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Channel integration services in online healthcare communities

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Completed Research Paper

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Abstract

In online healthcare communities, channel integration services have become the bridge between online and offline channels, enabling patients to easily migrate across channels. Different from pure online services, online-to-offline (On2Off) and offline-to-online (Off2On) channel integration services involve both channels. This study examines the interrelationships between pure online services and channel integration services. Using a panel dataset composed of data from an online healthcare community, we find that pure online services decrease patients' demand for On2Off integration services but increase their use of Off2On integration services. Our findings suggest that providing healthcare services online can reduce online patients' needs to visit physicians offline and convert physicians' offline patients into online patients. We further confirm that the substitution effect of online services for offline visits is driven by physicians' medical responses to patients' online enquiries. Our work contributes to the literature on online healthcare communities and channel integration in delivering healthcare services.

Keywords: Channel integration services, online healthcare community, panel vector autoregression, online-to-offline, offline-to-online

Introduction

Health information technologies have improved the allocative efficiency in the clinical process and led to revolutionary changes in healthcare delivery systems (Yeow and Goh 2015). Among such technologies, online healthcare communities enable patient-physician interactions remotely. Compared to offline services, online healthcare services can improve consultation efficiency (Li et al. 2016; Liu et al. 2020), overcome medical resource shortages caused by spatially unbalanced distribution (Goh 2016; Goh et al. 2011) and improve the physician-patient relationship (Grönloh et al. 2018; Hewitt-Taylor and Bond 2012). Seeking and providing online healthcare services via online healthcare communities gave rise to many multi-channel service providers and users (Roettl et al. 2016; Wu and Lu 2017), which has important implications for physicians' performance and the healthcare industry (Wang et al., 2020).

As online healthcare services become increasingly prevalent, patients and physicians face expanding communication options. For example, online healthcare communities support physicians to perform online consultations through different telecommunication channels such as picture/text consultation and phone consultation (Wang et al., 2020). Such online services are carried out via the online channel only. Besides the pure online services, physicians can also offer channel integration services that involve both online and offline channels. Unlike pure online services, channel integration services allow patients to execute various interactive activities across offline and online channels. The integration services streamline various healthcare services across online and offline channels (Huang et al. 2021), providing patients a seamless experience (Banerjee 2014; Sousa and Amorim 2018).

With channel integration services, patients can migrate across channels easily. Physicians can thus use channel integration services to manage demand and allocate capacity across channels, which can help to avoid patient congestion. According to the direction of channel migration, we can categorize channel integration services into online-to-offline (On2Off) and offline-to-online (Off2On) integration services. The On2Off integration services enable online patients to visit and consult the physician offline, while the Off2On integration services allow offline patients to interact with the physician online after their offline treatment (Swoboda and Winters 2021). For instance, as On2Off integration services, online appointment services enable patients to book online and visit physicians offline. As for Off2On integration services, offline patients may access the online page of a physician by scanning a quick response (QR) code, which can be advertised in any public locations. As such, the use of On2Off integration services moves online patients offline, whereas the use of Off2On integration services switches offline patients to online. Both On2Off and Off2On are a physician's offline demand that are directly affected by the online channel. Therefore, examining the relationship between pure online services and channel integration services can provide a better understanding on channel interactions in healthcare.

Prior studies on e-commerce have obtained mixed findings on cross-channel synergy and cannibalization (Pauwels and Neslin 2015). On the one hand, online and offline channels complement each other by providing different product information. The online channel enables consumers to compare product price information (Dekimpe et al. 2020), while the offline channel can provide fit information on overlapping products, which can reduce product uncertainty via a physical examination of the product (Gao and Su 2017; Sun and Gilbert 2019). In addition, one channel can capture the unsatisfied demand of the other channel. For example, consumers who visit offline stores but cannot find satisfactory products due to a limited assortment (Wan et al. 2012) can continue to search online for a wider product assortment (Avery et al. 2012; Tang et al. 2021; Zentner et al. 2013). On the other hand, one channel can compete with the other for demand. The online channel can substitute for the offline channel because the convenience of online search manifests the perceived ease and speed of gathering product information (Jang et al. 2017). In contrast, the offline channel can substitute for online demand because of instant gratification (Fisher et al. 2019; Wollenburg et al. 2018). Entry into an offline store also decreases online purchases from nearby locations by reducing consumers' transportation costs, especially for those who live far from pre-existing offline stores (Chintagunta et al. 2012; Emrich et al. 2015; Lim et al. 2021).

Online or offline channel in e-commerce often simply support intermittent transactions, while channel integration services in e-healthcare encompasses repeated interactions and continual correspondence between physicians and patients, such as booking online for offline treatment, storing and transferring medical records, conducting online follower-up of health management, etc. (Ayabakan et al. 2017; Das et al. 2015; Detz et al. 2013; Huang et al. 2021). For instance, in e-commerce, when a consumer makes an order online and pick up the product offline, then the transaction is completed (Mehra et al. 2018). However, a patient may consult a physician online, transfer to the offline for some physical examination, and then communicate with the same physician online for follow-up health management. Hence, theories on channel interactions in e-commerce with tangible products may not be applicable to healthcare services. However, there have been scarce studies on channel interactions in healthcare. Several studies on medical channel interactions found that online services provide demand enhancement effects for their offline counterparts because of operational integration (Wang et al., 2020), word of mouth (Shukla et al. 2021), and direct connection to the physicians (Bavafa et al. 2018). Others argued for the substitution effect of online channel for offline visits (Kilo 2005). As online channel is timesaving and an effective alternative for patients that do not require physical examinations, the online consultation can offset office visits (Bergmo et al. 2005). In addition, as suggested by resource-based theory, physicians are constrained by the time and energy to perform their offline duties (Butler 2001; Dugdale et al. 1999). Therefore, online channel and offline channel may compete for physicians' limited time and effort (Wang et al. 2020). In sum, although existing research on healthcare provide useful perspectives of how online healthcare channel affects the overall offline demand, how the use of online healthcare services directly changes the offline demand via patient migration across channels remains unknown.

