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ABSTRACT

Health systems globally face increasing morbidity and mortality from chronic disease, yet many —especially in low- and middle-income countries—lack strong primary care. We analyze China's efforts to promote primary care management for insured rural Chinese with chronic disease, analyzing unique panel data for over 70,000 rural Chinese 2011-2015. Our study design uses variation in management intensity generated by administrative and geographic boundaries—regression analyses based on 14 pairs of villages within two kilometers of each other but managed by different townships. Utilizing this plausibly exogenous variation, we find that patients residing in a village within a township with more intensive primary care management, compared to neighbors with less intensive management, had more primary care visits, fewer specialist visits, fewer hospital admissions, and lower inpatient spending. No such effects are evident in a placebo treatment year. Exploring the mechanism, we find that patients with more intensive primary care management exhibited better drug adherence as measured by filled prescriptions. A back-of-the-envelope estimate of welfare suggests that the resource savings from avoided inpatient admissions substantially outweigh the costs of the program.

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1 Introduction

Primary care—effective, affordable medical care in a convenient local community clinic—has often been held up as vital for health systems globally to cope with the challenge of growing incidence and prevalence of non-communicable chronic diseases (NCDs) such as cardiovascular diseases and diabetes. Globally, NCDs account for about two-thirds of deaths and an increasing burden of morbidity that reduces productivity, increases medical spending, and shortens lives (Bloom et al. 2012). The importance of primary care once again received global attention at the October 2018 Global Conference on Primary Health Care, which issued a declaration commemorating the 40th anniversary of the famous Alma Ata declaration.[1]

Yet many health systems—especially in low- and middle-income countries—lack strong primary care systems for managing patients with NCDs, contributing to loss of productivity, premature mortality, and growing medical spending that may undercut the sustainability of universal health coverage. This paper examines a national program in China that financially encourages physicians to manage patients with NCDs. Through the lens of Tongxiang county and its mostly rural residents, we analyze whether the program is effective in improving health outcomes for such low- and middle- income populations.

China provides an important case study, as a large and rapidly developing middle-income country once famous for its "barefoot doctors" lauded in the Alma Ata declaration, but now with a hospital-based service delivery system for its aging population. Managing chronic disease is of increasing importance given China's rapidly aging population and the widespread under-diagnosis and poor management of prevalent conditions such as hypertension (Yang et al. 2008, Lu et al. 2017). High blood pressure was the leading preventable risk factor for premature mortality in China already in 2005 (He et al. 2009). According to a study of 1.7 million Chinese aged 35-75, compared to urban results, rural residents had slightly higher prevalence of hypertension (46.1%) and significantly lower awareness (43.8%), treatment (28.2%), and control (6.1%) in 2014-2017 (Lu et al. 2017).[2] China is also home to about one-quarter of the world's population with diabetes, with prevalence increasing with age and urbanization, and half or more undiagnosed (Zhao et al. 2016). Among those aware of their conditions, control of blood pressure and blood sugar is still far from optimal (e.g. less than 40% of patients treated for diabetes had adequate glycemic control; Xu et al. 2013),

[1] See http://www.who.int/primary-health/conference-phc, Kumar (2018) and Lancet (2018). Policymakers from around the world committed to support primary health care providing "a comprehensive range of services and care, including but not limited to vaccination; screenings; prevention, control and management of noncommunicable and communicable diseases; . . . . [that will] be accessible, equitable, safe, of high quality, comprehensive, efficient". . . https://www.who.int/docs/default-source/primary-health/declaration/gcphc-declaration.pdf [accessed 26 October 2018]. Other national and international organizations focus on improving primary as a foundational component of well-functioning health systems. For example, the Primary Health Care Performance Initiative (https://improvingphc.org/) is a partnership between the Bill & Melinda Gates Foundation, World Bank Group, and World Health Organization, with technical partners Ariadne Labs and Results for Development.

