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PHYSICIAN HEALTH MANAGEMENT SKILLS AND PATIENT OUTCOMES

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ABSTRACT

A host of different factors affect health and longevity, ranging from genetic endowments to public policy. Physicians have a substantial influence on patients' health and health-related costs, but we know little about the extent of this influence beyond clinical decisions such as adequate diagnosis and treatment. This paper demonstrates that the health management styles of primary care physicians significantly affect the health outcomes of their patients. Using data on the population of statin users in Denmark and matching patients to their primary care physicians, we show that the physician's ability to facilitate adherence with prescription medications has significant positive effects on patient outcomes and health costs even after controlling for observable and unobservable patient characteristics. Policy interventions aimed at improving this aspect of physicians' health management styles have important implications for patient outcomes and health care costs.

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Introduction

There are large, persistent differences in patient outcomes across physicians and health facilities (Epstein & Nicholsen, 2009; Currie et al, 2016; Molitor, 2016). The root causes of these differences are not well understood. Variations in clinical quality across physicians are unlikely to fully account for the gaps in outcomes, and neither are disparities in patient backgrounds. A possible contributing factor is that the patients of different physicians pursue different health behaviors. It is an open question whether these behaviors can be affected by the health management style of the physician. Recent work suggests that this is likely the case. Using Danish population registry data Koulayev et al (2017) demonstrate substantial differences in average patient adherence with prescribed medication across different physicians.[1] Analyzing the results from a randomized experiment Alsan and co-authors (2018) show that black men in Oakland are much more likely to complete preventive screening tests and to communicate with their doctors when seen by a black (male) physician, though they report no difference in patient perceptions of physicians' clinical abilities.

There are several reasons why it is important to better understand if physicians' health management styles can affect patient health outcomes and health costs. First, insight into what features of the physician's style of health management affect patient outcomes is crucial in the design of contracts between payers and providers. As health care systems struggle to address growing health care costs, quality contracts are becoming increasingly popular. Such a contract between the payer and the health care provider specifies that a portion of the provider's financial compensation is dependent on adequate performance according to a set of health quality metrics taken over the patient population. In outpatient and primary care settings, these quality metrics usually include routine screening and vaccinations, as well as proper maintenance of chronic conditions and avoidance of preventable (re-) hospitalizations. Practitioners have argued that despite attempts to adjust such metrics to the patient mix, providers who disproportionately work with patients whose health behaviors are harder to manage, are at a great disadvantage.

Second, we need to understand better how different dimensions of physician management skills relate to patient outcomes. While it is widely recognized that multiple dimensions of firms' management matter for firm output (Bloom & Reenen, 2007, 2010) and hospital performance (Bloom, Propper, Seiler and van Reenen, 2015), it has yet to be studied in the case of outpatient-based health care provision. It is particularly relevant to investigate the role of patient health management skills in the primary care and outpatient settings, where

[1] Simeonova (2013) shows that racial gaps in chronic heart failure survival rates persist even after individual physicians' unobserved characteristics are controlled for, but there are no racial survival gaps if patients mostly adhere with their prescribed medication regimen.

patients have substantial control over what provider they see and the actions they take conditional on receiving a clinical recommendation by the physician.

Third, a key question in the literature is whether cross-physician differences in patient outcomes are due to physician management, or due to patient selection. For example, if a physician's practice happens to be geographically located in an area where most people adhere with medication and engage in proper health maintenance, the physician will likely score high on any patient health outcomes metrics. This is particularly important because in some settings provider-specific quality metrics, or "report cards", have been made public. These "report cards" are based on past patient outcomes for common conditions. On the one hand, this may facilitate efficient patient allocation across providers and encourage better quality among physicians who lag behind their peers. On the other, the literature on quality report cards suggests that patients who are able to shop for providers, either because they are healthier or because they are better informed, would select out of lower-quality providers after quality information becomes public (Cutler et al, 2004; Santos et al, 2017). If patient selection and sorting account for some of the differences in observed provider quality, making quality metrics public will likely result in any remaining "good" patients abandoning practices with suboptimal patient mix.

We use Danish registry panel data on the population of statin users and their primary care physicians to investigate how physician patient management styles impact patient health outcomes. We construct a measure of physician health management style based on her patients' adherence with prescribed medication therapy[2]. This measure captures the physician's ability to inspire the patient to adhere to that therapy, perhaps by clearly communicating its benefits and encouraging and responding appropriately to patient feedback about their experience with the medication. We consider this metric a proxy measure of the physician management style and show how it affects patient hospitalizations for cardio-vascular diseases and associated costs.

This paper makes several contributions to the existing literature. First, we show that the physician's ability to facilitate patient adherence with prescribed therapy has sizeable effects on patient outcomes and health care costs. Second, we show that the physician's health management skill maintains its strong explanatory power even after we control for patient selection into practices and unobserved patient heterogeneity. Overall, the estimates suggest that investing in improving physician health management skills would have substantial positive effects on health outcomes and result in reductions in health cost for cardio-vascular diseases.

[2] Adherence measures the intensive side of following prescribed therapy, namely taking as much of the medication as prescribed over a pre-determined period. If a patient stops taking statins altogether, she becomes non-persistent and is excluded from the sample. Our measures and estimated effects are based on deviations from adequate therapy compliance conditional on maintaining the patient on the therapy. Patients who completely discontinue the therapy likely experience different, potentially much more severe, health consequences.

Third, we demonstrate that differences in established measures of clinical quality (based on Ambulatory Care Sensitive Conditions) across primary care physicians correlate strongly with patient outcomes, but are in fact due to patient selection. Denmark, along with many other European countries, does not have a public physician (or hospital) quality reporting system, and so our findings are not affected by any actions that may be taken by physicians to influence the type of patients selecting into their practice. We uncover differential sorting of patients across physicians based on unobservable patient characteristics that positively correlate with health outcomes. Because of the institutional setting, this sorting appears to be demand-driven. Incentive contracts tied to such measures of clinical quality would likely introduce supply-side sources of selection in addition to the demand-side selection we document here. Further, making these clinical quality metrics public would exacerbate patient selection. To our knowledge, this is the first study to explicitly investigate whether individual patient adherence with therapy affects health outcomes, conditional on controlling for physician clinical quality, and observed and unobserved patient characteristics.

2. Background and institutional setting

A large body of work documents differences in clinical treatment styles across physicians (Grytten and Sorensen, 2003; Epstein and Nicholson, 2009; Burke et al, 2010; Phelps and Mooney, 1993; Phelps, 1995). The reasons behind the variation in clinical treatment choices across doctors are subject to an active debate in health economics (e.g. Chandra et al, 2011), but the physician influence on health outcomes is not restricted to the choice of clinical therapy. Notably, at least one study in economics and a number of studies in medical sociology report that physicians' communication styles also affect patients' adherence decisions (Koulayev et al, 2017; Cooper, 2009; Sleath, 2000; Haynes, 2002; and review by DiMatteo, 2004). This is important because recent adjustments to physician compensation schemes have introduced quality metrics into the contracts in some health care systems. Quality is generally assessed using patient health outcomes, such as avoidable (re-) hospitalizations and good maintenance of chronic conditions such as diabetes and hypertension, as well as more routine metrics such as vaccinations and recommended recurring checkups. In practice, what contributes to good performance on these quality metrics is not well understood. The correct clinical diagnosis and choice of treatment is obviously an important first step. Once this has been established, and especially in the management of chronic diseases in an outpatient setting, the patient is an equally important partner in the health care process. The physician's ability to respond to individualized patients' needs, such as medication side effects, and to effectively communicate clinical decisions to the patient is a very likely additional and important determinant of health outcomes.

We analyze the physician's ability to inspire and manage optimal patient health behavior, which we term the physician's health management skill. We argue that in the case of preventive medicine, this dimension of the physician's treatment style is relevant, and if maximizing population health is the goal, then pay-for-performance schemes should also provide incentives along this dimension. Prior research has shown that primary care providers vary significantly in the average adherence of their patients (Koulayev et al, 2017). Though intuitive, the link between patient adherence and health care costs and outcomes is harder to identify. An important source of bias is the association between unobserved patient health status and its progression, and medication adherence. When individuals feel worse, or perceive their health as deteriorating, they are more likely to follow doctor's orders. As recognized by Encinosa et al, (2010), among others, this biases the estimated coefficients from simple regression models. Using an instrumental variables approach, studies find large positive effects of adherence on health outcomes and cost reduction.

2.1 Institutional Setting

The Danish health care system can be divided into two main sectors: the primary health care sector and the hospital sector. The primary health care service sector deals with treatment and care from primary care physicians, specialists, physiotherapists, and dentists, among others. Furthermore, the primary sector also includes preventive health schemes and preventive health care. The Hospital Sector deals with conditions that are more complex and require more advanced treatment. Admission in non-acute cases requires a referral from the primary sector.

Denmark has universal and tax-financed health insurance run by the government. All individuals residing in Denmark are given a social security number. The social security number ensures free access and treatment at primary care physicians and specialists, as well as free in-hospital stays. All services provided to an individual are registered via the social security number and all expenses are picked up by the national health insurance.

Primary care physicians

The Danish public health insurance provides visits and services at the primary care physician (PCP) free of charge. In Denmark, PCPs serve as gatekeepers to the rest of the health care system in the sense that they refer to specialists and hospital admissions. There are approximately 3,500 PCPs in Denmark working from 2,200 different practices. In order to get reimbursed by the national insurance, the physician needs to acquire a clinic-ID (*ydernummer*). The number of clinic licenses is controlled by the government, based on factors such as the population density in different areas.

The PCPs are responsible for a large portion of the patient's medication therapy. The physician has no financial incentives to choose specific medication brands. First-choice medication recommendations are issued by the national health authorities, but practitioners can choose a different therapy if they consider it more appropriate. Prescription drugs are sold at government licensed pharmacies only. All information about purchases is registered in a database at the Danish Medicines Agency (DMA). It is important to note that an individual's choice-set of PCPs is limited in Denmark. A patient can choose any PCP, as long as the PCP's practice is located within 15km from the patient's home[3]. The patient needs to be enlisted with a PCP in order to visit him or her and changing to a different PCP costs a fee of 150 DKK[4], and can be done only if the new doctor is open for patient intake. This restricts the possibility of changing PCP as well as the possibility for choosing PCPs not in the individual's choice-set.

An institutional feature of great importance to this study is the fact that it is very difficult for physicians to selectively turn away individual patients. When a clinic list has reached 1,600 patients (per physician) the physician can apply to the local government to stop the intake of new patients[5]. However, if working below this capacity the physician has to take in patients who wish to be listed with her. According to the collective agreement made between the government and the Danish primary care physicians, a physician can discontinue the physician-patient relationship only if the patient acts violently or threatening, or in any other way misbehaves during the clinical encounter.

Hospitals

There are 5 regions in Denmark in charge of operating a total of 54 hospitals. The funding is partly state grants which are activity and demography-based, partly funded by the municipalities. Out-patient and in-patient care is free of charge for the individual. There is a group of specialized privately operated hospitals, where patients are covered by public insurance if waiting lists at public hospitals exceed two months.

3. Empirical strategy

The main goal of the paper is to highlight one of the mechanisms through which physicians impact the health of their patients. To this end, we leverage the observed link between physicians and patients in the registry data. To have a setting where we expect physician patient health management skills to be relevant, we focus on the prevention of cardio-vascular disease-related hospitalizations. Cardio-vascular disease is the leading cause of death and hospitalization in most developed economies. The PCP has a central role as a first-line health care provider. Importantly, modern treatment has a pharmacological component that is both crucial in the maintenance of these chronic conditions and also allows for the construction of measures of patient health behavior outside of the physician's office.

