid periods	All other
Propensity for online	0.80	0.65	0.67	0.72
	(0.10)	(0.070)	(0.10)	(0.071)
Fixed Effects	✓	✓	✓	✓
Observations	1408	3256	2298	2366
First-stage K-P F-statistic	61	85	43	103
Baseline mean	0.42	0.43	0.41	0.45

Note: This table reports the first stage of our IV in different sub-samples. The median age in our sample is 33, while the median income is 287,300 SEK. We restrict university education to patients above or equal to 23 years old. "Immigrant" indicates that the patient was born outside the EU15 countries and Scandinavia. "Other physical health issue" is a label suggesting the patient should see an in-person doctor, given by the algorithm that takes patient symptoms as inputs. The baseline mean is the mean of the dependent variable for in-person doctor consultations. The First-stage K-P F-statistic is the Kleibergen-Paap F-statistic. Robust standard errors are in parentheses.

Table A7. In-consultation probability that patient scores the consultation

	OLS				IV			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Consultation was online	0.21	0.21	0.22	0.21	0.16	0.20	0.23	0.23
	(0.014)	(0.014)	(0.014)	(0.015)	(0.073)	(0.084)	(0.086)	(0.089)
Fixed Effects		✓	✓	✓		✓	✓	✓
Demographics			✓	✓			✓	✓
Any comorbidity			✓	✓			✓	✓
Nurse-set ICD group				✓				✓
Observations	4664	4664	4531	4518	4664	4664	4531	4518
First-stage K-P F-statistic					198	145	138	133
Baseline mean	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Note: This regression table is based on the doctor sample and shows the estimated probability that the patient answers the post-meeting survey to score the consultation based on the patient's satisfaction level. Each panel documents OLS and IV estimates with four different sets of controls each. The instrument of the IV specifications is the propensity to online π_i. For a description of the control variables we use, please see main text. The baseline mean is the mean of the dependent variable for in-person doctor consultations. The First-stage K-P F-statistic is the Kleibergen-Paap F-statistic. Robust standard errors are in parentheses.

Table A8. Patient outcomes in the 30 days after the nurse meeting

	OLS				IV			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
A: Avoidable hospitalizations within 30 days								
Consultation was online	-0.000091	-0.00014	-0.00029	-0.00039	0.0021	0.0019	0.0017	0.0022
	(0.0011)	(0.0010)	(0.0011)	(0.0011)	(0.0035)	(0.0052)	(0.0057)	(0.0053)
Fixed Effects		✓	✓	✓		✓	✓	✓
Demographics			✓	✓			✓	✓
Any comorbidity			✓	✓			✓	✓
Nurse-set ICD group				✓				✓
Observations	4050	4050	3941	3928	4050	4050	3941	3928
First-stage K-P F-statistic					147	104	97	92
Baseline mean	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
B: Any hospitalization within 30 days								
Consultation was online	0.0026	0.0024	0.0022	0.0020	0.032	0.034	0.037	0.039
	(0.0031)	(0.0030)	(0.0031)	(0.0033)	(0.018)	(0.021)	(0.022)	(0.023)
Fixed Effects		✓	✓	✓		✓	✓	✓
Demographics			✓	✓			✓	✓
Any comorbidity			✓	✓			✓	✓
Nurse-set ICD group				✓				✓
Observations	4050	4050	3941	3928	4050	4050	3941	3928
First-stage K-P F-statistic					147	104	97	92
Baseline mean	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008
C: Any Emergency Department visit within 30 days								
Consultation was online	0.013	0.0095	0.010	0.012	0.12	0.11	0.12	0.13
	(0.0070)	(0.0071)	(0.0073)	(0.0078)	(0.044)	(0.053)	(0.056)	(0.058)
Fixed Effects		✓	✓	✓		✓	✓	✓
Demographics			✓	✓			✓	✓
Any comorbidity			✓	✓			✓	✓
Nurse-set ICD group				✓				✓
Observations	4050	4050	3941	3928	4050	4050	3941	3928
First-stage K-P F-statistic					147	104	97	92
Baseline mean	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044

Note: This table reports coefficients from regressions using the doctor sample (see text for discussion). The instrument in the IV specifications is the propensity to online π_i. For a description of the variables, please see the main text and appendix. In Panels A and B, we show estimates of hospitalizations (i.e., when a patient was registered as an inpatient in a hospital). In Panel A, we restrict these hospitalizations to avoidable hospitalizations where the patient received a diagnosis that could have been handled by a primary care physician if caught earlier. In Panel C, we show estimates of emergency visits, which are outpatient hospital visits, i.e. Emergency Department (ED). There are 37 hospitalizations, 5 avoidable hospitalizations, and 199 ED visits after a nurse meeting. The baseline mean is the mean of the dependent variable for in-person doctor consultations. The First-stage K-P F-statistic is the Kleibergen-Paap F-statistic. Robust standard errors are in parentheses.