Literature on healthcare so far has paid limited attention to channel integration services, which reflect the direct interactions and patient migration across channels. Huang et al. (2021) examined how online-offline service integration affects physicians' demand. The results indicated that using online-offline service integration function would increase physicians' online demand but decrease their offline demand. Although this paper has examined medical service integration from an overall perspective, it does not yield insights into the effects of channel integration services with different patient migration directions. In addition, how channel integration services, as part of the functions enabled by online communities, interact with pure online services at the physician level has not been studied.

To address aforementioned research gaps, we focus on the online-offline channel interactions via channel integration services and examine the interrelationships between pure online services and channel integration services. Moreover, according to the direction of integration, we categorize channel integration services further into On2Off and Off2On integration services and investigate how pure online services interact with On2Off and Off2On services, respectively. To answer this research question, we collect a panel dataset from a physician-driven online healthcare community and employ a Panel Vector Autoregressive Model (PVAR) for empirical analyses. We find a substitution effect of online for offline channel such that pure online services of a physician decrease On2Off integration services of the same physician. This finding suggests that online health services are indeed able to benefit patients and improve medical efficiency by replacing offline services. We also find a positive and significant effect of pure online consultation services on the physician's Off2On integration services. That is, online services provided by a physician can encourage more offline patients to migrate to the online channel. This finding indicates that online health services also enable physicians to effectively manage their demand and capacity across channels.

Hypothesis Development

Before diving into the empirics, we elaborate on the conceptual motivation and theoretical foundation in our study. We hypothesize the dynamic effects among three types of online services in an online healthcare community in Figure 1: pure online services, On2Off integration services, and Off2On integration services.

Pure Online Services and On2Off Integration Services

We first consider the mutual impact between pure online services and On2Off integration services. While pure online services allow online patients to interact with physicians and seek medical advice online, On2Off direct online patients to visit physicians offline for medical advice. When several product or service categories serve a similar purpose, they may compete for similar potential consumers (Srivastava et al. 1981, 1984). From this perspective, pure online services and On2Off services compete with each other for the demand of online patients.

On one hand, some online patients seek consultations out of anxiety or uncertainty as they lack medical knowledge and would like reassurance. Under this scenario, pure online services alone can completely satisfy their medical needs (Wu and Lu 2017). Offline visits are also considered as a more burdensome alternative for patients not needing additional physical examinations (Bergmo et al. 2005). In addition, pure online services is able to compete with On2Off services by decreasing healthcare transaction cost (Fichman et al. 2011). Pure online services can be used effectively to overcome geographic constraints and reduce transportation costs, especially for rural residents (Goh 2016). Patients can use the online channel outside of physicians' office hours, avoid travel expenses and waiting time in the hospital (Almathami et al. 2020; Goldzweig et al. 2009). This type of remote health consultation can improve patients' health conditions at very low cost (Vismara et al. 2013). Therefore, if more patients use pure online services to consult a physician, these online patients will have reduced need to visit the same physician offline. Therefore, we propose the following hypothesis:

H1: A physician's pure online services decrease his/her On2Off integration services.

On the other hand, On2Off integration services can generate a similar substitution effect on pure online services by serving the patients whose medical needs cannot be completely satisfied by online consultations. Such patients often require offline treatment, such as physical examination, surgery, or hospitalization. Especially for online patients that are familiar with the online channel, choosing On2Off integration services indicates that pure online services alone can no longer solve their health problems and that the offline visits are necessary. Therefore, when more online patients choose to use On2Off integration services, the demand of pure online services for the same physician will decrease. Therefore, we propose the following hypothesis:

H2: A physician's On2Off integration services decrease his/her pure online services.

Pure Online Services and Off2On Services

Next, we explore the interrelationship between pure online services and Off2On integration services. Different from the use of On2Off integration services which is completely a patient's decision, the use of Off2On integration services has to be first initiated by physicians to their offline patients. From the physician's perspective, a large number of pure online services denotes a physician's preference for the online channel and the rich experience handling online medical enquiries. The accumulated online experience also enables a physician to serve offline patients on the online channel. Thus, physicians providing more pure online services are more likely to encourage offline patients to use their online services. From the offline patients' perspective, the more they observe their physicians' active participation in pure online services, the more likely they will switch to the online channel after being offered Off2On integration services by their physicians. Thus, we anticipate that a physician will experience an increase in the demand of Off2On integration services when his/her pure online services increase. Formally, we propose the following hypothesis:

H3: A physician's pure online services increase his/her Off2On integration services.