Our empirical strategy is implemented in several steps. First, we calculate adherence rates for patients who were prescribed lipid lowering drugs to reduce cholesterol levels. Next, we use information on all other patients at a practice to estimate a time constant measure of health management skills, relying on logic similar to the teacher value added literature (Chetty et al, 2014a). That is, we leverage the average behavior of patients

[3] 5 km in some non-rural areas
[4] USD $1 is approximately DKK 6.
[5] If the physician is more than 60 years old he/she can apply to stop the intake of new patients at a lower threshold.

with the same physician to measure an individual physician-specific component in individual patient adherence. We refer to these systematic differences across physicians as physician health management skill. In the absence of patient sorting across physicians, our estimated physician health management skill is a consistent estimator of a physician's impact on patient health. The assumption that patients do not sort across physicians is a strong one. We check its validity by assessing whether this particular dimension is sensitive to inclusion of observed and unobserved patient heterogeneity. Ultimately, this strategy allows us to investigate whether differences in health management skill across physicians matter for patient health, or whether the relationship between a physician's skills in health management and patient health outcomes is driven by patient composition and sorting.

Estimating health management skills

Previous research shows that there is persistent heterogeneity in medication adherence rates of patients across physicians (e.g. Simeonova, 2013; Koulayev et al., 2017). We focus on adherence with the major cholesterol lowering drug group, statins[6].

The effectiveness of lipid lowering drugs in reducing the risk of fatal and non-fatal events has been documented in numerous clinical trials (see e.g. Scandinavian Simvastatin Survival Group, 1994; Sacks et al,1996; Shepherd et al, 1995). In some trials (Scandinavian Simvastatin Survival Group, 1994) reductions in mortality are found after approximately 1 year in the treatment group, but other studies find effects on non-fatal outcomes of treatment after only a month (O'Driscoll el al, 1997) and Ratchford et al, 2011). Some of the most widely prescribed statins are simvastatin (brand name Zocor), atorvastatin (brand name Lipitor) and fluvastatin (brand name Lescol). Treatment with statins is chronic, and patients are typically instructed to take one pill a day[7], which makes it easier to measure adherence[8] with treatment using claims data.

We start out by constructing patient specific leave-one-out adherence rates. Using data on all individuals with at least two statin prescription claims in Denmark we calculate the leave-one-out average adherence within each physician

[6] There are two forms of cholesterol found in the blood 1) high-density lipoprotein (HDL) and 2) low-density-lipoprotein (LDL). The first form is commonly denoted "the good cholesterol" as it transports the harmful cholesterol (LDL) out of arteries, and high blood level concentrations of HDL is recommended. The latter form (LDL) – or "bad cholesterol" – is what potentially combine with other fats to create blockage of arteries and veins.

Atherosclerosis, thickening of artery walls, is partly due to high levels of cholesterol, and is broadly recognized as an important and modifiable risk factor for CVD. Plaque causes the actual clogging, and is often a result of a cumulative build-up of lipids – small fatty particles penetrating the walls from the blood to arteries, with a speed conditional on the concentration of cholesterol in one's blood.

Lipid lowering drugs reduce the buildup of plaque, thus effectively reducing the likelihood of clogging. However, lipid build-up is irreversible, and once present in veins/arteries, and pharmacological treatment only prevents further buildup. Hence, for the treatment to be effective, a continuous intake of medication is necessary, and pharmacological treatment is considered permanent.

[7] This is the case for 98% if the patients in our sample

[8] Adherence is calculated as proportion of days covered, aka the medication possession ratio. For details see next section.

$$ADH_{-itj} = \frac{\sum_{h \neq i} ADH_h}{m_{jt} - 1} \quad (4)$$

ADH_{-itj} is the individual specific average adherence rate with physician *j* at time *t* not including the focal (index) individual. m_{jt} is the number of patients at physician *j* at time t with at least two statin claims. We then residualize ADH_{-itj} by regressing it on patient and physician observables, as well as a patient fixed effect to obtain the residual, $\hat{\sigma}_{it}$. Finally, the health management skill, Q_j^{HMS}, is constructed by averaging $\hat{\sigma}_{it}$ over time within physician *j*:

$$Q_j^{HMS} = \frac{1}{T_j} \sum_{\tau=1}^{T_j} \frac{1}{m_{j\tau} - 1} \sum_{h \neq i} \hat{\sigma}_{h\tau} \quad (5)$$

Validating our measure of health management skill

It is important to notice that Q_j^{HMS} only truly reflects physician health management skills if patients do not select into physicians on the basis of the physician's ability to inspire adherence with statin medications in her patients. Hence it is important for our analysis to verify that this derived metric is not reflecting patient selection. Given the Danish institutional setting, the choice of primary care physician is up to each patient and likely endogenous with some physician characteristics. As information about alternative physicians within the patient's choice set is very limited, one might not be as worried about *sorting into* the "good" physicians, as much as the *sorting out* of the *"*bad*"* physicians. Hence, we are interested in finding situations in which we can identify separations of patients from physicians where the switching is less likely to be related to the health status of the patient or the physician health management style we outlined above. We identify two different types of patient-physician separations in an attempt to tease out the potential impact of patient composition from the true underlying physician health management skill.

The two types of separations we identify are:

i) Separations due to clinic closures. These are patients who are forced to change physician, because their physician goes out of business due to retirement or residential relocation.

ii) Separations due to patient residential relocation: Those that shift physician because they relocate residentially and cannot stay affiliated with their primary care physician.

When physicians close their clinic, patients affiliated with the clinic are forcibly separated from their physician, and are effectively spread out across other local physicians[9]. We believe that this is the setting with the least scope for sorting out of clinics due to bad physician quality.[10]

Leveraging these pseudo exogenous separations we examine whether the changes in health management skills that patients are subsequently exposed to lead to changes in adherence even in setting with limited scope for physician selection.

Estimating the impact of health management skill on health outcomes

In an ideal research setting, we would be able to randomly assign patients to different physicians and estimate the effects physician management style on patient outcomes. In the absence of such an experiment, we rely on rich registry data and "natural experiments" in physician-patient matching precipitated by residential relocations of patients and primary care clinic closures in Denmark.

To assess the impact of the health management style on patient health outcomes we estimate a model of risk of cardio-vascular disease related hospitalization as a function of the physician management skill. We estimate the model

$$Y_{it} = \beta_0 + \beta_1 Q^{HMS}_{j(i,t)} + \boldsymbol{X}_{it}\beta_2 + \varepsilon_{it}, (6)$$

The experiment we try to mimic is to see how similar individuals would react to different physicians. In equation (6), β_1 is identified from both between and within-patient variation in the quality indices. Hence the coefficients reflect differences in quality dimensions across the entire population of patients and physicians, however we are primarily interested in the estimates that are derived from within-individual variation in exposure to physician management skills. The thought experiment is to assign the same patient to different physicians and track the evolution of her health outcomes across those physicians. To do this, in some models we estimate equation (6) but also control for time-invariant individual heterogeneity through the individual fixed effect, α_i

$$Y_{it} = \beta_0 + \beta_1 Q^{HMS}_{j(i,t)} + \boldsymbol{X}_{it}\beta_2 + \alpha_i + \varepsilon_{it}, (7)$$

The primary outcome variables of interest are hospitalization due to a cardio-vascular disease and health care expenditures due to cardio-vascular disease hospitalizations. As $Q^{HMS}_{j(i,t)}$ is constant across time and within physician, β_1 in (7) is estimated off variation in physicians within the same patient across time. That is, we

[9] When a clinic closes, the patients are free to choose a physician from their choice set that is open for intake of new patients.

[10] We are not the first to use these types of separations. (Markussen et al, 2013) and (Godøy et al, 2018) uses separations due to closures to assess the impact of physicians on sickness absence. (Finkelstein et al, 2016) and (Laird and Nielsen, 2016) uses residential relocators to identify place and provider fixed effects.

only identify the coefficient from individuals seeing different physicians over time, and we will use the separations described previously as natural instruments of separations to assess the robustness of our results. In addition to the challenge of sorting between patients and physicians, we need to include sufficient controls for baseline CVD hospitalization risk, in order to allow for a physician value added interpretation. We achieve this as our regressions include highly detailed patient characteristics as well as the past CVD and other comorbidities that have been demonstrated to predict all cause and CVD mortality.

4. Data

We use the full population of adult individuals in Denmark who have at least two statin claims[11] between January 1st 2004 and July 1st 2008. In addition to the prescription data we have data on hospitalization and the primary diagnoses (by ICD-10) for hospitalizations, as well as health care expenditures. The prescriptions and hospitalization data are augmented with detailed individual level economic and demographic information from several different registries.

Our main sample is constructed by observing the initial individual purchases of lipid-lowering prescription drugs. We then calculate the adherence as a proportion of days covered through a period of 6 months. The outcome measures are the probability of cardio vascular disease-related hospitalizations and the associated hospitalization expenditures within the subsequent 12 months.

This approach offers the possibility to evaluate the relationship between short-term fluctuations in adherence and short-term health outcomes as well as strictly separating the periods in which adherence and hospitalization outcomes are measured. This is important because adherence may respond to a hospital stay either mechanically, through patients receiving new directions or new therapies during their in-patient stay, or as a behavioral response to a negative update on their health status which triggers (temporarily) improved adherence.

	6 months	6 months	6 months	6 months
Ind. A	Adherence t=1	Outcome: CVD hospitalization t=1		
Ind. A		Adherence t=2	Outcome: CVD hospitalization t=2	

Figure 1: *Sample construction linking adherence to outcomes over time.*

Figure 1 explains the sample construction. For individual A we observe adherence for 6 months initiated at the first pharmacy claim. We also observe whether the individual is hospitalized in the subsequent 12 months. We measure adherence as *Proportion of Days Covered*[12]. Starting from the day of initiation of treatment we

[11] The first claim is the initiation. We drop individuals, who never has more than one claim, to calculate adherence rates.
[12] Also sometimes referred to as a "Medication Possession Ratio"

measure the fraction of days within a 6-months period the individual is covered with any statin. The individual is allowed to keep excess medication for one period, and because we focus on adherence on the intensive margin, we drop individuals when there is no claim in a period and no excess medication from previous periods. Patients who completely discontinue treatment in this fashion are non-persistent, or could have discontinued the therapy for reasons unknown. The fact that we focus on the intensive margin of adherence has implications for the interpretation of the results. Namely, our estimates capture the effects differences in patient adherence with statins on health outcomes, *conditional on continued statin intake*. The effects we find are identified from *marginal changes in the adherence rate*, not from drastic changes in the therapy initiated by the physician or the patient. We exclude 0.25 percent of the patient-observations because the individual dies in a period and where we observe a statin claim or excess medication has been kept from a previous period.

Table 1 displays the means and standard deviations of the main demographic and outcome variables in the full sample and in the different subsamples. We separate out patients who changed physicians over the observation period, and within that sample we identify two distinct subsamples: those who changed physician because they re-located to a different residential address; and those who changed physician because the original clinic closed. A priori one would have different expectations regarding the causes of these shifts, relative to the rest of physician-patient separations. It is reasonable to expect that patients who initiate a separation without any observable external event tend to switch based on personal preferences, individuals who relocate are forced change physicians. The set of individuals affiliated with primary care clinics that close due to e.g. physician retirement, long term sickness or geographic re-location of the physician[13], are also effectively forced to initiate a switch. Thus, for these two sets of physician-patient separations, we can plausibly assume that the change in physician is not the results of patient selection out of the care of the provider. About 17 percent of the sample change physicians during the observation period for any reason. Less than half of those changes are precipitated by a clinic closure or patient residential re-location.

Statin-users in Denmark are more likely to be male and married, on average in their early- to mid-60s, with annual incomes roughly equivalent to forty thousand dollars. About 40% of them have completed only primary education, 50% have finished vocational training or some college, and only about 6% have university education. Only 5% of the sample are born outside of Denmark.

The prescriber ID we observe in the data pertains to the *clinic* and not the individual prescribing physician within the clinic. However, in our sample 46% of primary care clinics have only one physician associated with

[13] The only other reason why a clinic might close is that a physician's license is revoked. Effectively this never happens.

them, so that the clinic ID will uniquely identify the prescribing physician. In cases where the clinic is operated by more than one physician, we interpret any measure of quality as representing an average treatment style of the clinic. The analysis has been conducted separately for clinics with only one physician, and the results are qualitatively and quantitatively similar, as can be seen from appendix table A1 and A2. Moving on, we will use the words clinic and physician interchangeably.

Table 1: Descriptive statistics by subgroup measured at sample entry. Standard deviations in square brackets below the variable mean.