Table A9. Patient outcomes in primary care 30 days after doctor consultation

	OLS				IV			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
A: Doctor books a revisit within 30 days								
Consultation was online	0.10	0.10	0.10	0.11	0.17	0.22	0.23	0.24
	(0.012)	(0.012)	(0.013)	(0.013)	(0.069)	(0.082)	(0.085)	(0.088)
Fixed Effects		✓	✓	✓		✓	✓	✓
Demographics			✓	✓			✓	✓
Any comorbidity			✓	✓			✓	✓
Nurse-set ICD group				✓				✓
Observations	4004	4004	3895	3882	4004	4004	3895	3882
First-stage K-P F-statistic					148	102	95	90
Baseline mean	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
B: Doctor books an in-person revisit within 30 days								
Consultation was online	0.098	0.099	0.10	0.11	0.20	0.25	0.25	0.26
	(0.010)	(0.011)	(0.011)	(0.012)	(0.063)	(0.075)	(0.076)	(0.079)
Fixed Effects		✓	✓	✓		✓	✓	✓
Demographics			✓	✓			✓	✓
Any comorbidity			✓	✓			✓	✓
Nurse-set ICD group				✓				✓
Observations	4004	4004	3895	3882	4004	4004	3895	3882
First-stage K-P F-statistic					148	102	95	90
Baseline mean	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
C: Doctor books an online revisit within 30 days								
Consultation was online	0.0040	0.0025	0.0015	-0.0010	-0.031	-0.023	-0.018	-0.018
	(0.0065)	(0.0066)	(0.0068)	(0.0069)	(0.034)	(0.041)	(0.043)	(0.045)
Fixed Effects		✓	✓	✓		✓	✓	✓
Demographics			✓	✓			✓	✓
Any comorbidity			✓	✓			✓	✓
Nurse-set ICD group				✓				✓
Observations	4004	4004	3895	3882	4004	4004	3895	3882
First-stage K-P F-statistic					148	102	95	90
Baseline mean	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
D: Patient initiated follow-up visit								
Consultation was online	0.024	0.031	0.034	0.039	0.030	0.079	0.10	0.11
	(0.014)	(0.015)	(0.015)	(0.016)	(0.079)	(0.094)	(0.098)	(0.10)
Fixed Effects		✓	✓	✓		✓	✓	✓
Demographics			✓	✓			✓	✓
Any comorbidity			✓	✓			✓	✓
Nurse-set ICD group				✓				✓
Observations	4004	4004	3895	3882	4004	4004	3895	3882
First-stage K-P F-statistic					148	102	95	90
Baseline mean	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27

Note: This table reports coefficients from regressions using the doctor sample (see text for discussion). The instrument in the IV specifications is the propensity to online π_i. For a description of the variables, please see the main text and appendix. In Panels A, B, and C, we show estimates on whether the doctor booked a second meeting for the patient within 30 days. In Panels B and C, we also condition on the consultation format. Panel D shows estimates on whether the patient contacted the primary care provider to book another meeting within 30 days. The baseline mean is the mean of the dependent variable for in-person doctor consultations. The First-stage K-P F-statistic is the Kleibergen-Paap F-statistic. Robust standard errors are in parentheses.

Table A10. Medium-run results

	OLS				IV			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
A: Avoidable hospitalizations after at least 30 days								
Consultation was online	-0.00027	-0.00030	-0.00027	-0.00020	-0.0026	-0.0021	-0.0024	-0.0016
	(0.00085)	(0.00087)	(0.00090)	(0.0010)	(0.0041)	(0.0053)	(0.0056)	(0.0056)
Fixed Effects		✓	✓	✓		✓	✓	✓
Demographics			✓	✓			✓	✓
Any comorbidity			✓	✓			✓	✓
Nurse-set ICD group				✓				✓
Observations	4004	4004	3895	3882	4004	4004	3895	3882
First-stage K-P F-statistic					148	102	95	90
Baseline mean	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Mean days observed	111	111	111	111	111	111	111	111
B: Any hospitalization after at least 30 days								
Consultation was online	0.0022	-0.00030	0.0000011	-0.0019	0.029	-0.0055	-0.0053	-0.0090
	(0.0041)	(0.0042)	(0.0043)	(0.0043)	(0.028)	(0.035)	(0.037)	(0.038)
Fixed Effects		✓	✓	✓		✓	✓	✓
Demographics			✓	✓			✓	✓
Any comorbidity			✓	✓			✓	✓
Nurse-set ICD group				✓				✓
Observations	4004	4004	3895	3882	4004	4004	3895	3882
First-stage K-P F-statistic					148	102	95	90
Baseline mean	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016
Mean days observed	111	111	111	111	111	111	111	111
C: Any Emergency Department visit after at least 30 days								
Consultation was online	0.014	0.0074	0.010	0.0090	0.13	0.053	0.083	0.085
	(0.0073)	(0.0074)	(0.0076)	(0.0079)	(0.046)	(0.053)	(0.055)	(0.058)
Fixed Effects		✓	✓	✓		✓	✓	✓
Demographics			✓	✓			✓	✓
Any comorbidity			✓	✓			✓	✓
Nurse-set ICD group				✓				✓
Observations	4004	4004	3895	3882	4004	4004	3895	3882
First-stage K-P F-statistic					148	102	95	90
Baseline mean	0.048	0.048	0.046	0.046	0.048	0.048	0.046	0.046
Mean days observed	111	111	111	111	111	111	111	111
D: New visit to primary care provider after at least 30 days								
Consultation was online	-0.020	-0.035	-0.031	-0.029	0.23	0.010	0.044	0.047
	(0.016)	(0.015)	(0.015)	(0.016)	(0.091)	(0.096)	(0.099)	(0.10)
Fixed Effects		✓	✓	✓		✓	✓	✓
Demographics			✓	✓			✓	✓
Any comorbidity			✓	✓			✓	✓
Nurse-set ICD group				✓				✓
Observations	4004	4004	3895	3882	4004	4004	3895	3882
First-stage K-P F-statistic					148	102	95	90
Baseline mean	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Mean days observed	111	111	111	111	111	111	111	111

Note: This table reports coefficients from regressions using the doctor sample (see text for discussion). The instrument in the IV specifications is the propensity to online π_i. For a description of the variables, please see the main text and appendix. In Panels A and B, we show estimates of hospitalizations (i.e. when a patient was registered as an inpatient in a hospital). In Panel A, we restrict these hospitalizations to avoidable hospitalizations where the patient received a diagnosis that could have been handled by a primary care physician if caught earlier. In Panel C, we show estimates of emergency visits, which are outpatient hospital visits, i.e. Emergency Department. There are 66 hospitalizations in our sample, 3 avoidable hospitalizations, and 216 emergency visits. The baseline mean is the mean of the dependent variable for in-person doctor consultations. The First-stage K-P F-statistic is the Kleibergen-Paap F-statistic. Robust standard errors are in parentheses.