Off2On integration services provide opportunities for offline patients to adopt and familiarize with the online channel. For these offline patients, using Off2On integration services can help them build trustworthiness towards the online channel and lower their perceived risk of online consultations (Gulati 1995; Schoenbachler and Gordon 2002). Some of them will continue to use the online channel to consult the physician in the future. In this sense, physician-initiated offline-to-online patient migration can convert offline patients into regular online patients. In addition, a physician's offline patients are more likely to use his/her online services. In e-commerce, a customer's previous experience of a channel has a positive impact on the use of the other channels of the same provider (Chang et al. 2018; Dinner et al. 2014; Lee et al. 2007). Offline patients often adopt Off2On services because of their satisfaction with the physician's offline services. Therefore, we propose the following hypothesis:

H4: A physician's Off2On integration services increase his/her pure online services.

On2Off and Off2On Integration Services

Lastly, we turn to the mutual effects between On2Off and Off2On integration services. Although Off2On services are initiated by physicians, offline patients still can decide whether to adopt it and migrate to the online channel. From the physician's perspective, transferring offline patients to online channel is an effective way to overcome capacity constraints offline. As major medical service providers, physicians are restricted by available time and resources, especially offline (Dugdale et al. 1999). When On2Off integration services increase, a physician will face greater pressure due to the increased offline demand from online patients. To reduce offline pressure and workload, the physician can rebalance resource allocation across online and offline channels by offering more Off2On integration services to offline patients so as to reduce the offline demand from offline patients. From the patient's perspective, the more they familiar with the online channel, the more likely they will adopt Off2On services after being offered by their physicians. This is because that aggregated usage experience and channel selection can affect their subsequent demand and behavior (Ansari et al. 2008; Dholakia et al. 2005; Thomas et al. 2004). The lack of prior experience with online channel is associated with consumer decision not to choose the online channel for subsequent purchases (Thomas and Sullivan 2005). Patients using On2Off integration services have already adopted and are even familiar with the online channel. These patients are more likely to revert to the online channel when offline visits are no longer necessary. Therefore, we propose the following hypothesis:

H5: A physician's On2Off integration services increase his/her Off2On integration services.

Similarly, the patients that prefer offline services originally are more likely to revert to the offline channel if possible. Patients using Off2On integration services have already experienced offline treatment by the physician. When these patients face new medical problems requiring offline treatment in the future, they are more likely to reach out to the physician offline via On2Off integration services. Therefore, we propose the following hypothesis:

H6: A physician's Off2On integration services increase his/her On2Off integration services.

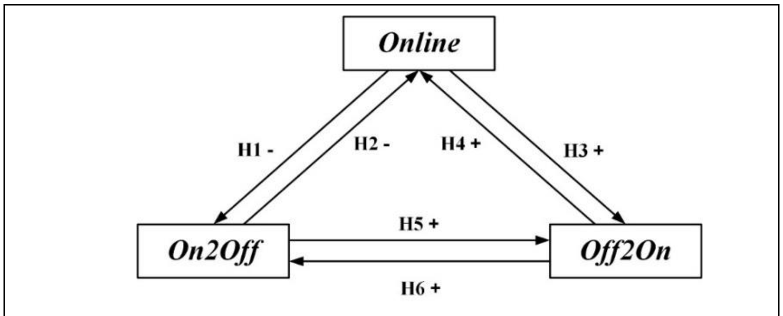


Figure 1. Research Framework and Hypotheses

Research Context and Data

Empirical Setting

We collected physicians' service data from a pioneering Chinese online healthcare community, established in 2006. By 2021, more than 780,000 physicians have registered on the platform. The platform hosts a homepage for each registered physician, presenting the physician's demographic and service information. All the services provided by a physician are also summarized and recorded on the physician's homepage. Figure 2 shows a screenshot of an example service record. Each service record contains the patient's biographic information, service type, case information and communication between the patient and the physician. To protect patient privacy, personal identity information such as patient name and account ID is masked in the service record.

It is important to differentiate distinct services on the platform. There are three types of services physicians can provide: ***online consultation*, *offline appointment for online patients*, and *online check-in for offline patients***. Online consultations enable e-health services, where patients communicate with physicians and physicians provide medical advice and treatment via online messages or phone calls. Physicians are obligated to answer patients' questions for paid services but not free consultations. As for the other two service types, both offline appointment and online check-in reflect a physician's offline demand partly. Offline appointment allows patients to make a reservation online according to their medical needs and visit the physician offline. It converts online patients into offline demand. Online check-in is free one-time online consultation service offered by a physician to his/her offline patients in case they need additional medical advice following their offline treatments. Via online check-in, physicians can manage their offline demand and proactively encourage offline patients to use the online channel for disease management.

Further, this platform also has a review system to show patients' feedback, which reflects patients' satisfaction of physicians' healthcare services. Patients can share their treatment experiences and make comments on the treatment effects and attitude of physicians through online reviews. Both online and offline patients can write reviews for a physician, but most reviews are from patients who received offline services from this physician (Wang et al., 2020).