[2] Another study of nationally representative biomarker data found that 41% of men and 45% of women aged 45 and above in China in 2010-11 have hypertension, but a large minority of them—43% of hypertensive men and 41% of hypertensive women—were not diagnosed and thus unaware of the condition (Lei et al. 2014).

and spending on care for hypertension and diabetes represents a substantial burden for rural households despite basic health coverage (Liu et al. 2016). All of these factors underscore the importance of improving primary care for chronic disease management in China.

However, primary care use in China has decreased relative to hospital-based care since 2009 national health reforms despite policymaker rhetorical embrace of primary care and recent moves toward implementing a universal "family doctor system."[3] Patients' skepticism of primary care in China is warranted; most of the quality resources in medical care, both human capital and modern diagnostic and therapeutic technologies, have been concentrated in China's hospitals, which traditionally operate large outpatient departments. Both patients and providers frequently perceive hospital-based care to be of higher quality (Wu et al. 2017). Such a pattern is far from unique to China. Hospital-based delivery systems dominate East Asia, with China's higher per capita income neighbors of Japan and South Korea also struggling to reduce dependence on hospital-based care and to develop systems of primary care to manage chronic disease for their aging populations.

The disparities in quality between primary care and hospital care are especially stark in rural areas. Under-diagnosis of hypertension and diabetes is higher in rural areas (Lei et al. 2014, Zhao et al. 2016, Lu et al. 2017), and rural residents are less likely to be under control even when diagnosed (Xu et al. 2013, , Lu et al. 2017).[4] Successful primary care management of NCDs in rural areas relies heavily on grassroots physicians, which have limited medical education and access to it. In 2012, 84% of China's rural doctors did not have a college degree, compared to 60% in urban areas (World Health Organization 2015). Even when there is heterogeneity in physician competence, rural patients have difficulty perceiving quality differences (Fe et al. 2017) and may not respond to them. Poor control and management of NCDs contributes to the wide gap in mortality rates between urban and rural China. For example, although there is greater prevalence of diabetes in urban areas, diabetes is associated with greater excess mortality in rural China (Bragg et al. 2017). The questionable quality of primary care may be one reason why China's decades-long rhetorical embrace of primary care has shied away from any imposition of gatekeeping or mandatory referrals, but rather allowed patients freely to self-refer to higher-level of providers according to ability and willingness to pay. China's universal health coverage system through local monopoly social health insurance does generally provide higher reimbursement rates and low copayment requirements for primary care, but the continued crowding at hospital outpatient departments reveals patients' ongoing skepticism that primary care is an

[3] Wu and Lam (2016) and Qingyue Meng (2018) keynote address at primary care conference, Stanford Center at Peking University, June 2018. As one metric, nationally as utilization has increased, the percentage of healthcare visits at the primary care level has fallen from over 63% in 2005 to less than 55% by 2017 (Statistical yearbooks, various years; http://www.nhfpc.gov.cn/guihuaxxs/s10743/201806/44e3cdfe11fa4c7f928c879d435b6a18.shtml).

[4] Lei et al. (2014, p.71) show that a rural *hukou* is associated with a higher rate of under-diagnosis of hypertension, controlling for other factors. Xu et al. (2013) document that overall awareness, treatment, and control rates are all lower among rural residents than among urban residents with diabetes.

adequate substitute for hospital-based physician expertise.[5]

In light of this important and challenging context of primary care services in China, we analyze the effectiveness of a program promoting primary care management for insured rural Chinese with chronic disease since 2009, which financially rewards grassroots physicians in managing local residents with chronic diseases. Assembling a unique dataset linking administrative and health data between 2011 and 2015 at the individual level for over 70,000 rural Chinese diagnosed with hypertension or diabetes, we utilize variation in management intensity generated by administrative and geographic boundaries to study program effects. We focus on villages that are within two kilometers of each other, but have primary care services managed by different townships. The 14 pairs of boundary villages are balanced across observable population characteristics such as age, gender, and educational attainment, and their residents enjoy identical insurance coverage and hospital access; but they differ in intensity of primary care management (partially explained by the pre-existing stock of primary care physicians in the township).