Table A11. Comparison of nurse-triaged patients sent to online doctors (in our sample) to sample of patients who went straight to online doctors without nurse triage

	OLS				
	(1)	(2)	(3)	(4)	(5)
A: Any in-person visit within 30 days					
Consultation is in online doctor sample	0.083	0.16	0.15	0.19	0.14
	(0.0093)	(0.016)	(0.015)	(0.033)	(0.019)
Fixed Effects		✓	✓	✓	✓
Demographics			✓	✓	✓
Any comorbidity			✓	✓	✓
ICD code				✓	
Symptom ID					✓
Observations	22096	22096	21556	21476	21306
Dep. var mean	0.089	0.089	0.088	0.088	0.088
B: Any Emergency Department visit within 30 days					
Consultation is in online doctor sample	0.0066	0.025	0.025	0.038	0.019
	(0.0058)	(0.016)	(0.016)	(0.024)	(0.018)
Fixed Effects		✓	✓	✓	✓
Demographics			✓	✓	✓
Any comorbidity			✓	✓	✓
ICD code				✓	
Symptom ID					✓
Observations	22100	22100	21560	21480	21310
Dep. var mean	0.051	0.051	0.051	0.051	0.051
C: Any hospitalization within 30 days					
Consultation is in online doctor sample	-0.000051	-0.0042	-0.0048	-0.0076	-0.0071
	(0.0026)	(0.0093)	(0.0096)	(0.012)	(0.010)
Fixed Effects		✓	✓	✓	✓
Demographics			✓	✓	✓
Any comorbidity			✓	✓	✓
ICD code				✓	
Symptom ID					✓
Observations	22100	22100	21560	21480	21310
Dep. var mean	0.011	0.011	0.011	0.011	0.011

Note: This table shows descriptive OLS regressions based on the online doctor sample and the restricted drop-in sample. The comparison is between nurse-triaged online doctor patients to patients who went straight to online doctors. Both samples have the same restrictions in place as described for the doctor sample. The controls for the online doctor sample are based on the nurse meeting and for the restricted drop-in sample on the doctor consultation. Fixed effects include Year*Month, 4 hour blocks, day of the week and where the patient was listed. Demographics include age, immigrant background, civil status and work status. The ICD-10 code for the online drop-in sample is based on the nurse meeting, while the ICD-10 code for the restricted drop-in sample originates from the doctor consultation.

Table A12. Provider cost sources

	Provider cost estimates	**How cost is calculated**	**Year**	**Source**
PCP online	500 SEK	Out-of-region compensation recommendation for digital care services	2019/2020	Vård- och omsorgsanalys (2022)
PCP in-person	(1838+2166)*0.5 = 2002 SEK	Average cost of 2019/2020 (National estimates)	2019/2020	Vård- och omsorgsanalys (2022)
ED visit	(3963+4020)*0.5 = 3991.5 SEK	Average cost of 2019/2020 (Southern Sweden)	2019/2020	Södra Regionsvårdsnämnden (2020)

Note: This table reports provider costs based on the years 2019 and 2020 and adds background information to the cost table (Table 7). The PCP online provider costs from 2019 were extracted from the report of Vård- och omsorgsanalys (2022, p. 127) and for 2020 (Södra Regionsvårdsnämnden 2020, p. 91). The PCP in-person provider costs can be found in the same report for 2019 (Vård- och omsorgsanalys 2022, p. 201) and 2020 (Vård- och omsorgsanalys 2022, p. 202), which together make up the average PCP in-person cost. The in-person provider costs are estimated, as there are no fixed total fees and reimbursement is through a mix of capitation and some fee for service. The ED provider costs are based on Southern Sweden for 2019 (Södra Regionsvårdsnämnden 2019, p. 47) and for 2020 (Södra Regionsvårdsnämnden 2020, p. 47), which also together make up the average ED cost. See Section A.7.3 for more information and sources regarding the cost table.

Table A13. Variable descriptions

Variable	Description
Total consultation time, minutes	Provided by primary care provider data
Patient-facing consultation time, minutes	Provided by primary care provider data
Administrative consultation time, minutes	Total consultation time − Patient-facing consultation time
Days between meetings	Number of calendar days between Nurse meeting and doctor consultation
Doctor set an informative diagnosis	ICD-10 code not in "R" (Symptoms such as cough or rash) or "Z" (Health status factors) categories.
Patient received a prescription	Provided by primary care provider data
Patient collected prescription within 30 days	Patient is observed in the prescription data picking up a prescription we tied to the primary care meeting (see Section A.1.4 for details).
Doctor makes a specialist referral	The doctor consultation resulted in a specialist referral. Due to differences across regions, this outcome was only possible in Stockholm.
Patient score, 1-5	The patient's score on a 1-5 scale of the meeting asked in a voluntary post-consultation survey. The best score is 5.
Avoidable hospitalizations within 30 days	We observe the patient in an in-patient hospitalization (they are in a ward for observation or treatment) within 30 days of the doctor's consultation where the ICD-10 code set at the hospital is from a list of ICD-10 codes known (see Section A.7.5) to have been preventable in primary care.
Any hospitalization within 30 days	We observe the patient in an in-patient hospitalization within 30 days of the doctor's consultation.
Any Emergency Department (ED) visit within 30 days	We observe the patient in an out-patient emergency department visit within 30 days of the doctor's consultation.
New visit to primary care provider within 30 days	We observe the patient in a second doctor consultation within the primary care provider company within 30 days of the doctor's consultation. We restrict to actual doctor consultations, so we do not include meetings with nurses, psychologists, or prescription renewals or ordered tests.
Replacement for in-person answer	The patients' response to a post-online consultation survey asking the patients whether the online consultation replaced an in-person consultation. Positive answers to the question are coded as 1, "Don't know" responses as 0.5, and negative responses as 0.
Doctor books a revisit within 30 days	We matched the doctor's consultation to a doctor-booked revisit meeting within 30 days, which means that the second consultation is likely a follow-up from the first. See Section A.2 for details on the matching.