Figure 2. Screenshot of a consultation record of a physician

Data Collection and Description

Although data about various diseases are available from the platform, we focus on lung cancer, a chronic disease that requires long-term management. Focusing on this patient group enables us to better explore the dynamics of patient migration between different channels. As chronic diseases like lung cancer require planned regular treatment and continuous follow-up with physicians, both online and offline channels can be important for patients. On one hand, lung cancer, as a physical illness, often requires offline examination and treatment. Given the severity of the disease, patients prefer to seek services from physicians with high reputation. Thus, online appointments provide an effective way for them to seek offline treatment. On the other hand, due to unbalanced resource distribution, many well-known physicians are not easily accessible offline for those patients in remote areas. Therefore, online channel is an important means for patients to reach these specialists remotely. Our final dataset contains the complete data on patient reviews and service records for all physicians in Beijing specializing in Lung cancer from January 1, 2012 to February 28, 2021. During this period, a total of 1,048 physicians specializing in Lung cancer provided 361,221 online consultations, 74,510 offline appointments for online patients and 120,548 online check-ins for offline patients.

Variables

To ensure sufficient observations for each time period, we aggregate the data by month. Therefore, our main empirical analysis is at the physician(i)-month(t) level. We denote online consultation as $Online_{i,t}$, which is the number of physician i's online consultations. We denote offline appointment for online patients $On2Off_{i,t}$, which reflects patient migration from online to offline. Online check-in for offline patients is denoted by $Off2On_{i,t}$, which shows patient migration from offline to online. We also use two physician-level variables as controls, include patient reviews and physician's online experience. The key variables are defined as in Table 1. Table 2 presents the monthly summary statistics. During the 109-month observation period, an average of 5.24 Online, 1.08 On2Off and 1.75 Off2On services were provided by each physician specializing in lung cancer each month. Each physician received approximately 0.41 reviews from the patients every month and had online consultation experience of around 5 years on average. There are fewer service observations than reviews because not all registered physicians provide online services, but they all can receive reviews from their offline patients.

<table>
<tr><th colspan="2">Variable</th><th>Definition</th></tr>
<tr><td colspan="2">Online$_{i,t}$</td><td>The number of pure online services (including text, phone and video consultations) requested by physician i's online patients in month t.</td></tr>
<tr><td colspan="2">On2Off$_{i,t}$</td><td>The number of offline appointments made online for physician i in month t.</td></tr>
<tr><td colspan="2">Off2On$_{i,t}$</td><td>The number of online check-ins by physician i's offline patients in month t.</td></tr>
<tr><td rowspan="2">Control Variables</td><td>Review$_{i,t}$</td><td>The number of reviews received by physician i in month t.</td></tr>
<tr><td>Experience$_{i,t}$</td><td>The number of months between physician i's registration date on the platform and month t.</td></tr>
</table>

Table 1. Variables and Definitions

Variable	Observations	Mean	Std. Dev.	Min	Max
Online	68,863	5.24	19.07	0	950
On2Off	68,863	1.08	6.78	0	305
Off2On	68,863	1.75	7.94	0	359
Review	115,280	0.41	1.75	0	97
Experience	68,863	60.82	37.60	0	155

Table 2. Summary Statistics of Key Variables by Physician-Month

Empirical Methodology

Model Specification

We employed a PVAR model to explore the dynamic relationships between online consultation, offline appointment for online patients and online check-in for offline patients. PVAR models have the advantages of both VAR models and the structure of panel data. On the one hand, VAR models perform well to measure complicated dynamic interactions among endogenous variables, supposing that each dependent variable is affected by its own lags and the lags of all other dependent variables (Stock and Watson 2001). In addition, it can handle the issues of non-stationarity, spurious causality, endogeneity, serial correlation, and reverse causality. On the other hand, retaining the structure of panel data, PVAR can address unobserved individual heterogeneity and use lagged dependent variables as instruments in the generalized method of moments (GMM) estimation to obtain consistent estimates (Chen et al. 2015; Dewan and Ramaprasad 2014; Love and Zicchino 2006; Song et al. 2019; Wang et al. 2021). Our model is specified as follows:

$$\begin{pmatrix} Online_{i,t} \\ On2Off_{i,t} \\ Off2On_{i,t} \\ Review_{i,t} \end{pmatrix} = \sum_{j=1}^{k} \boldsymbol{\Gamma}_j \begin{pmatrix} Online_{i,t-j} \\ On2Off_{i,t-j} \\ Off2On_{i,t-j} \\ Review_{i,t-j} \end{pmatrix} + \beta Experience_{it} + \boldsymbol{\delta_t} + \boldsymbol{u_i} + \boldsymbol{\varepsilon_{it}}, \quad \textbf{(1)}$$

where Γ is a 4×4 matrices of slope coefficients for the endogenous variables. k is the number of lags. Leveraging the panel data structure, we incorporate vector $\delta_t = (\delta_{1,t}, \delta_{2,t}, \delta_{3,t}, \delta_{4,t})'$ as time dummies controlling for time fixed effects, such as seasonality. $u_i = (u_{1,i}, u_{2,i}, u_{3,i}, u_{4,i})'$ is a vector of unobservable physician fixed effects characterizing the time-invariant attributes of physicians. The vector $\varepsilon_{it} = (\varepsilon_{1,i,t}, \varepsilon_{2,i,t}, \varepsilon_{3,i,t}, \varepsilon_{4,i,t})'$ stands for the remaining error terms.