Utilizing this plausibly exogenous variation, we find that patients residing in a village within a township with more intensive primary care management, compared to neighbors with less intensive management, had more primary care visits, fewer specialist visits, fewer hospital admissions, and lower inpatient spending in 2015. No such effects are evident in the placebo treatment year 2011 immediately after the luanch of the program. Results are robust to examining differences in health outcomes since initiation of the program, and a "leave-1-out" measure of township management intensity to mitigate any concern that unobserved differences in health demand of adjacent villages may explain the differences in management.

Exploring the mechanism for reduced specialist and hospital utilization, we find that patients with more intensive primary care management exhibited better drug adherence as measured by medication-in-possession (e.g., the number of days in which the patient had a filled anti-hypertensive prescription in 2015). This finding is important, given substantial evidence that drug adherence is crucial for preventing complications from chronic conditions such as hypertension and diabetes and narrowing disparities in health outcomes (Simeonova 2013, Conn et al. 2016). Overall our results suggest that primary care chronic-disease management in rural China can improve drug adherence, reduce health spending and improve health outcomes as measured by fewer hospitalizations. A back-of-the-envelope estimate of welfare implies that the resource savings from avoided inpatient admissions substantially outweigh the public subsidy costs of the program, even if we ignore the value of any associated improvements in quality of life and survival.

Our study contributes to two strands of health economics literature. First, primary care has been the focus of much health economics research (see Gravelle (1999), Scott (2000), Sørensen and Grytten (2003), Malcomson (2004), Starfield et al. (2005), Doran et al. (2006), Dusheiko et al. (2006), Iversen and Lurås

[5] For more on China's system of social health insurance and health service delivery, see Burns and Liu (2017).

(2006), Brekke et al. (2007), Gravelle et al. (2007), Levaggi and Rochaix (2007), González (2010), Kahn et al. (2010), Dusheiko et al. (2011), Iversen (2016), Olsen et al. (2016), and Strumpf et al. (2017)). As noted by Scott and Jan (2011) in their excellent review, there is robust evidence of a strong positive association between the "strength" of primary care and various positive health system outcomes (e.g. better health at lower per capita cost), as well as a few studies that control for endogeneity of primary care physician supply (e.g. Gravelle et al. 2008) or use dynamic panel data approaches (Aakvik and Holmås 2006); however, most such research focuses on high-income countries in Europe or North America, although the need for rigorous study designs "is particularly acute in low- and middle-income settings where policies are being introduced that will shape the fundamentals of the future health system on the basis of little empirical evidence" (Scott and Jan 2011, p.480). Studies of primary care in LMIC are often limited by reliance on cross-sectional data or pre-post data without a comparison group and/or lack of data on relevant outcomes of interest, including any unintended program effects. For example, a World Bank review of studies on the impact of patient-centered integrated care found inconclusive or insufficient evidence in most categories for LMIC including China (World Bank 2016 Annex 5, p.147). Audit studies in rural areas are rare and usually of small sample size (Sylvia et al. 2014); large surveys of primary care to date are mostly cross-sectional (Su et al. 2017, Xue et al. 2018) and therefore unable to assess the impact of programs strengthening primary care.

Accordingly, the second strand of health economics literature to which we contribute is the rigorous study of health system development in low- and middle-income countries (LMIC).[6] Many such systems are plagued with weak primary care systems, including challenges in recruiting and retaining skilled providers (Mills 2014). Studies highlight the difficulties in strengthening primary care doctors' skills and accountability in many LMIC health systems, including India (Das et al. 2016), South Africa (Akintola 2015), and Brazil (Reis 2014).