		All	**Movers**	
			Residential relocation	**Clinic closures**
Variable		Mean	Mean	Mean
Age		64.29	62.64	65.07
		[11.32]	[11.85]	[10.58]
Income (in DKK 1,000)		192.19	195.73	186.41
		[114.15]	[118.93]	[111.10]
Married		0.63	0.57	0.64
		[0.48]	[0.49]	[0.48]
Male		0.51	0.53	0.51
		[0.5]	[0.5]	[0.5]
Education	Primary School	0.42	0.39	0.42
		[0.49]	[0.49]	[0.11]
	High school	0.01	0.02	0.01
		[0.12]	[0.14]	[0.48]
	Vocational	0.35	0.35	0.37
		[0.48]	[0.48]	[0.48]
	Tertiary Short	0.15	0.16	0.14
		[0.35]	[0.37]	[0.35]
	Tertiary Long	0.06	0.08	0.06
		[0.24]	[0.26]	[0.23]
Foreign born		0.05	0.07	0.05
		[0.21]	[0.25]	[0.21]
Charlson CI		0.80	0.92	0.85
		[1.24]	[1.33]	[1.24]
CVD Hospitalization		0.05	0.07	0.06
		[0.22]	[0.26]	[0.23]
Hospital Expenditures (1000 DKK)		4.05	4.85	5.03
		[21.7]	[23.6]	[23.7]
Adherence		0.82	0.82	0.84
		[0.23]	[0.24]	[0.23]
Individuals		510,159	20,185	17,538

For the patients who switch providers during the observation window, we assign the health management metric of the new physician based on all years for all of her patients other than the index individual i. That is, in t=0 where we observe the new physician-patient match, we assign the time-constant health management skill of the new physician. We have assigned the health management skill values of the original physician at t=-2,-1 and the value of the new physician on t=0,1,2.

Figure 2 shows the standardized distributions of physician health management skill. The standard deviation in the non-standardized measure is 0.005

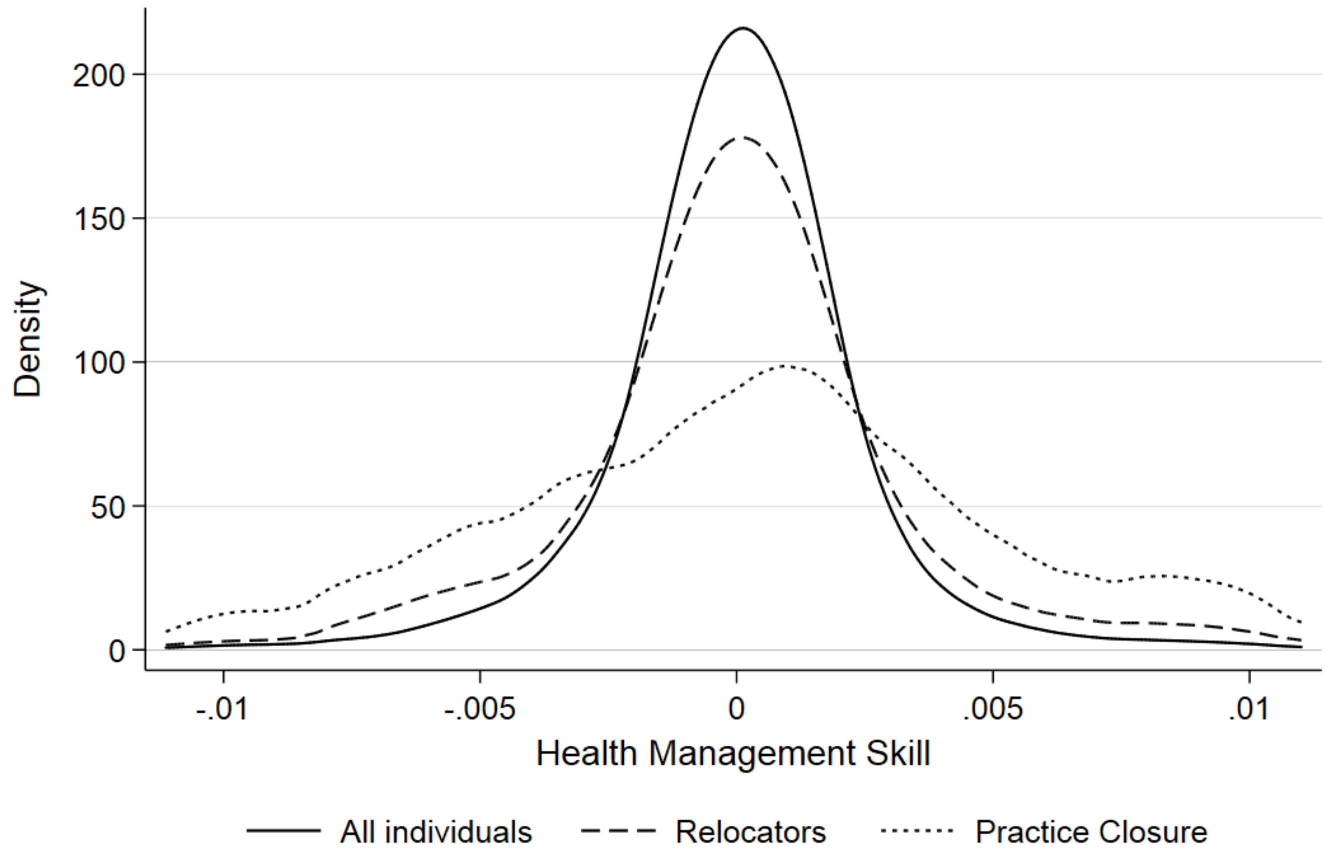


Figure 2: Kernel density estimate of the standardized health management skill measure for the entire sample, as well as the two subsamples experiencing relocations or practice closures. The kernel used is gaussian and the bandwidth is 0.001. The standard deviation in the entire population is 0.005. For the relocation and the practice closure samples the standard deviation is 0.01 and 0.017 respectively.

6. Validating the metric of health management skill

In this section we seek to validate our measure of physician health management skills. To do this we establish that individual adherence is affected by the physician health management skill, and is not the results of patient sorting. In particular, we show that individual adherence with statins improves upon switching to a new physician who has better health management skills, or decreases when the patient encounters a new physician with worse health management skills. This finding is robust to controlling for individual-specific time-invariant unobservable characteristics. We also show that physician health management exhibits mean reversion upon changes, indicating that our findings are not a result of patient sorting.

To establish that individual adherence is affected by physician health management skills we estimate models similar to eq. (6) and (7) with adherence as the outcome. These results are reported in Table 2. The first 2 columns in panel A report results based on the entire population. Column 1 shows how an increase in average health management skill of one standard deviation increases individual adherence by about 1 percentage point, and this effect is not sensitive to inclusion of individual characteristics in column 2.

Having shown that health management skill affects individual health behavior, we utilize the quasi- exogenous patient-physician matches formed after patients relocate or physicians close their practice to verify the metric of health management skill. These new matches are less likely to suffer from selection. We start off by showing in an event-study type setting that the forced change of primary care physician leads to an immediate change in health management style, to which adherence responds accordingly. We also show that health management skill exhibits mean-reversion, in the sense that individuals who experienced lower levels of physician health management pre-closure (pre-relocation) on average experience the largest increases in physician health management skill post-closure (post-relocation). It is important for the validity of our estimates that certain types of patients do not sort into specific types of physicians. If, for instance, high-adhering patients systematically choose particular physicians, these physicians would seemingly have a high level of health management skill. Hence, we would like to see that the physician health management skill exhibits mean reversion properties in the event of exogenous physician switches, such that individuals who had high-type physicians do not systematically switch to new high-type physicians.

Analyzing changes in health management skills in a standard event study framework is problematic. When switching to a new physician in these types of settings the change is not guaranteed to be uniformly either positive or negative, as a switch from high to low levels for some individuals might be offset by low to high level switches for other individuals. Hence, the changes in health management skills might balance out on average. To overcome this issue, we conduct separate analyses based on the level of health management skill of the patient's pre-closure physician. [14]

Figures 3 and 4 present the evolution in adherence for patients who re-locate and individuals experiencing a clinic closure, respectively. The graphs depict the evolution in adherence for individuals who pre-separation have providers with physician health management skill in the lowest quartile (Panel A), and physician health management skill in the highest quartile (Panel B).[15] These graphs show that physician health management has a substantial impact on patient adherence.[16] In Figure 3 panel A we see that individuals who prior to relocating have a physician with health management skills in the lowest quartile, on average see an *increase* in their adherence increases by 4.3 percentage points or 5.4% relative to the mean. On the contrary, figure 3

[14] We do this by analyzing changes in adherence when an individual separates from a provider from different quartiles of health management skills. The quartiles are calculated within the respective samples. In the relocator sample the standard deviation of the health management skill is .009, while it for the clinic closure sample it is 0.018

[15] Similar graphs for individuals with pre-physician health management in the 2nd and 3rd quartile are presented in the appendix.

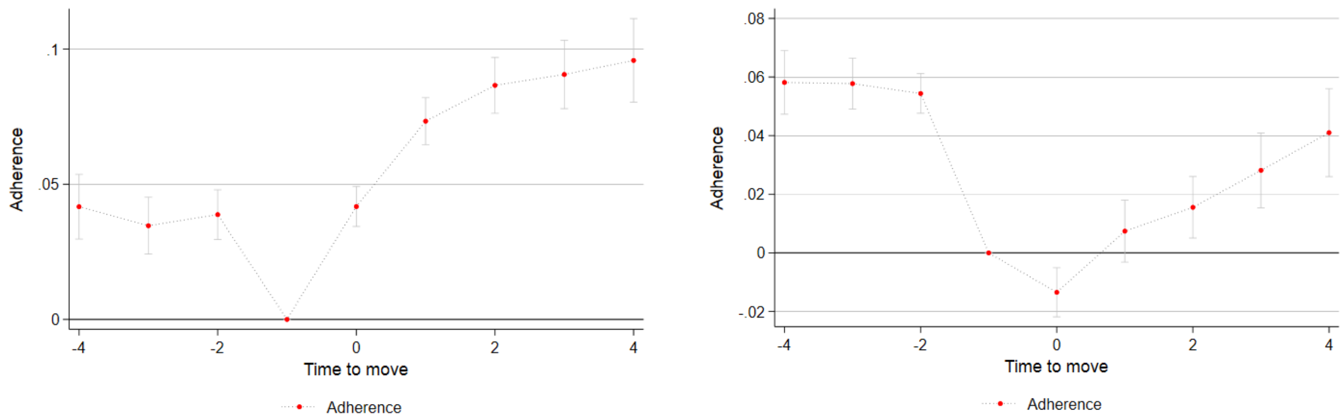
[16] To measure the change in adherence, we estimate regression models of the form $Adh_{i\tau} = \mu A_{i\tau} + \theta_\tau + \eta_{i\tau}$ for each quartile of the health management skill of the patient's pre-closure physician. The results are available in appendix tables A1 (relocators) and A2 (practice closures). Similar regressions are estimated with the outcome being health management skill. These results are also available in the appendix.

panel B shows that individuals in the highest quartile of physician health management pre-relocation, on average experience a *decrease* in adherence of 2.8 percentage points or 3.3% relative to the mean.