PVAR Identification

We follow the standard method to perform PVAR analysis. For PVAR analysis, dependent variables need to satisfy the requirement of stationarity. Because of the unbalanced panel, we conduct Fisher-type root test

(Choi 2001) for stationarity via checking for the absence of unit roots. The results verify that all dependent variables are stationary. Subsequently, we conducted the lag selection procedure using the moment and model selection criteria (MMSC) following the standard method in PVAR literature (e.g., Abrigo & Love, 2016; Wang et al., 2021). Lag 1 is chosen as the optimal lag length in our main analysis according to MMSC-Bayesian information criterion (MBIC)and MMSC-Hannan and Quinn information criterion (MQIC). We also use lag 2 which yields the optimal MMSC-Akaike's information criterion (MAIC) as a robustness check in Robustness Checks Section.

Panel-specific fixed effects could be correlated with the regressors due to lags in the dependent variables (Arellano and Bover 1995; Love and Zicchino 2006). To address this problem, Helmert transformation, or forward orthogonal deviation in other words, is used to eliminate physician fixed effects (Arellano and Bover 1995). Next, we examine whether the lagged dependent variables predict future values of dependent variable in the whole PVAR system via Granger causality tests (Granger 1969). The results are presented in Table 3 and show that 9 out of 12 (75%) possible effects show significant Granger causality ($p < 0.1$). It is thus reasonable to consider the full dynamic system (Trusov et al. 2009; Wang et al. 2021).

Variable	$Online_{i,t}$	$On2Off_{i,t}$	$Off2On_{i,t}$	$Review_{i,t}$
$Online_{i,t-1}$		9.220 (0.002)	3.631 (0.057)	15.676 (0.000)
$On2Off_{i,t-1}$	1.495 (0.221)		13.714 (0.000)	7.150 (0.007)
$Off2On_{i,t-1}$	3.987 (0.046)	0.041 (0.840)		64.729 (0.000)
$Review_{i,t-1}$	3.986 (0.046)	0.077 (0.781)	3.305 (0.069)	

Notes: Granger Causality tests are performed with 1 lag for consistency with PVAR model estimations. The null hypothesis is that the row variable does not Granger-cause the column variable.

Table 3. Granger Causality Test χ^2 and p-Values

Main Results

Table 4 presents the main results for the dynamics among online consultation, offline appointment for online patients and online check-in for offline patients. First, we observe interesting patterns for the relationship between *Online* and *On2Off*. *Online* has a significant negative predictive influence on *On2Off,* which supports H1. Specifically, an increase in *Online by 1* can lead to a decrease of 0.016 in *On2Off*. Based on our earlier theoretical discussion, this negative association can support the substitution of online services for offline medical services, such that online patients obtaining satisfactory responses from the physician have reduced needs to visit the same physician offline. This channel substitution effect could suggest that online health services are indeed able to improve medical efficiency by replacing some offline services. However, as our analysis is at the physician level, another opposite alternative explanation is that patients, without receiving satisfactory online services from the physician, decide to not visit the same physician offline and instead turn to other physicians. We further explore the mechanism and rule out this alternative explanation in the next section. In addition, we find that *On2Off* does not affect *Online* significantly, rejecting H2. That is, the increased appointments made by online patients for offline services does not reduce their use of online services, suggesting that online patients are rather satisfied with the convenience and outcome of online services. The alternative explanation that *Online* and *On2Off* are used by two different patient groups could also result in insignificant relationship between *Online* and *On2Off*. However, this has been ruled out by the significant effect of *Online* on *On2Off*.

Then we analyze the interrelationship between *Online* and *Off2On*. The coefficient estimate on *Online* at lag 1 (0.010*) is positive and statistically significant (Column (3)), indicating that *Off2On* increases in the following month as *Online* increases. Thus, H3 is supported. That is, physicians that have conducted more online consultation services bring more offline patients to use online services following offline treatment This finding may be explained by physician's preference for online channel. If a physician has accumulated rich experience of handling online medical demand via providing online services, he/she can better integrate online channel into serving the offline patients. Moreover, *Off2On* at lag 1 also positively and significantly affects *Online* (Column (1)), supporting H4. Specifically, a one-unit increase in *Off2On* can lead to a 0.04 increase in *Online*. That is, 4% of the increased offline patients that checked-in online will use online services of the physician in the following month. This finding confirms the effectiveness of physician-initiated offline-to-online patient migration in converting offline patients into regular online patients. Although *Off2On* is offered by the physician to his/her offline patients for free, it provides opportunities for these patients to familiarize with online channel, and some of them eventually utilize online channel to reach out to the physician for medical needs in the future.

	Dependent Variables			
	$Online_{i,t}$ (1)	$On2Off_{i,t}$ (2)	$Off2On_{i,t}$ (3)	$Review_{i,t}$ (4)
$Online_{i,t-1}$	0.792*** (0.029)	-0.016** (0.005)	0.010* (0.005)	0.007*** (0.002)
$On2Off_{i,t-1}$	-0.016 (0.013)	0.706*** (0.079)	0.077*** (0.021)	0.016** (0.006)
$Off2On_{i,t-1}$	0.040** (0.020)	0.002 (0.011)	0.726*** (0.033)	0.096*** (0.012)
$Review_{i,t-1}$	0.141** (0.071)	0.012 (0.043)	0.140* (0.077)	0.361*** (0.036)
$Experience_{i,t}$	0.003 (0.006)	0.011* (0.006)	0.001 (0.004)	0.001 (0.002)

Notes: Variables are forward mean differences. ***, **, and * denote significance at 1%, 5%, and 10%, respectively.