Table A13. Variable descriptions (continued)

Variable	Description
Shift (start to end with breaks), hours	Doctor online or in-person shift in hours. The start of shift is the start of the first consultation and end of shift is the end time of the last consultation. All breaks have been included. Consultations that extended beyond than midnight have also been removed. See Section A.7.2 for details on the definitions of shifts.
Shift (start to end without breaks), hours	Doctor online or in-person shift in hours. The start of shift is the start of the first consultation and end of shift is the end time of the last consultation. All breaks have been removed. Consultations that extended beyond than midnight have also been removed. See Section A.7.2 for details on the definitions of shifts.
(In FE) Time of day indicators	Indicators for four-hour time clocks: 12am-4am; 4-8am; 8am-12pm; 12pm-4pm; 4pm-8pm; 8pm-12am.
(In FE) Day of the week indicators	Indicators for days of the week: Monday, Tuesday, ...
(In FE) Provider center	Indicators for each of the four provider centers.
(In FE) Year*Month indicators	Indicators for particular months, e.g. September 2019.
(In Demographics) Age	The age of the patient in 2018.
(In Demographics) Indicator for foreign born	Patient is a first-generation immigrant, that is, the patient was born outside of Sweden.
(In Demographics) Indicator for second-generation immigrant	Patient is a second-generation immigrant born in Sweden, but both their parents were born outside Sweden.
(In Demographics) Indicator for born outside EU15 and Scandinavia	The patient was born outside the EU15 countries and Scandinavia.
(In Demographics) Indicators for married and divorced	Indicators for two variables on the patients' marriage status in 2018. Children have a separate category for each variable.
(In Demographics) Employed	An indicator for the patient being employed in 2018. This only applies if the patient is between 16 and 74; the remaining patients receive their own category.
Any comorbidity	An indicator for whether the patient had any co-morbidity from 2013-2017, based on the Elixhauser co-morbidity index (see Section A.7.1) and outpatient data.
ICD group	The letter level category of the ICD-10 code set by the nurse who redirected the patient to the doctor consultation in our primary sample (doctor sample).

A Data appendix

A.1 Data sources

Our analysis is primarily based on consultation-level data from the start of 2019 to the end of 2020 from a Swedish private primary healthcare provider offering both in-person and online medical consultations on the primary care level. For all individuals observed as patients in this consultation level data, who will be referred to as patients from now on, we have administrative individual-level panel data from Statistics Sweden's Integrated Database for Labour Market Research (LISA) from 2013 - 2020. Furthermore, for all patients, we have healthcare panel data on the visit level, on all other care than primary care (e.g., a hospital stay or specialist visit), from 2013 - 2020. The specialist care data includes inpatient and outpatient care data and is provided by the National Board of Health and Welfare (NBHW/Socialstyrelsen). Finally, for all patients, we have prescription data on the drug level, i.e., each prescribed drug makes an observation line over 2013-2020, again provided by Socialstyrelsen. This prescription data includes both primary care and other levels of care, i.e. prescriptions from all healthcare that are collected at the pharmacy by patients.

We note that all datasets are proprietary and confidential and were accessed after applications to the Stockholm Regional Ethics Council (2018, number 2108/2318-31 and later the Swedish Ethics Authority (2019, number 2019-06062) had been approved. Additionally, Statistics Sweden and the other entities carried out their own confidentiality assessments before approving the sharing of data. Statistics Sweden matched all datasets, and then anonymized the personal identifiers and then shared only an anonymized version of the data.

A.1.1 Primary care provider data

The consultation level data from 2019 to 2020 from a large private Swedish primary care provider provides the backbone for our analysis. The primary care provider started in 2016 as a digital-only healthcare provider. However, since 2019, it has extended its offering to include in-person doctors' consultations. In-person services were rolled out at different times for different locations, with services first offered in Lund (a city in the Scania region) and then expanded to different areas in and around Stockholm. The observed opening date is the date of the first logged in-person doctors consultation at the clinic.

For each consultation, we have data on when it occurred (minute precision), the form it took, if it was in-person or online, and the fee the patient paid. Any patient in the country can use the firm's online care. To receive in-person primary care, Swedish citizens need to register with some primary care provider (public or private, where the private ones have contracts with the public health insurance and cost the same to patients) and can change at will without any fee. For all patients registered with the healthcare firm's in-person clinics, we know which clinic they were registered with. Therefore, for patients registered with the healthcare firm, we have information about the location of the in-person consultations.

Moreover, we have data on the duration of the consultation, including a breakdown of the patient's and clinician's consultation duration, where the latter also encompasses administrative work related to the consultation. We also have data on the provider's internal code for the symptom the patient provides when seeking care through the provider's mobile app. The providers' mobile app is the primary channel for seeking care and the only one relevant to our study. In the app, the patients start by filling in what symptoms they are seeking care for before having a consultation. Finally, we also know the consultations "type"; this is an internal categorization of consultations depending on whom the patient met (e.g., "nurse meeting" or "psychology meeting"), whether it was booked ahead of time (e.g., "drop-in" or "doctor booked revisit"), or the purpose (e.g., "prescription renewal" or "test ordered"). We are primarily concerned with a sequence of consultations starting with a "nurse meeting" and resulting in a "doctor booked revisit" (booked by the nurse); see section A.2 for more details.

Regarding the outcome of the consultation, we have data on the clinician's diagnosis and whether the patient was prescribed anything. The patient diagnosis is in the form of an ICD-10-SE code with 4-5 characters of precision. We do not have data from the provider on what was prescribed. However, we have prescription data from the prescription registry from the National Board of Health and Welfare to fill in the gap. We also have information on whether the doctor referred the patient to a specialist for the Stockholm-based clinics.