Figure 4 shows that the same pattern exists for individuals who move to a new physician due to a clinic closure. Panel A of Figure 4 shows that individuals who prior to closure have a physician in the lowest quartile of health management skills, on average see an increase of 8.8 percentage points in adherence. This corresponds to 11.1% relative to the mean of adherence. Similar to those who re-locate their geographic residence, patients experiencing a closure of a PCP office that was in the highest quartile of physician health management skills experience a reduction in adherence of 1.4 percentage points or 1.6% to the mean of adherence. Appendix tables A1 and A2 also report the implied changes in health management skills. It is clear that coming from a lower (higher) level of health management skill on average results in increases (decreases) in health management skill post separation. In appendix figures A1 and A2, figures similar to figure 3 and 4 also including the change in health management skill, show how the change in health management skill is sudden and persistent[17]

Figure 3: Residential re-locators

Panel A: 1st Quartile pre-HMS   Panel B: 4th quartile pre-HMS



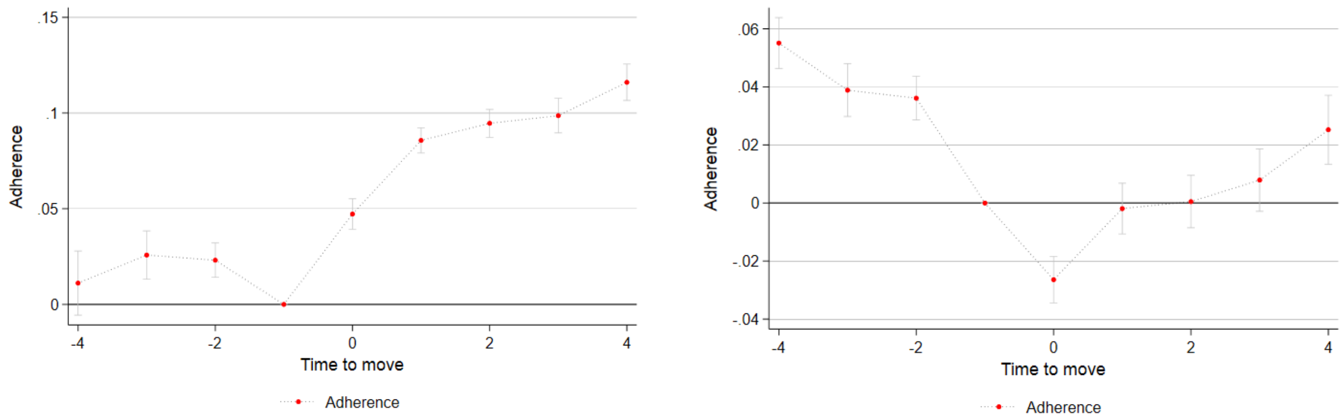
Notes: Physician health management skill and adherence for individuals relocating by quartile of pre-closure level of physician health management skill. Individuals are measured relative to the last period where the old physician is encountered (t=-1)

[17] Note that in these figures there is a slight fluctuation in pre-closure health management skills due to patients entering and leaving the sample when they stop using statins. In appendix figures A5 and A6 we present graphs that are constructed by restricting the sample to those that have only one physician in the periods prior to the closure, and are in our sample for the 4 periods prior and 4 periods after (6 months each) experiencing the patient-physician separation. From these it is even more evident that the shift indeed leads to an immediate change in physician health management skills.

Figure 4: Physician health management skill and adherence for individuals experiencing a clinic closure.

Panel A: 1st Quartile pre-HMS

Panel B: 4th quartile pre-HMS



Notes: Physician health management skill and adherence for individuals experiencing a clinic closure by quartile of pre-closure level of physician health management skill. Individuals are measured relative to the last period where the old physician is encountered (t=-1).

Having shown that changing provider lead changes in health management skills that implies changes in adherence we leverage the pseudo exogenous changes in provider to validate the impact of health management skill. Columns 3 and 4 in table 2 estimate models similar to columns 1 and 2 for the entire subpopulation of residential re-locators. The specifications in Columns 5 and 6 repeat the exercise for the subgroup experiencing a clinic closure. The impact of a 1 standard deviation increase in physician health management skill on adherence is 0.8 percentage points and 0.7 percentage points in the group of residential re-locators and individuals experiencing a clinic closure respectively. The estimates are not affected by the inclusion of individual characteristics. In panel B we control for time-invariant individual unobserved heterogeneity (individual fixed effects) and find very similar results.

Table 2: Individual-level adherence regressed on health management skills. Re-locators and individuals experiencing a clinic closure are followed 2 periods before and 2 periods after.

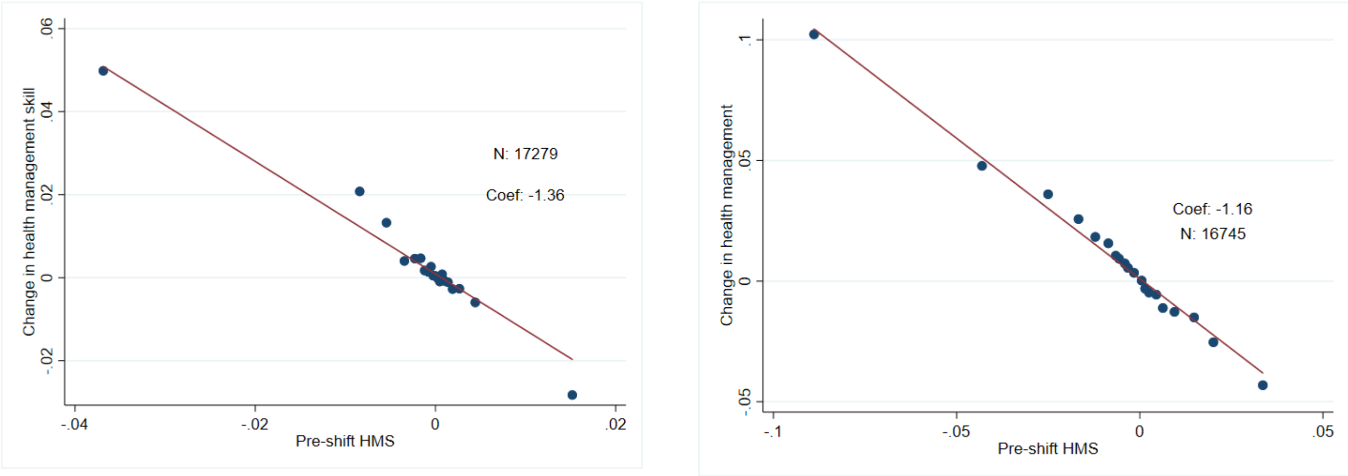
Panel A						
	(1)	(2)	(3)	(4)	(5)	(6)
Outcome	Adherence					
HMS	0.009***	0.009***	0.008***	0.008***	0.007***	0.007***
(std)	(0.0005)	(0.0005)	(0.0009)	(0.0009)	(0.0004)	(0.0004)
Observations	2,675,429	2,675,429	84,406	84,406	79,933	79,933
Mean Adherence	0.82	0.82	0.82	0.82	0.84	0.84
R-squared	0.020	0.027	0.025	0.036	0.045	0.051
Time	Yes	Yes	Yes	Yes	Yes	Yes
Region	Yes	Yes	Yes	Yes	Yes	Yes
Ind. Cov	No	Yes	No	Yes	No	Yes
Comorbidities	No	Yes	No	Yes	No	Yes
Population	All observations	All observations	Relocators	Relocators	Clinic Close	Clinic Close

Panel B – including patient fixed effects						
	(1)	(2)	(3)	(4)	(5)	(6)
Outcome	Adherence					
HMS	0.009***	0.009***	0.009***	0.009***	0.007***	0.007***
(std)	(0.000291)	(0.000296)	(0.000557)	(0.000564)	(0.000279)	(0.000279)
Observations	2,675,429	2,675,429	84,406	84,406	79,933	79,933
Mean Adherence	0.82	0.82	0.82	0.82	0.84	0.84
R-squared	0.428	0.428	0.481	0.481	0.468	0.468
Time	Yes	Yes	Yes	Yes	Yes	Yes
Region	Yes	Yes	Yes	Yes	Yes	Yes
Ind. Cov	No	Yes	No	Yes	No	Yes
Comorbidities	No	Yes	No	Yes	No	Yes
Population	All observations	All observations	Relocators	Relocators	Clinic Close	Clinic Close

To further support our finding that physician health management skill exhibits mean reversion, we analyze how the change in health management skill is associated with the health management levels before the change. While figure 2 and 3 illustrated how individuals in opposite quartiles of pre-shift health management levels experienced opposite evolutions in health management skill, figure 5 illustrates the case for the entire distribution of pre-shift health management skill. To construct this figure, we collapse the data to the periods immediately before ($t \in$(-2 , -1)) and after ($t \in$ (0,1, 2)) and calculate the change in health management skill. We then group the data into 20 equally sized bins based on pre-shift health management skill and calculate the mean change in health management within each of these bins. We do this separately for separations due to residential re-locators (panel A) and for individuals experiencing a clinic closure (panel B). Additionally, we fit a line through the bins to estimate the relationship between pre-shift health management skills and the change. We find that, based on re-locations, a 1 standard deviation higher pre-shift health management skill is associated with a change in health management skill of 1.36 of a standard deviation. Similarly, for individuals experiencing a clinic closure, a 1 standard deviation higher pre-shift health management skill is associated with a change of 1.16 of a standard deviation

Figure 5: Mean reversion in physician health management skill

Panel A: Relocations Panel B: Clinic closures



Notes: Mean reversion in physician health management skill. The figure plots the change in health management skill relative to pre-shift health management skill. Pre-shift health management skill is group into 20 equally sized bin, within which the mean change is calculated. The coefficient (highly significant at a 1% level) is the fitted line through these 20 points.

7. Results – health management skills and patient outcomes

In this section we estimate the impact of physician health management skills on patient health outcomes. After presenting results from the entire population we conduct robustness analysis on the subgroups switching physicians due to either residential relocation or clinic closure. Table 3 shows the results from empirical models of hospitalization risk of CVD-related admissions, measured as a binary variable, as a function of health management style. The health management style index is standardized with mean zero and unit standard deviation, and coefficients should be interpreted as the impact of a one standard deviation increase in the skill dimension on the outcome of interest. The time window for hospitalization is within one year after the end of the 6-month period during which the adherence measure is calculated.

In column 1 of panel A of Table 3 the regression includes only calendar year fixed effects and geographic region fixed effects. Taking the results at face value, column 1 shows that a one standard deviation increase in physician health management skill decreases the probability of a CVD-related hospitalization in the subsequent year by 0.07 percent. Taken relative to the outcome mean of 5.7 percent this is a relative reduction of 1.3 percent.

Controlling for individual level socio-demographic information in column 2 and health status (captured here through the Charlson comorbidity index) only marginally reduces the estimate of the impact of health management skills.

Panel B reports the same specifications as in panel A, but adding patient fixed effects, to control for time-invariant individual level unobserved heterogeneity. The estimates of the associations between physician health management skills and CVD-related hospitalizations are mostly unchanged after the inclusion of the patient-level fixed effects.

The models in Table 4 are identical to those presented in Table 3, but the outcome is now the log of CVD-related hospitalization expenditures in Danish crowns (DKK) incurred in the year after the end of the 6-month period over which the health management skill measure was calculated. The pattern is the same as for the hospitalization risk. Consistently across all specifications a one standard deviation increase in physician health management skills is associated with a 0.24-0.3 percent decrease in CVD-related hospitalization expenditures in the next year. In appendix tables A1 and A2 we re-do tables 3 and 4 respectively for single physician clinics only. The results are similar.

Table 3: The association between physician health management skills and Cardio-Vascular-Disease-related hospitalization risk. Linear probability regressions. Standard errors are clustered at clinic level.

	(1)	(2)	(3)
Panel A (No Individual FE)			
Health Management Skill	-0.0734***	-0.0703***	-0.0649***
(x100)	(0.0247)	(0.0242)	(0.023)
Panel B (individual FE)			
Health Management Skill	-0.0691***	-0.0732***	-0.0672***
(x100)	(0.0236)	(0.0234)	(0.0235)
Observations	2,601,554	2,601,554	2,601,554
Mean CVD hospitalization	0.05	0.05	0.05
R-squared	28%	28%	29%
Time	Yes	Yes	Yes
Region	Yes	Yes	Yes
Ind. Cov	No	Yes	Yes
Comorbidities	No	No	Yes

Robust standard errors in parentheses, clustered on the clinic level
*** p<0.01, ** p<0.05, * p<0.1

Table 4: The association between physician health management skills and Cardio-Vascular-Disease-related hospitalization expenditures. The outcome measure is the log of CVD-related hospitalization costs over a six-month period. Linear regression models. Standard errors are clustered at clinic level.