Table 4. PVAR Estimation Results

Hypothesis	Results
H1: A physician's pure online services decrease his/her On2Off integration services.	Supported
H2: A physician's On2Off integration services decrease his/her pure online services.	Rejected
H3: A physician's pure online services increase his/her Off2On integration services.	Supported
H4: A physician's Off2On integration services increase his/her pure online services.	Supported
H5: A physician's On2Off integration services increase his/her Off2On integration services.	Supported
H6: A physician's Off2On integration services increase his/her On2Off integration services.	Rejected

Table 5. Hypotheses Testing Results

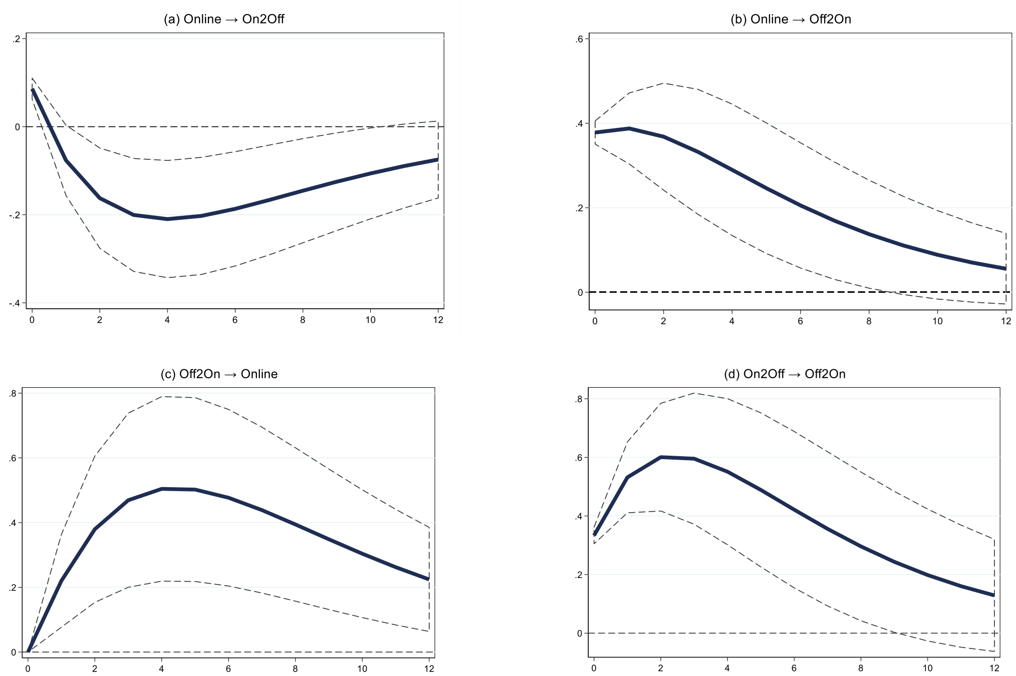
Next, we turn to the analysis regarding the mutual effects between On2Off and *Off2On*. *On2Off* at lag 1 is positively and significantly correlated with *Off2On,* supporting H5. Specifically, an increased offline appointment for an online patient can increase online check-in services by 0.077 in the subsequent month. The increased offline visits to a physician leading to more online check-in's of the physician's offline patients be can attributed to two reasons. From the physician's perspective, to manage the increase in offline workload as On2Off increases, physicians offer more Off2On to transfer certain offline patients to the online channel. From the patient's perspective, the offline patients coming from online channel via On2Off are more likely to use online consultation opportunities after offline visits. However, *Off2On* does not predict *On2Off* significantly, rejecting H6 and indicating that although offline patients choose to use online check-in services, they will not directly use online channel to book offline visits.

As expected, all three types of services increase *Review* significantly. In particular, *Off2On* has the strongest effect on *Review*, suggesting that most reviews are still contributed by offline patients (Wang et al., 2020). *Review* has a significant positive effect on both *Online* and *Off2On* but not *On2Off*, confirming the importance of physician reputation in patients' choice of physicians and adoption of online channel. The control variable *Experience* only affects *On2Off* positively and significantly.

Impulse Response Functions

We supplement the PVAR estimates with the analysis of the corresponding impulse response functions (IRFs). IRFs graphically present the response of an endogenous variable to a one-unit shock in another endogenous variable over a period. Therefore, we can use IRFs to check whether the effect is transitory or long-term (Stock and Watson 2001). We conduct orthogonal IRFs with 90% confidence intervals generated from Monte Carlo simulations with 1,000 repetitions. The length of the forecast horizon is set to be 12 months. Figure 5 illustrates the IRFs for the main effects identified in Table 4.

Based on IRFs, the short-term results at lag 1 are consistent with our main analysis in Table 4. Figure 3(a) represents how a physician's online consultations affect his/her offline appointments for online patients. We see that a unit shock to *Online* will lead to a decreased number of *On2Off* from month 1 to month 10, and this effect becomes stronger initially and weakens after 4 months. Figure 3(b) and (c) illustrate how *Online* and *Off2On* affect each other. According to Figure 3(b), a unit shock to *Online* can lead to an increase in *Off2On*. This positive effect is more salient at the beginning and gradually diminishes within month 9. Figure 3(c) demonstrates a long-term effect of *Off2On* on *Online*. Specifically, a unit shock to *Off2On* can create an increase in *Online* that remains significant over a year, although the effect attenuates after 4 months. Figure 3(d) shows that a unit shock to the number of offline appointments for online patients can lead to more online check-ins, and this effect takes around 2 months to reach the peak. In sum, the four main effects identified are rather persistent over time, especially the effect of *Off2On* on *Online*.