For the clinicians and patients, we know their age and gender; however, with a very high share of missing values for the clinicians. Furthermore, for the clinicians, we know their specialization and their seniority level.

A.1.2 Demographic and socioeconomic data

To complement the primary care data, we have demographic and socioeconomic micro-data on patients from Statistics Sweden drawn from the Integrated Database for Labour Market Research (LISA). This panel data provides information on individual income, educational attainment, municipality, immigration background, and marriage status. The variables are provided at the patient level, with yearly measurements. The income measurement is a summation for the year, the education attainment is measured at the end of the year's spring semester, immigration background is constant, and municipality and marriage status are measured either 31st of December or the 1st of January of the year after. Therefore we exclusively use the 2018 values for the demographic and socioeconomic controls employed throughout the paper. This decision ensures that all control variables were measured before or at the start of our sample (which is on the 1st of January 2019). An exception is where we do not use the demographic and socioeconomic variables as controls, but rather for a representativeness comparison in Table A2. Then, we use the 2019 values for both our sample and the municipality and nationwide public data, to ensure the values are comparable and reflective of the time when they sought care (in 2019 or 2020).

A.1.3 Specialist care data

The National Board of Health and Welfare (NBHW / Socialstyrelsen) provided the non-primary care data. This data, covering 2013-2020, may be divided into inpatient and outpatient care data. Inpatient care means that the patient is admitted to the hospital, i.e. hospitalized. Outpatient care includes emergency department visits and other non-primary care visits to clinics, e.g., planned specialist consultations. The inpatient and outpatient data sets contain up to 30 ICD-10 diagnostic codes with a precision of three characters. The datasets also include external cause codes for applicable cases, classifying events such as falls and bites. Both datasets provide the visit date (and discharge date for inpatient visits). The outpatient data also includes the exact admission time, assessment time, and discharge time for emergency visits.

A.1.4 Prescription data

The prescription data was also provided by the NBHW (Socialstyrelsen). This data encompasses all prescriptions patients picked up between 2013 and 2020. Each distinct drug picked up takes up an observation line, so a single trip to the pharmacy may be represented by multiple observations. We know the date of when the drugs were picked up, but not whether they were picked up at the same pharmacy or during the same visit to the pharmacy. The data includes some information about the prescriber. We have anonymized codes for the prescribing clinic and the type of care it was prescribed from, such as psychiatric, primary care, or paediatric. We also know the specialization of the prescribing clinician.

Furthermore, we have information on the drugs picked up. For each drug, we have data on its Anatomical Therapeutic Chemical (ATC) code. We also know the number of pills in the packages prescribed, the number of packages prescribed, and the intended number of daily doses of each package. Finally, we have data on the cost of the picked-up prescription to the patient and the region (the public insurer).

A.2 Matching between nurse meetings and doctor consultations

We start with the doctor visits which are labeled as booked by someone in the firm; these are consultations with doctors which had some preceding (originating) meeting with someone at the firm (online or in person). This originating meeting can be of any type, e.g., nurse meetings, drop-ins, or psychologist visits. To find the originating meeting, we search in a time window of 30 days before the doctor consultation.

Then we utilize two strategies to find this initial meeting. The first strategy is to match the doctor consultation with a preceding meeting with the same symptom, as specified by the patient when seeking care. This label usually follows automatically in a care episode with multiple visits. Sometimes, the symptom is changed in a later visit to "revisit" or "phone triage". The second strategy is developed to deal with these cases. In these cases, we allow the doctor-booked revisit to match the closest preceding meeting with the healthcare firm within the 30-day window.

This approach allows for multiple potential matches, and three conflicts may arise. First, a doctor consultation may match with more than one potential originating meeting in the first strategy. To resolve these, we prioritize matches in which the window between the doctor-booked revisit and the originating meeting is as short as possible. Second, two different doctor consultations may match with the same preceding meeting. These conflicts are resolved in favor of earlier doctor-booked revisits over later ones. This rule ensures that matched meetings flow nicely into each other chronologically.

A.3 Defining samples

A.3.1 Doctor sample and nurse sample

We document how our two primary samples are created in Appendix Table A1. Our analysis focuses on patient cases from 2019 to 2020, starting with a nurse meeting. These cases number 241,121, as seen from the first row of Appendix Table A1. We define a “case” as an online meeting between patient i and nurse j and its resulting “treatment” (either an online or in-person doctor consultation or no consultation).

In Appendix Table A1, we implicitly exclude visits with the provider that do not fit the “case” definition. Most of the excluded visits are those where the patient, when seeking care, is matched directly to a doctor. The other excluded visits are visits categorized by the provider as pertaining to a different care path. Explicitly, these are visits to a psychologist; prescription renewal visits; visits where the patient was given an automatic recommendation by the system for a pediatrician or a doctor speaking some language, or for a revisit; also consultations where the patient booked a time with a doctor of their choice; consultations where patients chose a time instead of the next available; and visits for ordered tests.

Appendix Table A1 then shows how we go from the set of all cases to the nurse and doctors' samples we use for our analysis. We impose five conditions on the cases; the first three ensure that the patient is "at risk" for an in-person consultation. The first of these three conditions removes patients who cannot access in-person care within this provider, i.e., they are not registered with this firm as their primary care provider. Or they are marked as registered, but at a clinic where, at the time, there have not yet been any in-person consultations.[34] The other two remove patients with symptoms (chlamydia, breastfeeding issues, and Covid-19) as well as infants. These patients follow care pathways differing from those outlined in Figure 1. Chlamydia cases are sent a home test, breastfeeding cases are directed to a breastfeeding consultant rather than a doctor, and covid cases had their own pathways, which changed during the pandemic due to changing availability of testing and changing guidelines. The final two conditions on the set of cases are imposed to limit our sample to cases where we have sufficient statistical power. We refer to the 8,907 resulting cases handled by 62 nurses as the "Nurse meeting sample" in 1 (or "Nurse sample" in brief).