	(1)	(2)	(3)
Panel A (No Individual FE)			
HMS	-0.298***	-0.286***	-0.264***
(x100)	(0.101)	(0.0986)	(0.0939)
Panel B (Individual FE)			
HMS	-0.267***	-0.281***	-0.257***
(x100)	(0.0914)	(0.0913)	(0.0919)
Observations	2,601,554	2,601,554	2,601,554
Mean Hosp. Exp (1000DKK)	4.05	4.05	4.05
R-squared	0.28	0.28	0.29
Time	Yes	Yes	Yes
Region	Yes	Yes	Yes
Ind. Cov	No	Yes	Yes
Comorbidities	No	No	Yes

Robust standard errors in parentheses, clustered on the clinic level

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

Subgroup analysis – exogenous separations: residential re-locations and clinic closures

We now present a set of sensitivity analyses to assess whether the relationship between health management skills and CVD outcomes are due to patient selection.

Again we focus on two particular groups of patients: patients who relocated their residence and thus had to change physician, and patients whose original physician practice closed.

It is unlikely that patients would move residence because they want to switch physicians or that practices would close because of the quality of the patient load. That is why estimates based on these two subsamples are less likely to be affected by selective patient-physician matching. The sample size is reduced considerably to approximately 10% of the original for two reasons: first, we discard those individuals who stay with the same physician for the entire observation window, and secondly, we focus on the time period close around the switches (results are similar if we include time periods further away from the switches; see appendix Tables A5 and A6). We assign the old physician's health management skill to the months during which the patient is visiting that physician; the new physician's skill for the months after the change.

The results are reported in Table 5. Panel A reports the estimates from the general pooled regressions and Panel B presents the corresponding estimates from models including patient fixed effects.

For the two groups of switchers where the separation from the physician is plausibly due to non-health related reasons we see comparable estimates to those of the full sample. Considering switches due to clinic closures in columns 2 and 3, we find that the estimates are qualitatively the same as those for the entire sample (column 1). For those who switch physician due to residential relocation (column 2) the point estimate is numerically larger at -0.114, however it is not statistically significantly different.

Table 5: Associations between physician health management skills and Cardio-Vascular-Disease hospitalization risk. Linear probability regressions. The table only includes observations for t={-2,0-2} for individuals who are separated from their physician before t=0. Standard errors are clustered at the origin clinic.

	(1)	(2)	(3)
Outcome	CVD hospitalization		
Panel A: No Patient Fixed Effects			
HMS	-0.0803***	-0.114**	-0.0885***
(x100)	(0.0267)	(0.0545)	(0.0326)
Observations	340,486	85,168	80,401
R-squared	0.055	0.059	0.056
Panel B: Including Patient Fixed Effects			
HMS	-0.0756***	-0.105**	-0.0652**
(x100)	(0.0238)	(0.0433)	(0.0328)
Observations	340,486	85,168	80,401
Mean CVD hosp	0.05	0.07	0.06
R-squared	0,34	0,361	0,343
Year FE	Yes	Yes	Yes
Region	Yes	Yes	Yes
Ind. Cov	Yes	Yes	Yes
Comorbidities	Yes	Yes	Yes
Sample	All Shifters	Residential	Clinic Closures

Robust standard errors in parentheses, clustered on the clinic level
*** p<0.01, ** p<0.05, * p<0.1

We report the results for the hospitalization expenditures in Table 6 panels A and B, and the results are comparable to those of Table 4; for the sample of all movers we find that one standard deviation increase in health management skills decreases CVD-related hospitalization expenditures for the physician's patients in the next year by 0.275 percent.

Table 6: Associations between physician health management skills and Cardio-Vascular-Disease hospitalization expenditures. The table only includes observations for t={-2,0-2} for individuals who are separated from their physician before t=0. Linear regression models. Standard errors are clustered at clinic level.

	(1)	(2)	(3)
Outcome: Ln (CVD-related Hospital Expenditure)			
Panel A: No Patient Fixed Effects			
HMS	-0.317***	-0.421**	-0.355***
(x100)	(0.107)	(0.196)	(0.133)
Observations	340,419	85,115	80,401
R-squared	0.057	0.062	0.058
Panel B: Including Patient Fixed Effects			
HMS	-0.275***	-0.359**	-0.255**
(x100)	(0.0919)	(0.156)	(0.126)
Observations	340,419	85,115	80,401
Mean Hosp. Exp (1000DKK)	4.05	4.85	5.03
R-squared	35%	37%	35%
Year FEs	Yes	Yes	Yes
Region	Yes	Yes	Yes
Ind. Cov	Yes	Yes	Yes
Comorbidities	Yes	Yes	Yes
Sample	All Shifters	Residential	Clinic closures

Robust standard errors in parentheses, clustered on the clinic level
*** p<0.01, ** p<0.05, * p<0.1

Health management skills and clinical quality

Having shown that there is a robust association between the health management skills of the physician and patient health, we might worry that our measure of physician skills is merely reflecting the clinical quality of the physician, or her ability to make an adequate diagnosis and prescribe the correct treatment. If clinical quality is highly correlated with health management skills, and we are not controlling for it, then this could lead to misleading interpretation of the estimates.

To explore this, we turn to the literature on clinical quality in primary care. Hospitalizations due to Ambulatory Care Sensitive Conditions (ACSC) are widely accepted and frequently used metrics used to assess the quality of primary health care (see e.g. Harrison et al, 2014; Oster et al, 2003, and Johnson et al, 2012). These are hospitalizations that are avoidable in the sense that proper outpatient care would prevent them. In a US setting, Oster and co-authors (2003) find that African Americans, patients covered by Medicaid, and uninsured patients constitute a disproportionate share of emergency department visits that accrue to ACSCs[18]. We identify the subset of ACSCs that are related to urinary tract infections, bacterial pneumonia, chronic obstructive pulmonary disease and dehydrations; see appendix table A8 for a complete list of ICD-10 codes. We specifically leave out hospitalizations for conditions related to CVD to measure aspects of physician quality that are not directly linked to our outcome of interest. As with the health management skill, we calculate leave-one-out means of the included admissions on a patient-physician level, and combine the admissions into one index. Next, we replicate the analysis from Table 5, with the inclusion of this new quality metric derived from avoidable hospital admissions (ACSCs); see Table 7. Note that a higher ACSC ('better quality') is associated with lower rates of CVD admissions. Strikingly, adding this quality metric to the regressions does not affect the impact of the health management skill variable in any meaningful way. In our preferred specification in column 3 using pooled data, we find that one standard deviation change in ACSC-based quality has similar effects on CVD hospitalization as one standard deviation change in physician management skills. Further, we notice that controlling for time-invariant unobserved patient characteristics drastically reduces the association from the ACSC quality metric and CVD outcomes (the coefficient becomes close to zero and insignificant); see panel B of Table 7. Similar to the results of table 5, adding individual fixed effects does not affect the estimated coefficient of HMS in any meaningful way.

Table 8 reports results for health care expenditures, and the conclusion is similar. Notably, the correlations of HMS and ACSC with health care costs are very similar in the pooled sample but the coefficient on the ACSC-based quality metric is positive and very close to zero when we account for unobserved time-invariant patient characteristics.

[18] Harrison et al. (2014) study the impact of a national primary care pay for performance scheme rolled out by the English National Health Service. As part of the performance scheme, reductions in a subset of the ACSCs were incentivized on the physician side, and the rates of these hospitalizations declined in comparison to non-incentivized ACSC hospitalizations.

Table 7: The association between physician health management skills, ACSC quality and CVD-related hospitalization risk. Linear probability regressions. Standard errors are clustered at clinic level.

	(1)	(2)	(3)
Outcome		CVD hospitalization	
Panel A: No Patient Fixed Effects			
HMS (x100)	-0.0816***	-0.0767***	-0.0691***
	(0.0250)	(0.0244)	(0.0233)
ACSC quality metric (x100)	-0.135***	-0.0916***	-0.0611***
	(0.0259)	(0.0230)	(0.0203)
Observations	2,686,216	2,686,216	2,686,216
R-squared	0.003	0.012	0.049
Panel B: Including Patient Fixed Effects			
HMS (x100)	-0.0724***	-0.0725***	-0.0669***
	(0.0233)	(0.0233)	(0.0234)
ACSC quality metric (x100)	0.0105	0.0103	0.0043
	(0.0199)	(0.0199)	(0.020)
Observations	2,601,554	2,601,554	2,601,554
Mean CVD hosp	0.05	0.07	0.06
R-squared	0.408	0.408	0.418
Year FE	Yes	Yes	Yes
Region	Yes	Yes	Yes
Ind. Cov	No	Yes	Yes
Comorbidities	No	No	Yes

Robust standard errors in parentheses, clustered on the clinic level
*** p<0.01, ** p<0.05, * p<0.1

Table 8: The association between physician health management skills, ACSC quality and CVD-related hospitalization risk. Linear probability regressions. Standard errors are clustered at clinic level.

	(1)	(2)	(3)
Outcome		CVD hospitalization costs	
Panel A: No Patient Fixed Effects			
HMS (x100)	-0.334***	-0.314***	-0.282***
	(0.103)	(0.100)	(0.0952)
ACSC quality metric (x100)	-0.579***	-0.396***	-0.270***
	(0.107)	(0.0944)	(0.0826)
Observations	2,685,804	2,685,804	2,685,804
R-squared	0.003	0.012	0.050
Panel B: Including Patient Fixed Effects			
HMS (x100)	-0.278***	-0.279***	-0.256***
	(0.0908)	(0.0909)	(0.0917)
ACSC quality metric (x100)	0.0379	0.0370	0.0147
	(0.0803)	(0.0802)	(0.0813)
Observations	2,601,554	2,601,554	2,601,554
Mean Hosp. Exp (1000DKK)	4.05	4.85	5.03
R-squared	0.420	0.420	0.429
Year FE	Yes	Yes	Yes
Region	Yes	Yes	Yes
Ind. Cov	No	Yes	Yes
Comorbidities	No	No	Yes

Robust standard errors in parentheses, clustered on the clinic level
*** p<0.01, ** p<0.05, * p<0.1

8. Health management skills and physician characteristics

We have established that the physician's health management skills affect patient health outcomes. Our setting provides a unique opportunity to investigate whether health management skills are associated with observable provider characteristics[19]. Previous research has demonstrated that the gender of the treating physician is correlated with patient outcomes: for example, investigating records on hospitalized Medicare beneficiaries in the US, Tsugawa and co-authors (2017) showed that patients who were treated by a female physician had significantly lower mortality and readmission rates. In another study on Canadian data, Wallis and co-authors (2017) found that among 25 different surgical procedures, 30-day readmission rates were statistically significantly lower when the surgeon was female (however the difference was small). As both are studies of associations it is not fully understood what the underlying mechanism is, i.e. if the findings are driven by a differential patient-mix (though some patient characteristics are controlled for). In a meta-analytic review Roter and co-authors (2002) found that female primary care physicians engage in more patient-centered communication and had visits of longer duration compared to their male colleagues. If this is the case, we would expect female gender of the PCP to be positively correlated with our measure of health management skills. To investigate this, we estimate the following physician-level regression of the standardized health management skill metric on practice level characteristics:

$$\hat{Q}_j = \gamma_1 X_{jt} + r_j + \tau_t + \theta_{jt} \quad (8)$$

$\hat{Q}_j$ is the estimated health management skill from (5), X_{jt} are practice level characteristics, r_j are municipality fixed effects, and θ_{jt} is an error term. X_{jt} includes an indicator for whether there is at least one female in the practice, whether there are any immigrant physicians in the practice and the mean age of physicians working in the practice. 48.9% of the practices have a female physician employed, and 9.2% have a physician with an immigrant background. The mean age of the physicians is 54.0 years, where the mean age in practices that do not employ females is 56.3, and it is 51.5 in practices that do employ at least one female. The results from estimating (8) are reported in table 9 below. All models include year and municipality dummies, and standard errors are clustered at the municipality level.

[19] As we only have characteristics on the practice level, we show that our findings are robust to limiting the sample to single-physician practices, where we know the specifics of the provider characteristics. In appendix table A6, we replicate our finding using only single physician practices, where we know for a fact whether the patients see a female or male physician. Histograms of the distribution of clinical and communication skills across providers are included in the appendix.