Notes: The x-axis in each plot is the forecast horizon (in months), and the y-axis is the forecasted response of the dependent variable to a unit shock in the corresponding.

Figure 3. Impulse Response Function

Additional Analysis

One important finding is the substitution effect of online channel for offline visits. Effective online consultation facilitates interactions between patients and physicians. If patients can obtain responses from the physician timely, their medical needs can be as satisfied as in some offline consultations. However, the opposite that patients, without receiving satisfactory online services from the physician, decide to not visit the same physician offline could also explain the reduction in offline visits. To test for the two alternative explanations, we divide online services into two categories: online consultations with response from the physician (*OnlineRes*) and online consultations without response from the physician (*OnlineNoRes*). We replace *Online* with these two endogenous variables and re-conducted the PVAR estimation in Table 6. We find that the effects of *OnlineNoRes on On2Off*, *Off2On*, and *Review* are consistent with the effects of *Online*, whereas *OnlineNoRes* has no significant effect on *On2Off, Off2On*, or *Review*. Therefore, the effect of *Online* is driven by *OnlineRes* only, supporting that online channel can be a substitution of offline channel to some extent.

	Dependent Variables				
	$OnlineRes_{i,t}$	$OnlineNoRes_{i,t}$	$On2Off_{i,t}$	$Off2On_{i,t}$	$Reviews_{i,t}$
$OnlineRes_{i,t-1}$	0.818*** (0.003)	-0.013 (0.019)	-0.016** (0.005)	0.011** (0.005)	0.008*** (0.002)
$OnlineNoRes_{i,t-1}$	-0.165** (0.078)	0.627*** (0.055)	-0.004 (0.013)	-0.008 (0.008)	-0.003 (0.006)
$On2Off_{i,t-1}$	-0.013 (0.012)	0.000 (0.006)	0.706*** (0.079)	0.077*** (0.021)	0.016** (0.006)
$Off2On_{i,t-1}$	0.012 (0.018)	0.014* (0.008)	0.002 (0.011)	0.726*** (0.034)	0.096*** (0.012)
$Reviews_{i,t-1}$	0.147** (0.064)	-0.009 (0.013)	0.012 (0.043)	0.139* (0.077)	0.361*** (0.036)
$Experience_{i,t}$	0.003 (0.005)	0.002 (0.003)	0.011* (0.006)	0.001 (0.004)	0.001 (0.002)

Notes: Variables are forward mean differences. ***, **, and * denote significance at 1%, 5%, and 10%, respectively.

Table 6. Additional Results

Robustness Checks

To verify the generalizability of our findings, we consider another type of chronic disease, depression. For depression, 626 physicians offered 288,853 pure online services, 36,419 offline appointments for online patients and 89,339 online check-ins by offline patients during the same observation period for lung cancer. We estimate our PVAR model using the service records for depression. The results for depression confirm the negative effect of Online on On2Off and the positive effect of Online on Off2On. The positive effects of Off2On on Online and of On2Off on Off2On are no longer significant. H1 and H3 remain supported. Then, we perform a robustness check on the number of lags that should be included in the PVAR specification. In the main analysis, we chose one lag according to the MBIC and MQIC criteria. However, MAIC would suggest two lags. As such, we re-conduct our analyses using two lags. Under this alternative specification, *Online* still has a negative association with *On2Off*, while the *Online* on the first lag can increase *Off2On* significantly. The other effects are no longer significant. Thus, H1 and H3 remain supported. Finally, we conduct a robustness check on the ordering of the variables in the system. PVAR model assumes that the variables that come earlier in the ordering will affect subsequent variables contemporaneously, while shocks on variables that come later in the ordering will affect only the previous variables with a lag (Abrigo and Love 2016). We consider several alternative permutations of the main variables and reanalyze the PVAR model. All the results remain unchanged. In sum, under all these robustness checks, although the effects of *Off2On* on *Online*, *On2Off* on *Off2On* are insignificant, the effects of *Online* on *On2Off* and *Off2On* remain consistent with our main results, supporting H1 and H3.

Discussion and Conclusion

Using a dataset of consultation records from an online healthcare community, we find that pure online services lead to a reduction in the patients' use of On2Off integration services, suggesting a demand substitution effect of online healthcare services on offline services for a physician. This is further confirmed by the additional finding that the reduction in On2Off integration services is mainly driven by online consultations with physicians' responses, and that the pure online services without physician's responses do not have significant impact. In addition, we also find that pure online services can increase the use of Off2On integration services, suggesting that more offline patients would switch to use the physician's online healthcare services as the physician's online services demand increases. Overall, our findings suggest that online healthcare services have been playing a more and more important role in increasing the quality and efficiency of the overall healthcare system.