Finally, on the last row in Appendix Table A1, we impose that the case results in either an in-person or online doctor consultation to obtain our primary analysis sample. This leaves us with 4,664 cases, referred to as the "Doctor consultation sample" in Figure 1 (or "Doctor sample" in brief).

There is a further implicit restriction in the last two rows of Appendix Table A1. As we explained in Appendix Section A.2, we have estimated the matching between the nurse meeting and the eventual doctor consultation the nurse directs the patient to. So, in the last two rows of Appendix Table A1, we also demand that the case is one of those we have successfully matched.

A.3.2 Doctor shift sample

To study doctor productivity in-person and online in Table 5, we define a larger sample. This sample refers to unregistered and registered patients who had a doctor consultation, both in person and online. The reason why we need to create this larger sample is that doctors work both with the patients in our smaller analysis samples (defined above) and with patients outside of that sample during a given day, so to study their productivity we need to include other patients that they saw in a day. We study only doctors here, so we exclude meetings done by other professions such as nurses. We exclude prescription renewals and ordering tests since they do not have a start time or an end time, but rather these are things that doctors do in their administrative time or break time. We also removed consultations without any duration time, consultations that end after midnight (since we

[34] In practice, this means throwing out all cases directed to an online consultation with patients registered at a clinic before the first one directed to an in-person consultation.

use 24-hour periods of calendar days), and all consultations on the same day a doctor had mixed work (both in-person and online consultations). Ultimately, the doctor shift sample consists of 1,269,163 individual consultations, which were then collapsed to the shift level per doctor and day. The most basic approach for creating a shift is to take the start time of the first consultations and the end time of the last consultations of a doctor within 24 hours in a calendar day. More on the creation of shifts can be found in Appendix Section A.7.2. There are 2046 in-person doctor shifts and 76367 online doctor shifts in our doctor shift sample based on 731 doctors.

A.4 Creating our instrument

After applying our primary sample restrictions, we define the instrument as nurse j's propensity to direct online, leaving out patient i's meeting:

$$\pi_i \equiv \frac{\sum_{i' \in I_j; i' \neq i} D_{i'j}}{\sum_{i' \in I_j; i' \neq i} D^0_{i'j}} \tag{5}$$

We also use our instrument in the nurse sample for Appendix Table A4. We define the instrument differently there since not all nurse meetings lead to a doctor's consultation. We define it in two ways depending on whether the meeting was redirected to a doctor. Like in the doctor sample, the redirected meetings are defined with the leave-own-out propensity. The meetings that are not redirected are given the value of the non-leave-own-out nurse's propensity to redirect to an online consultation among the redirected meetings.

A.5 Matching prescription data

As noted in Section A.1.4, we need to create a match between the Prescription Registry from the NBHW (where we observe prescriptions that the patient has collected from the pharmacy, to measure adherence) and the instances where we observe that there has been a prescription in the primary care provider data. As noted in Section A.1.4 we have data on all the prescriptions the patient picked up and the prescriber type. The prescriber type could be for instance primary care, school healthcare, elder care, the ED, palliative care, or various other categories. There is also a category called "other" care. We know whether or not the doctor made a prescription for the consultations in our sample. To match a patient-collected prescription (i.e. from the Prescription Registry) with a doctor's prescription in our data, we employed a simple rule. We associated each doctor consultation in our sample that resulted in a prescription with the first prescription in the Prescription Regsitry classified as "primary care" or "other", that was observed within 30 days after the doctor's consultation.

A.6 Sample patient representativeness of municipality and national population

Appendix Table A2 compares sample patients to the municipality and national populations. I.e. patients in the sample are compared to inhabitants (not primary care patients) nationally, as there is no nationwide data on primary care patients. The table consists of three columns with the mean for three different samples. The first column called "Sample mean" is based on the doctor sample, which consists of 4664 patients that had a nurse meeting and were directed to a doctor. The variables for the doctor sample are based on the year 2019. The "Municipality mean" column takes the same patient observations, but links public data on the municipality level from 2019 to compare patients to their municipality mean. As only 96 of the 290 municipalities in Sweden are represented in the sample, we weight the municipality mean by the frequency of patients in the municipalities. Patients in the doctor sample come primarily from municipalities located in the regions of Stockholm and Scania. The "National mean" column is independent of the other columns and shows the mean of all inhabitants in Sweden based on public data from 2019.

The public data for the municipality and national mean mainly comes from the Swedish government agency Statistics Sweden, also called SCB (2023). The "Municipality mean" column takes the weighted overall mean over the mean of each municipality. If not otherwise specified, the number of observations in a category have been divided by the total municipality population to obtain the municipality mean. For "Female", population data divided into in one year intervals for the ages 0 to 100+ has been downloaded and summed up for each municipality. The data for "Age" includes the age mean of each municipality for the overall population. This variable already reports the mean age for each municipality and does not need to be divided by the municipality population to obtain the municipality mean. For "University education", data in one year intervals for the ages 16 to 95+ has been downloaded. We took three categories of education levels that indicated education past secondary education: Post-secondary education less than 3 years, post-secondary education 3 years or more and post-graduate. Our variable added the amount of people that were in these three categories together and limited them to 23 years of age or older for each municipality. To obtain the municipality mean for university education, we divided this generalized post-secondary education variable by the municipality population above or equal to 23. The variable "Married" is based on data that has four categories for every age: Unmarried, married, divorced and widowed. The "Municipality mean" column shows the mean for those included in the category married divided by the population above 18 years old as it's only legal to marry in Sweden after turning 18. For "Immigrant background", the data is presented in five-year intervals from the age of 0 to 95+. Immigrant background is defined as if a person was born outside of Sweden or if both parents were born outside of Sweden. The data for "Income" takes information for everyone above 20 within three categories: Mean income in thousand SEK, median income in thousand SEK and total sum of income in million SEK. We focused on the mean income per municipality, which also includes salary and pension income from other Nordic countries. We did not have to divide by any specific municipality population as the reported income was already the mean income for everyone older than 20 years old. The only variable with another source than Statistics Sweden is "Big city municipality", which was downloaded from another government agency, Tillväxtverket (2021). This variable categorizes municipalities into three definitions: Rural municipalities, mixed municipalities and big city municipalities. The categorization was updated in 2021, which is the version we are using. A municipality is a big city municipality if at least 80% of the municipality live in densely populated areas and the municipality also shares a combined area with other municipalities with at least 500,000 inhabitants.