Table 9: Associations between practice health management skills and provider characteristics. Outcomes are standardized with mean 0 and unit standard deviation. All models include time and municipality dummies. Standard errors are clustered at the municipality level

	(1) Std. HMS	(2) Std. HMS	(3) Std. HMS
Female	0.156**	0.162**	0.0218
	(0.062)	(0.064)	(0.044)
Immigrant		-0.205	-0.269*
		(0.124)	(0.137)
Age			-0.030***
			(0.010)
Observations	12,665	12,655	12,655
R-squared	0.010	0.010	0.016

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Our results reveal an interesting pattern. In model 1 we find that practices with female physicians have better health management skills on average. Having a female in the practice is associated with approximately 16% of a standard deviation higher HMS. The estimate is statistically significant and the positive relationship aligns with the aforementioned literature on gender differences. Further controlling for physician immigrant status, the correlation between health management skills and female gender remains positive and statistically significant. However, when we also control for provider age, the association of having females in the practice and the management skill drops to approximately 2% and is insignificant at conventional levels. The coefficient on age is however highly significant, and implies that an increase in provider age of one year is associated with a decrease in health management skills of 3% of a standard deviation. Perhaps unsurprisingly, relatively younger practices are more likely to have female physicians, and younger practices are also more likely to have high levels of health management skills, conditional on patient characteristics. The difference in average health management skills between provider genders disappears when provider age is controlled for.

This is not only the case at the mean, as we can see in figure 6 below (see figure D3 in appendix D for single physician practices only). Here we present local linear regressions of the standardized health management skills on provider age. The relationship is presented for males and females separately. The negative relationship is evident in both groups, and they are never statistically different from each other. These findings are consistent with the fact that from 1977 to 2017, the female share of the Danish PCP workforce increased from 10 to 50%.[20] That is, the female PCPs in our sample are systematically younger than male PCPs. Hence, we feel confident concluding that in a setting that evaluates health management skills in primary care, where the patient mix is sufficiently controlled for, there is no differential return to female doctors, after we include

[20] https://www.laeger.dk/sites/default/files/plo_faktaark_2017_oktober_2.pdf (in Danish)

controls for the age of the physician. Further, we interpret our findings that more recent (and perhaps more up-to-date) training of physicians is an important factor in physician health management skills.

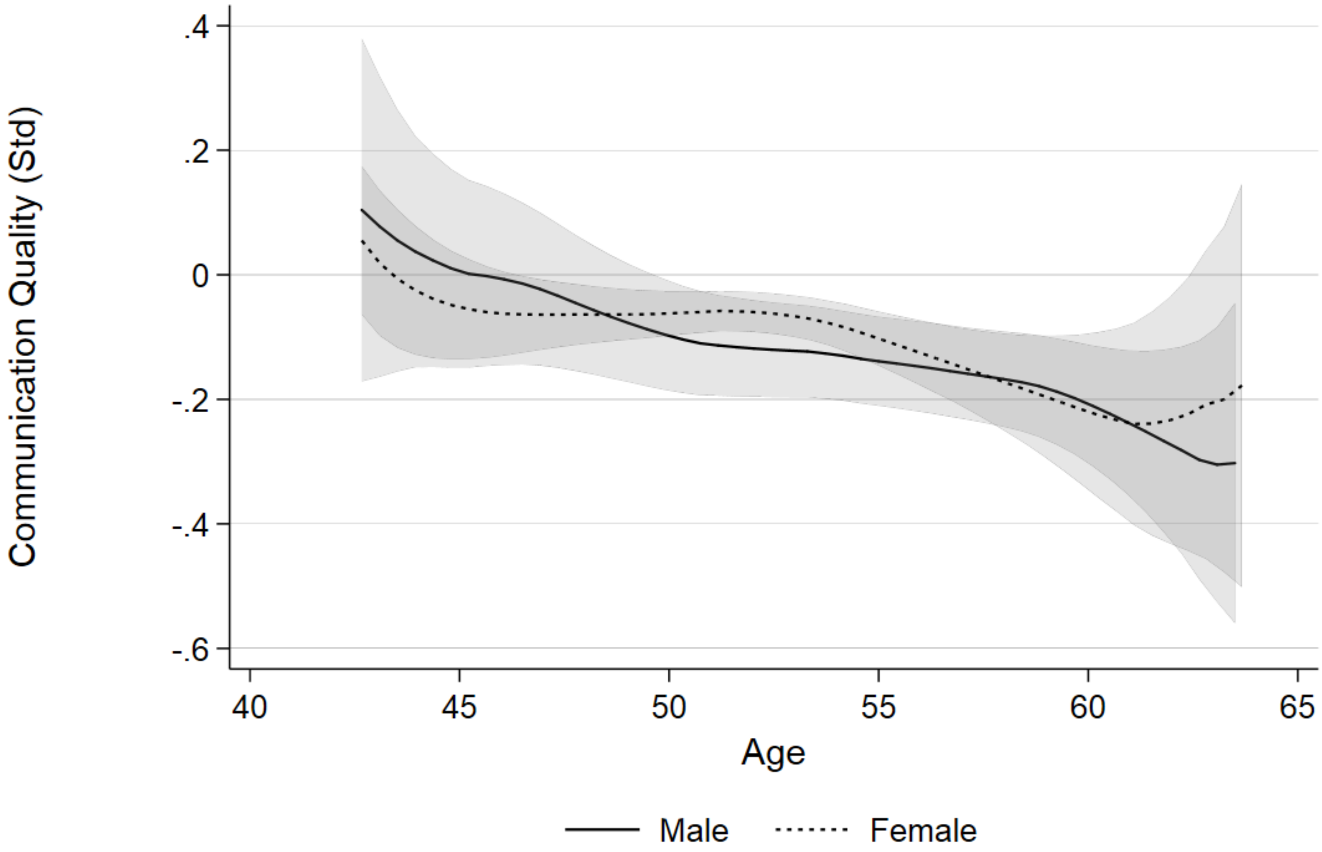


Figure 6 Local linear regressions of communication quality and age by provider gender.

9. Conclusions

The full extent of the contribution that physicians have to patient health, while intuitive, is not well understood. As quality contracts become increasingly popular across various health care systems, it is important to highlight what facets of individual physicians' health management styles have meaningful impact on health outcomes and to what extent they vary across physicians. The physician's ability to correctly diagnose and treat common conditions is one of the central tenets of quality contracts. But the link between these skills and patient outcomes is at best tenuous. Critics have emphasized that unobserved patient-specific characteristics are important and under-researched contributors to the variability of patient health outcomes conditional on physician clinical skill.

This research uses the population of Danish statin users between 2004 and 2008 and shows that the physician's health management skills, as proxied by that physician's average patient adherence with prescribed therapy, remain predictive of health outcomes even after accounting for individual patient heterogeneity. Further, investigating potential observable correlates of physician health management skills reveals that younger physicians have on average more adherent patients. We find no substantial difference in health management skills between male and female physicians after we control for physician age and the patient mix. Our research demonstrates that interventions aiming at improving physicians' health management skills as they relate to patient adherence with prescribed therapy will have positive impacts on patient health outcomes.

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Appendix A: Additional tables and figures

Table A1: The change in adherence before and after residential relocations.

	(1)	(2)	(3)	(4)
	Adherence	Adherence	Adherence	Adherence
Post	0.0428***	-0.0003	-0.0071**	-0.028***
	(0.003)	(0.003)	(0.003)	(0.003)
Observations	22,404	22,383	22,369	22,357
R-squared	0.007	0.000	0.000	0.003
Outcome mean	.796	.834	.841	.844

	(1)	(2)	(3)	(4)
	HMS	HMS	HMS	HMS
After	0.920***	0.090***	-0.035**	-0.492***
	(0.059)	(0.015)	(0.015)	(0.040)
Observations	22,404	22,383	22,369	22,357
R-squared	0.238	0.042	0.001	0.108
Mean	-1.01	-0.11	0.11	.556

Robust standard errors in parentheses

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

Table A2: The change in adherence and HMS before and after experiencing a practice closure by HMS of origin provider. Columns 1-4 reports the estimates by quartiles 1-4 respectively. The estimates are based on the two periods before and the three periods following the separation.

	(1) Adherence	(2) Adherence	(3) Adherence	(4) Adherence
Post	0.0875***	0.0233***	-0.00208	-0.0136*
	(0.00893)	(0.00846)	(0.00761)	(0.00781)
Observations	24,152	24,182	23,846	24,009
R-squared	0.027	0.003	0.001	0.011
Mean	.793	.858	.867	.865

	(1) HMS	(2) HMS	(3) HMS	(4) HMS
Post	1.976***	0.449***	-0.138***	-1.141***
	(0.046)	(0.009)	(0.009)	(0.018)
Observations	24,152	24,182	23,846	24,009
R-squared	0.532	0.608	0.069	0.576
Mean	-2.18	-0.35	00.12	1.01

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A3: The association between physician quality and Cardio-Vascular-Disease-related hospitalization risk for single physician clinics. Linear probability regressions. Standard errors are clustered at clinic level.

	(1)	(2)	(3)
Outcome		CVD hospitalization	
Panel A (No Individual FE)			
HMS	-0.0534*	-0.0434	-0.0492*
(x100)	(0.0279)	(0.0267)	(0.0277)
Panel B (individual FE)			
HMS	-0.0628**	-0.0605**	-0.0622**
(x100)	(0.0274)	(0.0267)	(0.0279)
Observations	1,215,964	1,215,964	1,215,964
R-squared	0.30	0.31	0.31
Time	Yes	Yes	Yes
Region	Yes	Yes	Yes
Ind. Cov	No	Yes	Yes
Comorbidities	No	Yes	Yes

Robust standard errors in parentheses, clustered on the clinic level
*** p<0.01, ** p<0.05, * p<0.1

Table A4: The association between physician quality and Cardio-Vascular-Disease-related expenditures risk for single physician clinics. Linear regression models. Standard errors are clustered at clinic level.

	(1)	(2)	(3)
Outcome: Log CVD hospitalization Expenditure			
HMS	-0.231**	-0.215*	-0.234**
(x100)	(0.114)	(0.113)	(0.114)
Panel B (individual FE)			
HMS	-0.265**	-0.275**	-0.250**
(x100)	(0.108)	(0.00108)	(0.110)
Observations	1,215,710	1,215,710	1,215,710
R-squared	0.31	0.31	0.31
Time	Yes	Yes	Yes
Region	Yes	Yes	Yes
Ind. Cov	No	Yes	Yes
Comorbidities	No	No	Yes

Robust standard errors in parentheses, clustered on the clinic level
*** p<0.01, ** p<0.05, * p<0.1

Table A5: Associations between health management skills and Cardio-Vascular-Disease hospitalization. The table includes observations for all pre and post periods for individuals who are separated from their physician before t=0. Standard errors are clustered at clinic level.

	(1)	(2)	(3)
Outcome: CVD hospitalization			
Panel A: No Patient Fixed Effects			
HMS	-0.069***	-0.089*	-0.070**
(x100)	(0.0253)	(0.052)	(0.034)
Observations	503,527	133,612	125,063
R-squared	0.054	0.056	0. 056
Panel B: Including Patient Fixed Effects			
HMS	-0.072***	0.12***	0.068***
(x100)	(0.023)	(0.040)	(0.032)
Observations	503,527	133,612	125,063
R-squared	00.40	00.40	00.39
Year FEs	Yes	Yes	Yes
Region	Yes	Yes	Yes
Ind. Cov	Yes	Yes	Yes
Comorbidities	Yes	Yes	Yes
Sample	All Shifters	Residential	Clinic closures

Robust standard errors in parentheses, clustered on the clinic level
*** p<0.01, ** p<0.05, * p<0.1

Table A6: Associations between health management skills and Cardio-Vascular-Disease hospitalization expenditures. The table includes observations for all pre and post periods for individuals who are separated from their physician before t=0. Standard errors are clustered at clinic level.