Theoretical Contributions

Our paper makes several contributions to existing literature. First, our paper contributes to the literature by expanding the scope of the related previous work on channel integration services from e-commerce to e-healthcare. To the best of our knowledge, our study is the first to empirically examine channel integration services with different directions in the healthcare field. Prior findings on channel integration services with different directions in e-commerce might not be directly applicable to e-healthcare due to the contextual differences (Das et al. 2015; Goh 2016; Huang et al. 2021). E-commerce mostly involves distinct transactions via online or offline channel (Gupta et al. 2009; Tian et al. 2018), while channel integration services in e-healthcare characterizes the provision of continual services (Huang et al. 2021). In e-commerce, On2Off options such as "ship-to-store" or "buy-online and pick-up-in-store" are found to decrease online sales as consumers still prefer nearby brick-and mortar stores if the offline assortment and price are comparable (Gallino and Moreno 2014; Serkan Akturk et al. 2018). However, our results show that On2Off medical integration services do not decrease pure online services, indicating online patients are rather satisfied with the convenience and outcome of online channel. As one type of Off2On integration services in e-commerce, showrooms deployed by online-first retailers enable customers experience products offline with an online fulfillment, which are found to increase demand overall and in the online channel as well (Bell et al. 2018). This is consistent with our results of lung cancer.

Second, although online channel has been found to be important influencer of the overall offline demand, how it affects offline demand directly transferred from the online channel remains largely unknown. The substitution effect of the online channel illustrates the social value of online healthcare communities for the entire healthcare system. Wang et al. (2020) find that online channel could be integrated with offline channel and lead to an increase of offline demand. However, we find that pure online services decrease patients' use of On2Off integration services, suggesting a substitution effect on offline visits. The divergent findings can be explained by the differences in the design of the two studies. Wang et al. (2020) is based on aggregated channel-level data and focus on the overall offline demand, while our study is based on physician-level data and focus on the offline demand directly transferred from the online channel. The overall offline demand may increase as online services can expand physicians' reputation, which can attract more offline visits from the offline demand for all physicians but not from the same physician's online patients.

Third, although some research explore the overall impact of channel integration services and cross-channel effects in the healthcare context (Bavafa et al. 2018; Huang et al. 2021; Wang et al. 2020; Yin et al. 2020), none of them evaluates the mutual impact between online channel and specific channel integration services, especially Off2On integration services. Off2On integration services initiated by physicians enable online follow-up with offline patients, which can facilitate chronic disease management and alleviate the intensive usage of offline resource. Our work suggests that physicians with higher online channel usage will move more of their offline patients to online. This can effectively help the physicians manage their capacity allocation for both channels, alleviating the side effects of increasing offline visits such as accepting fewer new patients (Bavafa et al. 2018).

Practical Implications

Our study also offers several practical implications for physicians, online healthcare platforms and policy makers. To begin with, multichannel patient management affecting resource utilization efficiency is becoming a pivotal component in physicians' marketing strategy. Our work indicates that pure online services can generate a substitution effect on subsequent offline visits, and lead to an increase of patients transferring from offline. As such, through providing more online services, physicians can solve online patients' medical problems efficiently, especially for patients who do not need physical examination, and thus alleviate intensive utilization of offline healthcare resources. Also, physicians' participation in online channel can attract more offline patients migrating to online channel.

For online healthcare platforms requiring a substantial number of users actively participating and continuously using, it is important to transfer new users of online channel to repeated users. Our results show that 4% of the increased offline patients that checked-in online will use online services of the physician in the following month. However, most of these continuous online consultations are free and cannot receive response from the physician, which may result in discontinuing use of the online channel. This result indicates the need for encouraging physicians to response to free services and patients to use paid services. In addition, offline appointments for online patients can positively affect online check-ins for offline patients. As such, online healthcare communities can design more types of customized integration functions with different directions to facilitate patient migration and encourage physicians offer these functions, to improve patient's long-term relationship and lifetime value with both physicians and online healthcare platforms.

For policy makers, our study suggests that online channel can address some patients' medical problems and thus help avoid redundant offline medical visits and increase efficiency in healthcare. This finding can serve as support for policy implementation regarding encouraging public to participate in the online healthcare industry, integrating medical insurance into online channel, and managing online prescriptions.

Limitations and Future Research

Our study has several limitations. First, as our dataset is at the physician level, we are unable to observe patient characteristics and examine patient heterogeneity in the use of pure online and channel integration services. For example, we do not consider the online patients that visited the physician offline directly without using On2Off. Although this does not affect our current research scope of focusing on patient migration between online and offline channels via channel integration services, it may underestimate the overall migrated patients. Future research with individual patient-level characteristics can also examine differences across patient segments, such as heavy users vs. occasional users, existing vs. new patients. Second, although our results contribute to the understanding of dynamic effects between different types of online healthcare services for chronic diseases, it is inherently limited to one selected disease type. It would be worthwhile to conduct future research on more disease types. The variation of channel complementarity and substitutability across disease types could be another meaningful extension. Third, as our work focus on how online channel directly affect the demand of channel integration services, pure offline demand is not considered in our study. Future research can examine the dynamic effects among pure online services, pure offline services, and channel integration services, to provide a more comprehensive understanding of the overall healthcare system. Finally, some interesting moderator variables are not included in our study, like the response speed of physicians, communication frequency between physicians and patients. Future research can explore how these moderator variables affect the relationships between different types of services.

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