The "National mean" column takes the overall mean over all of Sweden and includes the same variable definitions as within the municipality mean. If not otherwise specified, the number of people in a category has been divided by the total population of Sweden to obtain the national mean. The total population of Sweden in 2019 was 10.32 million inhabitants. For "Female", the total female population of Sweden was divided by the total population of Sweden. The data for "Age" includes the age mean for the overall population. This variable already reports the mean age for Sweden and does not need to be divided by the total population to obtain the national mean. The variable "University education", includes the same three categories for post-secondary education as for the municipality mean and is limited to people above or equal to 23. It as also divided by the total population above 23 to obtain the mean. The same goes for the variable "Married" for the Swedish population above 18 years old. For "Immigrant background", the same definition applies that someone has an immigrant background if this person was born outside of Sweden or if both parents were born outside of Sweden. The variable "Income" is reported as the mean for everyone above or equal to 20. The indicator "Big city municipality" on the national level was created by linking municipality population sizes to each municipality and then collapsing the indicator to its mean with weights on the municipality population.

A.7 Construction of variables

A.7.1 Patient comorbidity

Throughout the paper, we often control for whether the patient has any comorbidity, which is an indicator for having at least one of a number of diagnoses in prior healthcare in national registries (not primary care, which does not exist in national registries). The diagnoses defined as comorbidities are taken from the Elixhauser comorbidity index. This index defines approximately 30 diagnoses in the patient's medical histories that the medical literature has found to be important comorbidities. We specifically study the patient's medical history during 2013-20oct2019 in specialist care (inpatient and outpatient care) medical records from the National Board of Health and Welfare. Specifically, we used the Stata command "elixhauser" written by Vicki Stagg, Dr. Robert Hilsden, and Dr. Hude Quan from the University of Calgary, Canada. The complete list of comorbidities is: cardiac arrhythmias; valvular disease; pulmonary circulation disorders; peripheral vascular disorders; hypertension, uncomplicated; paralysis; other neurological disorders; chronic pulmonary disease; diabetes, uncomplicated; diabetes, complicated; hypothyroidism; renal failure; liver disease; peptic ulcer disease excluding bleeding; AIDS/HIV; lymphoma; metastatic cancer; solid tumor without metastasis; rheumatoid arthritis/collagen vascular; coagulopathy; obesity; weight loss; fluid and electrolyte disorders; blood loss anemia; deficiency anemia; alcohol abuse; drug abuse; psychoses; depression; hypertension, complicated.

A.7.2 Creation of doctor shifts for productivity regressions

Table 5 about doctor productivity is based on the creation of doctor shifts, i.e. periods during a day when they work. The shift variables for the doctor shifts are based on the doctor shift sample (see Section A.3). The starting point for defining a shift is to start from the start time of the first consultation and end with the end time of the last consultations of a doctor within 24 hours in a calendar day. The time in between the patient consultations can be in- or excluded from the shift. The time in between the patient consultations varies, but positive times between the consultations have been termed as breaks. Breaks longer than one hour make up 1.63% of the sample. We do not know whether the times between the meetings are actually breaks, waiting times or if the doctor was not working at all. The first meeting of a doctor in a day has no duration time in between consultations because there was no previous meeting yet. Based on this approach, we define two type of shift variables and use them in Table 5. The first shift variable is just the start to the end time of a shift of a doctor with all the (positive) times in between the consultations still included. The second shift variable is the start to the end time of a shift of a doctor with all the (positive) times in between the consultations removed.

For both shift variables, prescription renewals or test orders have not been taken into account since they do not have a duration. Further, 8083 consultations without any duration time have been removed. The consultation duration time variable has been winsorized at the first percentile (2.58 minutes) to to avoid unrealistic small consultation duration times. Consultations that went past midnight have also been removed to be able to have some cutoff of shifts which we defined as the 24-hour period of a calendar day. The number of consultations that took longer than midnight is 1173 consultations. After removing those consultations, shifts in which doctors work both in-person and online (4653 consultations) are excluded as well. Consultations that took longer than midnight and also change work types sum up to 9 consultations. In total, 13909 meetings (1.1%) from the original sample were removed before creating the outcome variables for the doctor shift regressions. In the end, 731 doctors are included in the analysis after applying the restrictions.

The outcome variables were created on the shift level, which means they were estimated per doctor and day. After collapsing from the meeting to the shift level, most of the outcome variables had no missing values with the exception of the break variables. As previously mentioned, this is because some shifts contain only one consultation and it is not possible to calculate a break without any previous consultation. There are 127 in-person shifts and 306 online shifts with only one consultation.

A.7.3 Cost calculations

There are two important costs to consider when looking at online healthcare – the cost to the health provider and the cost to the patient. When we think about provider costs, we think about the costs to the insurer (in this case, the public health insurance) or costs to a provider that takes the full healthcare costs into account, like a Health Maintenance Organization or a provider paid by capitation (the provider at hand is paid by capitation for the registered patients). In Table 7, we attempt to approximate the costs of these actors to compare online and in-person services. The provider costs are based the sources listed in Appendix Table A12. The cost estimates are in Swedish krona (SEK); the average exchange rate for 2020 for SEK to US-dollar is 1 SEK = 0.11 US-dollar (Riksbank, 2024).