	(1)	(2)	(3)

Outcome: Ln (Hospital Expenditure)			
Panel A: No Patient Fixed Effects			
HMS	-0.341***	-0.314*	-0.283**
(x100)	(0.111)	(0.185)	(0.137)
Observations	503,527	133,612	125,063
R-squared	0.057	0.062	0.058
Panel B: Including Patient Fixed Effects			
HMS	-0.282***	-0.428***	-0.29***
(x100)	(0.098)	(0.15)	(0.124)
Observations	503,527	133,612	125,063
R-squared	.35	.37	.35
Year FEs	Yes	Yes	Yes
Region	Yes	Yes	Yes
Ind. Cov	Yes	Yes	Yes
Comorbidities	Yes	Yes	Yes
Sample	All Shifters	Residential	Clinic closures

Robust standard errors in parentheses, clustered on the clinic level
*** p<0.01, ** p<0.05, * p<0.1

Table A7: ICD 10 codes used to classify admissions as CVD-hospitalization. CVD hospitalization expenditures are expenditures associated with these admission codes.

List of ICD-10 Codes used to classify Cardio-Vascular-Disease:		
	ICD-10	**Description**
Myocardial Infarction:		
	I22	Subsequent myocardial infarction
	I252	Old myocardial infarction
Congestive Heart Failure:		
	I099	Other Reumatic Heart Disease
	I220	Subsequent myocardial infarction of anterior wall
	I230	
	I232	Haemopericardium as current complication following acute myocardial infarction
	I255	Ischaemic cardiomyopathy
	I420	Dilated cardiomyopathy
	I425	Other restrictive cardiomyopathy
	I426	Alcoholic cardiomyopathy
	I427	Cardiomyopathy due to drugs and other external agents
	I428	Other cardiomyopathies
	I429	Cardiomyopathy, unspecified
	I43	Cardiomyopathy in diseases classified elsewhere
	I50	Heart failure
Peripheral Vascular Diseases:		
	I732	Other peripheral vascular diseases
	I738	Other specified peripheral vascular diseases
	I739	Peripheral vascular disease, unspecified
	I772	Rupture of artery
	I790	Aneurysm of aorta in diseases classified elsewhere
	I792	Peripheral angiopathy in diseases classified elsewhere
	K552	Angiodysplasia of colon
	K558	Other vascular disorders of intestine
	Z958	Presence of other cardiac and vascular implants and grafts
	Z959	Presence of cardiac and vascular implant and graft, unspecified
	I70	Atherosclerosis
	I72	Other aneurysm and dissection
Diabetes:		
	E11	Type 2 diabetes mellitus
	E12	Malnutrition-related diabetes mellitus
	E13	Other specified diabetes mellitus

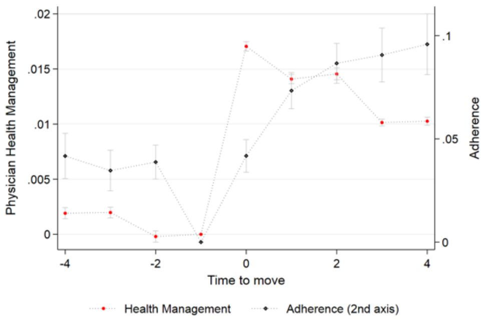
Table A8: Associations between practice quality metrics and provider characteristics for single physician practices. All models include time and regional dummies. Standard errors are clustered at the regional level

	(1) Std. HMS	(2) Std. HMS	(3) Std. HMS
Female	0.160*	0.172*	0.007
	(0.0824)	(0.0844)	(0.0629)
Immigrant		-0.350**	-0.442**
		(0.145)	(0.161)
Age			-0.046***
			(0.014)
Observations	7,352	7,352	7,352
R-squared	0.014	0.015	0.025

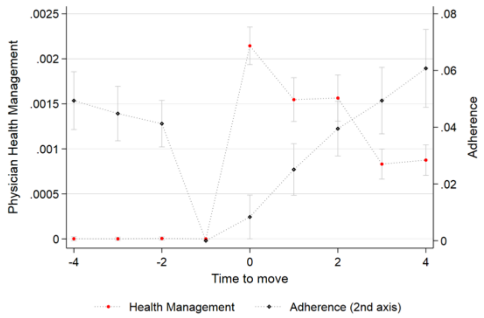
Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Figure A1:.Event graphs for relocators

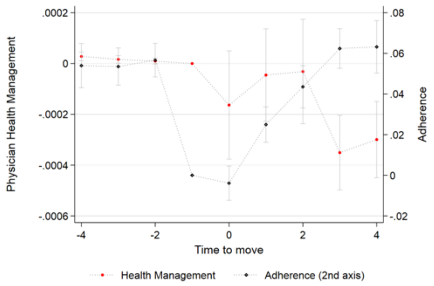
Panel A: 1st quartile pre-HMS



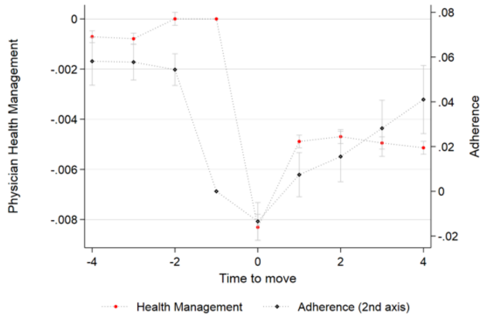
Panel B: 2nd quartile pre-HMS



Panel C: 3rd quartile pre-HMS



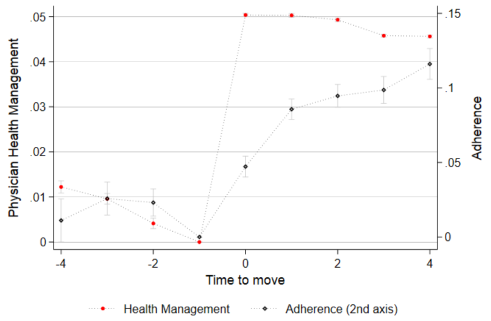
Panel D: 4th quartile pre-HMS



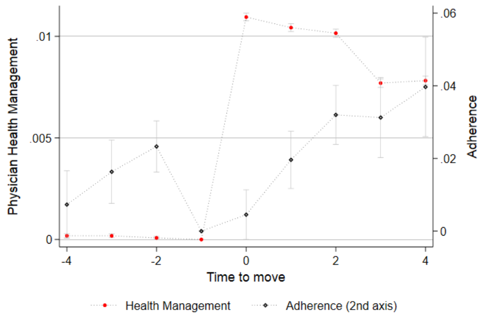
Notes: Physician health management skill and adherence for individuals relocating by quartile of pre-closure level of physician health management skill. Individuals are measured relative to the last period where the old physician is encountered (t=-1)

Figure A2:.Event graphs for clinics closing

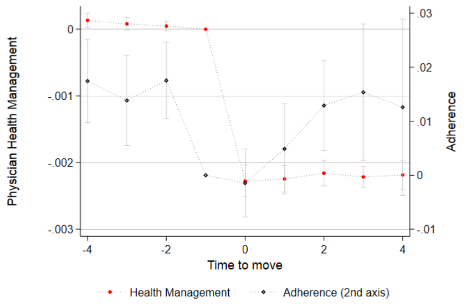
Panel A: 1st quartile pre-HMS



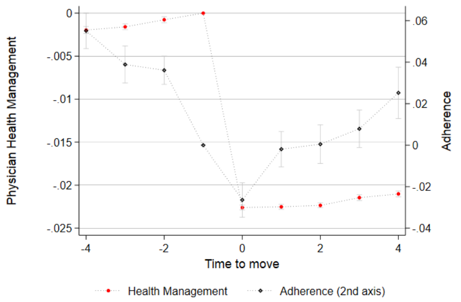
Panel B: 2nd quartile pre-HMS



Panel C: 3rd quartile pre-HMS



Panel D: 4th quartile pre-HMS



Notes: Physician health management skill and adherence for individuals experiencing a clinic closure by quartile of pre-closure level of physician health management skill. Individuals are measured relative to the last period where the old physician is encountered (t=-1)

Figure A3:.Associations between changes in health management skills and changes in adherence for relocators

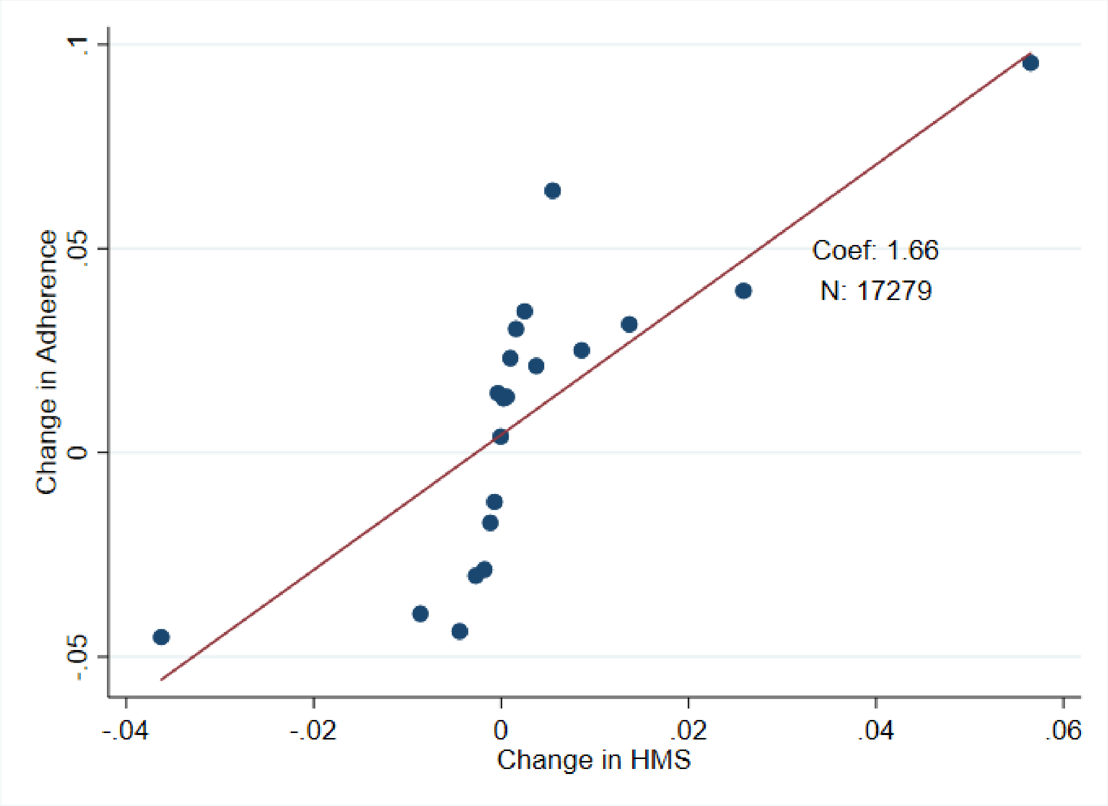


Figure A4:. Associations between changes in health management skills and changes in adherence for patients experiencing clinic closures

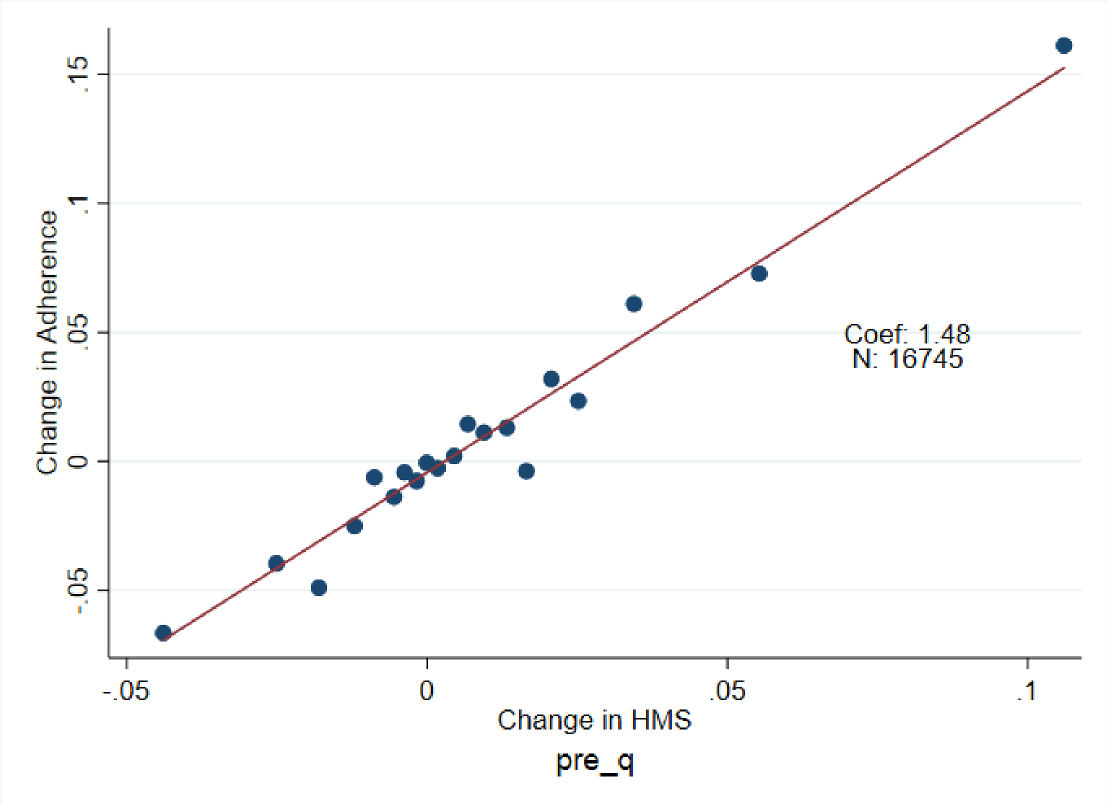
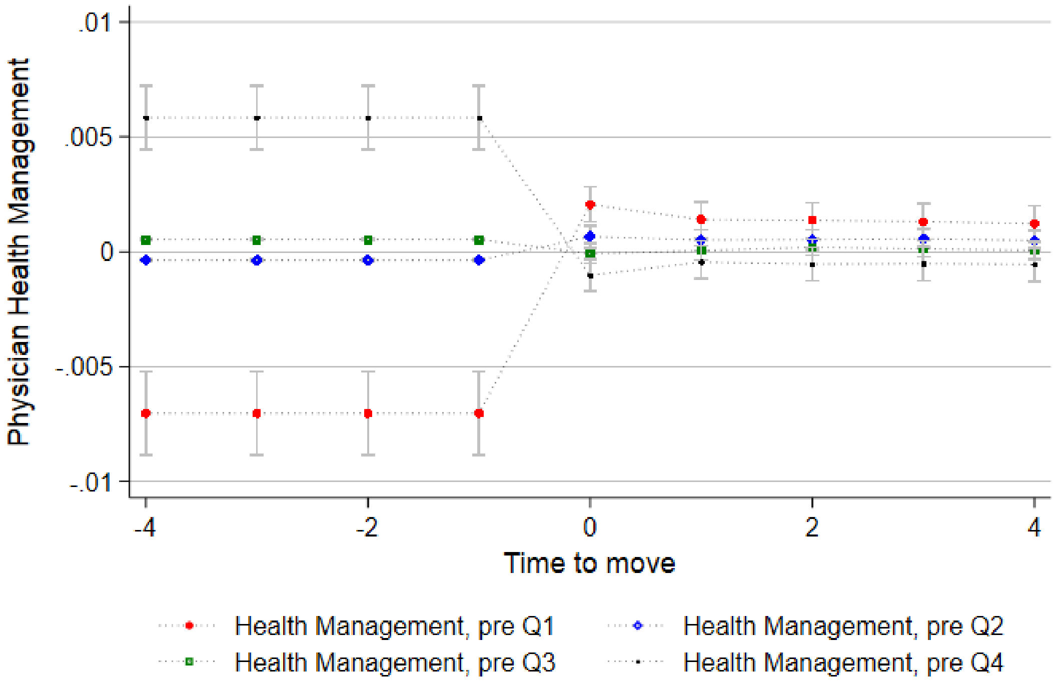
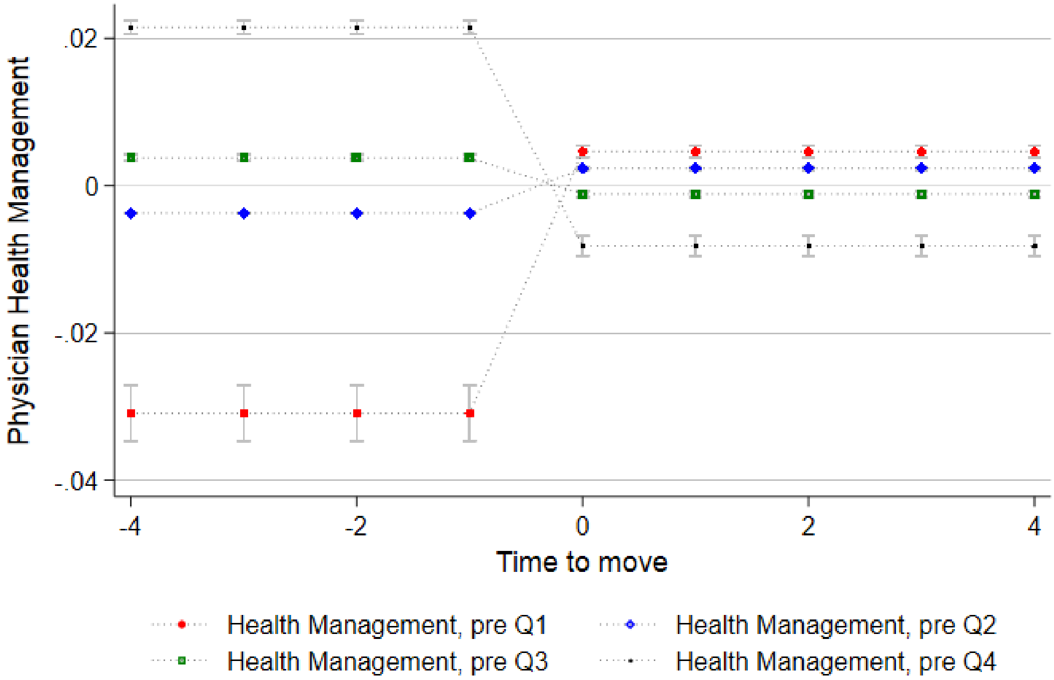


Figure A5:.Changes in physician health management skill for relocators



Notes: Changes in physician health management skill for relocators. The sample is restricted to those who only have one physician prior to the relocation and those who are in the sample for all 9 periods of observation ($t \subset [-4; 4]$) app. 20% of the complete sample of individual experiencing a residential relocation.

Figure A6: Changes in physician health management skill for individuals experiencing a clinic closure



Notes: Changes in physician health management skill for individuals experiencing a clinic closure. The sample is restricted to those who only have one physician prior to the relocation and those who are in the sample for all 9 periods of observation ($t \subset [-4; 4]$) this constitutes X observations or X% of the complete sample of individual experiencing a clinic closure.

Appendix C:

If there is a physician component in determining hospitalizations from Ambulatory Care Sensitive Conditions, we can estimate the physician quality dimension from means of residualized individual level indicators for admission with an ACSC. Our goal is to combine the available ACSCs into one time-constant physician specific measure based on all individuals affiliated with a physician, Q_j^C. We do this in several steps. First we calculate *leave one* out measures for each individual *i* and type *k* of ACSC at time *t as*

$$ACSC_{-itj(i,t)}^{k} = \frac{\sum_{h \neq i} ACSC_h}{n_{jt} - 1}.$$

This denotes the fraction of patients with a ACSC of type *k* at physician *j* at time *t* excluding individual *i*. Next, we combine the *leave one out* measure of the *k* different types of ACSCs into one metric. Let HI_{it} denote this index comprised of *k* categories of ACSCs using information on all patients affiliated with physician *j* except individual *i*:

$$HI_{it} = \sum_{r=1}^{k} \omega_r \, ACSC_{-itj(i,t)}^{k}$$

Where ω_r is the correlation between CVD hospitalization and ACSC hospitalization. We choose to construct the weights in this way because we are ultimately interested in estimating the effects of clinical quality on the probability CVD-related hospitalizations. In this way, we have used information on all of the doctor's patients other than individual *i* to construct the health index, such that it varies across individuals within physician.
To account for patient composition and calculate the time constant physician quality we first residualize the patient level health index and then collapse the calculated residualized means across time on a physician level using information of patients other than individual *i* affiliated with the same physician as individual *i*. Letting Q_j^C denote the estimate of the clinical quality of physician j, we start of by residualizing HI_{it}:

$$HI_{it} = \alpha_i + \boldsymbol{X}_{it}\delta_1 + \mu_{it} \; (Q1)$$

Where $\boldsymbol{X}_{it}$ contains time varying covariates of individual i – including dummies for comorbidities[21]. . If there exist systematic differences attributable to the physician, the error-term in (3) must have the following structure:

$$\mu_{it} = \gamma_{j(i,t)}^{c} + \vartheta_{it}$$

[21] The comorbidities are measured as an aggregated Charlson comorbidity index that varies across time. Details are presented in the data section.

Where $\gamma^{c}_{j(i,t)}$ denotes a physician fixed effect, and ϑ_{it} is normal distributed with mean zero and constant variance.

After obtaining the residuals from an estimation of equation (Q1) by OLS, we calculate leave-one-out means on the physician-year level:

$$Q^{c}_{jt} = \frac{1}{n_{jt} - 1} \sum_{h \neq i} \hat{\mu}_{ht}$$

where n_{jt} is the number of patients affiliated with physician *j* at time *t*. Finally, letting T_j denote the number of periods we observe physician j, we collapse the estimated Q^{c}_{jt} to construct a time constant physician specific measure of clinical quality.

$$Q^{c}_{j} = \frac{1}{T_j} \sum_{\tau=1}^{T_j} Q^{c}_{jt}$$

In this way we use information on all other patients across time, at your chosen physician to construct a time constant measure of clinical quality, Q^{h}_{j}.

The Interactive quality metric is constructed in a similar fashion. On the base of all statin users with at least 2 claims, m_{jt},starting from the analogue to equation (Q1):

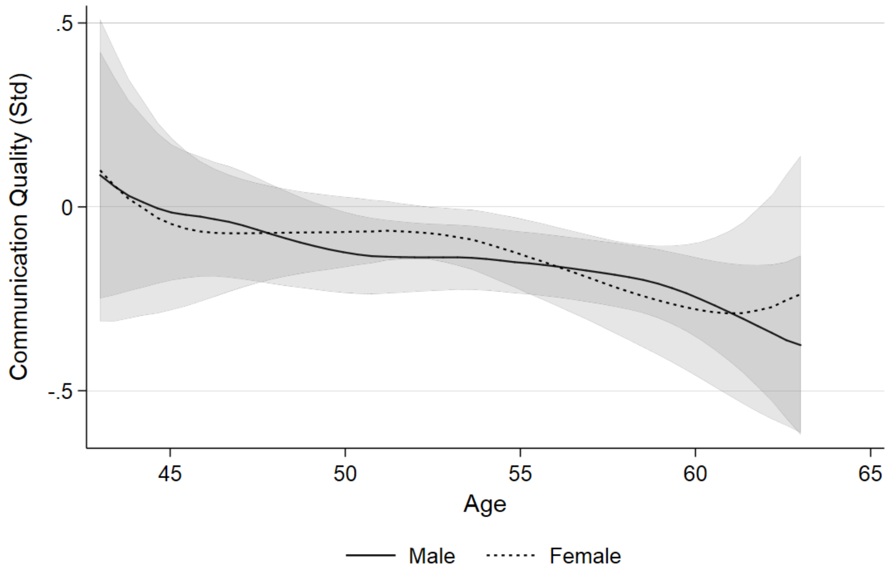
$$Adh_{it} = \alpha_i + \boldsymbol{X}_{it}\delta_2 + \mu_{it} \ (Q2)$$

Following similar steps, we estimate the interactive metric as

$$Q^{I}_{j} = \frac{1}{T_j} \sum_{\tau=1}^{T_j} \left(\frac{1}{n_{jt} - 1} \sum_{h \neq i} \hat{\mu}_{ht} \right)$$

Where $\hat{\mu}_{ht}$ are residuals from a linear regression of Q2.

Appendix D



q

Figure D2 Local linear regressions of communication quality and age by provider gender. Only for single physician practices.