The provider costs have to be estimated. For the costs of online consultations, we use the public payers' recommended reimbursement for online doctor consultations in cases where the consultation was not under capitation. This was 500 SEK in 2019 (Vård- och omsorgsanalys, 2022) on p. 127. In 2020, it was the same amount based on a report by Södra sjukvårdsregionen (2020), p. 91. The in-person provider costs are also estimated, as there are no fixed total fees and reimbursement is through a mix of capitation and some fee for service in some regions. The estimates for in-person provider costs came from the same publication as for the online costs Vård- och omsorgsanalys (2022), for 2019 on p. 201 and for 2020 on p. 202. We calculated the simple average for 2019 and 2020 for in-person consultations, which was 2002 SEK. For provider costs incurred when the patient visits the ED, we took estimates of what an ED visit costs from the regions in the South of Sweden for 2019 and 2020 to obtain the average of both years again. Based on the estimates by Södra sjukvårdsregionen (2019) and Södra sjukvårdsregionen (2020), both on p. 47, we obtain an average ED visit cost of 3991.5 SEK for providers.

We estimated patient costs in the following way. The average fees for a primary care visit with a doctor are taken from the administrative (healthcare paying) regions Stockholm and Scania because the majority of patients in our sample are located in these regions. Patients above the age of 18 and below the age of 85 (73.49% of our sample) have to pay co-pay/visit fee in Stockholm Region, while patients above 20 years old and below 85 years old (67.67% of our sample) have to pay the fee in Scania.[35] The average percentage of paying patients over these two regions is 70.58%. The fee for paying patients was 225 SEK in-person (the mean of 250 SEK for Stockholm and 200 SEK for Scania) and 150 SEK online (the mean of 100 SEK for Stockholm and 200 SEK for Scania) in 2023.

The waiting time in the doctor's office for in-person is 30 minutes based on Ekman (2018) and 15.3 minutes for online, based on our full data with registered and unregistered patients. The online waiting time was restricted to online consultations with doctors without missing values, negative values or waiting time values above 60 minutes.

Transport includes commuting by car, public transport, biking and walking along with their respective probabilities that they are chosen (Rosberg and Enström, 2019). We took time and frequency averages from commuting to work to estimate how likely a patient takes a certain transport to the doctor's office. The commuting costs by car for primary care are based on fuel costs, transport fees, the commuting time and parking fees. The average time to primary care is 11.71 minutes one-way and 23.42 minutes two-way after including frequencies of commuting types. We assume a tempo of 60km/h on average for the fuel cost and a fuel use of 0.5 liter per km. The fuel price was taken from 01 January, 2020 and was 16.03 SEK per liter. The fuel cost is calculated for a 20 minute drive to the doctor and back. We calculate the fuel costs and multiply it with the probability of 57% that they use the car to get to work. Parking fees were taken as 15 SEK/hour on average and weighted by the patient-facing consultation time and multiplied by the probability that patients would take the car. The assumed parking time is 5 minutes for finding a parking spot before going to the doctor's appointment and 5 minutes after the appointment (including the walking distance to the doctor's office). The transport fee is multiplied by the probability that the patient takes public transport to the appointment, which is 24%. We assume that most one-way tickets are valid 90 minutes after the purchase, so that patients are not forced to buy two tickets in total for their in-person doctor appointment. The public transport fee is the average price for a one-way ticket in Sweden in 2021: 30,91 SEK.

The average time to an ED is 15.5 minutes one-way and 31 minutes two-way, estimated by calculations based on the transport probabilities by Rosberg and Enström (2019) and travel times to EDs by Vård- och omsorgsanalys (2018). We assume that commuting to an ED is only done by car; therefore fuel costs are included as well. We assume no parking fees for an ED visit because we assume that most ED visits will occur during the night where no

[35] Patients who have reached the deductible ceiling do not have to for a year, but we do not consider this.

parking fees may apply or free parking spots may be available for acute visits. The median stay time of a patient in an ED is 3.18 hours over all regions in Sweden (Socialstyrelsen, 2017).

A.7.4 Emergency Department distances to municipality centroids

The average distance from a municipality centroid to an emergency department (ED) is reported in Section 5.6.2. We use municipality centroid as municipality is the level of location information we have on patients. There are in total 71 EDs in Sweden (Swedish Healthcare Information 1177, 2023), if you exclude specialty clinics, e.g., for eyes that have an acute intake. Sweden has 290 municipalities within 21 regions, therefore, not every municipality has an ED. The distances to an ED in the rural north of Sweden are bigger than in the south of Sweden. We used an address list of Swedish ED (Swedish Healthcare Information 1177, 2023) to obtain geolocations (latitude/longitude). Then, we calculated the shortest (linear) distance of each ED for each of the 290 municipality centroids based on Vincenty's formula. The municipality centroid is the center point of a municipality and represents a generalization of location for every person living in that municipality. They were originally obtained as x-/y-coordinates, but transformed into latitude/longitude as well. The smallest distance is 1.09km for Jönköping, while the largest distance to an ED is 208.74km for Arjeplog. On average, the distance from an ED to a municipality centroid is 31.94km. Weighted by the amount of EDs each municipalities has, the average distance is 34.33km. The closest ED doesn't have to lie within the municipality. It's therefore possible that a municipality centroid could be closer to an ED outside of the municipality even if it has an ED located in the same municipality.

A.7.5 Avoidable hospitalizations (AH)

The avoidable hospitalization (AH) variable we use in, e.g., Table 4 is an indicator for whether the patient was hospitalized and given an ICD-10 code indicating that the hospitalization might have been preventable in primary care under the right circumstances. Avoidable hospitalizations as a concept, sometimes also called Ambulatory Care Sensitive Conditions, is defined in the medical literature as a hospital admission that could have been avoided with sufficient and timely primary care—the definition of conditions that count as avoidable is listed by medical research independently from this study. We have followed the definition by Page et al. (2007); see Table A1 in Page et al. (2007) for a complete list of the ICD-10 codes used.

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