We contribute to this literature by providing evidence from rural China using administrative data and a geographic discontinuity study design. Compared to survey data, administrative data usually contains more accurate and detailed information on patients' utilization and health outcomes. The sample size is also usually larger, generating better power for statistically detecting program effects. Our study also contributes to the methodology for assessing health policy impacts in the absence of a randomized controlled trial. Although a few studies have set up experiments in rural doctor reimbursement (e.g. Wang et al. 2011) or used audit study methods (Currie et al 2010, 2014), few have utilized the rich geographic variation in policy implementation short of difference-in-difference studies by locality (e.g. Zhou et al. 2017). We employ a research design identifying causal effects by utilizing boundary discontinuities. Such methods could

[6] See discussion in Assefa et al. (2018) on primary care in Ethiopia; Malik and Bhutta (2018) on primary care in Pakistan; and Ghebreyesus et al. (2018), Hone et al. (2018), and Kluge et al. (2018) on primary care and the sustainable development goals more generally.

be applied more broadly to identify the impact of health policies with clearly defined boundaries and natural heterogeneity in implementation caused by plausibly exogenous factors (see MacDonald et al. 2016.)

The intervention we study represents a distinctive supply-side approach to increasing primary care utilization in LMIC countries. Many studies focus on giving incentives to patients to use primary care such as commitment devices for seeking primary care and cash incentives (Bai et al. 2017). As far as we are aware, ours is the first study to document reduction in overall spending from a supply-side intervention to induce physicians to persuade patients to use primary care. This approach is related to the literature on financial and reputational incentives for motivating public workers and administrators to improve human capital in LMICs (Duflo et al. 2012, Luo et al. 2018). For example, Luo et al. (2018) demonstrate how incentives to administrators can spur innovation—i.e., effort and inputs along relevant margins not dictated directly by the incentives—in the context of rural China. They focus on school administrators and incentives to improve the health of school-age children (primarily to reduce iron-deficiency anemia through supplementation at school and/or persuading parents to change nutrition provided at home). They demonstrate that incentives to Chinese rural administrators can enhance health outcomes. Since school and health sector workers face similar civil servant evaluation systems administered by local governments, their evidence is also relevant for our context. We find that budget funds earmarked for NCD management paid to townships are passed along to front-line workers in ways that lead to improvement in outcomes for individuals managed at the clinics overseen by that township. Both their study and ours confirm that aligning local officials' incentives and accountability mechanisms with health goals can contribute to improved outcomes.

The remainder of the paper is organized as follows. The next section provides background on the China setting and our unique data. Section III describes our empirical strategy and results. Sections IV provides some robustness checks. Section V presents the welfare implications. Last, section VI discusses and concludes.

2 Setting and Data

2.1 Tongxiang and Primary Care Management

Our data comes from Tongxiang, a mostly rural county in Zhejiang province, eastern China.[7] As of the end of 2014, the population totaled 687,000 registered residents, of whom 415,000 were rural (agricultural) *hukou* residents and 272,000 were urban (non-agricultural) *hukou* residents. Tongxiang is one of the richest rural counties in China. As of 2015, the annual per capita income for rural *hukou* residents was 27,357 RMB [8]

[7] The administrative structure in China is such that a given county or municipality has jurisdiction over the surrounding rural areas and residents with agricultural *hukou*.

[8] From http://xxgk.tx.gov.cn/xxgk/jcms_files/jcms1/web24/site/art/2016/3/25/art_3620_79724.html. Accessed on November 29 2018.

($4,392 USD using the 2015 exchange rate).[9] This income level, though high for rural China, still represents a fraction of that of high-income (OECD) countries and thus could be considered representative of emerging market populations beginning to gain access to the living standards of high-middle-income countries.

Like most of rural China, Tongxiang county has provided universal health coverage for almost two decades through social health insurance programs with heavily subsidized premiums for the voluntary insurance program for rural residents (New Cooperative Medical Scheme) and urban residents not engaged in formal sector employment (Urban Residents Basic Medical Insurance), which have been merged since before our study period into a single "resident insurance" risk pool (jumin yibao). For more details about the insurance programs and their benefit structure, see the appendix A1 .

The Tongxiang primary care chronic-disease management project is one constituent part of the essential public health services program launched under broad guidelines as part of 2009 national health reforms.[10] The primary care chronic-disease management project therefore also began in 2009 in Tongxiang county and expanded gradually over the years. Local public hospitals and the center for disease control collaborated in developing the program to screen and manage individuals with hypertension and type 2 diabetes(T2DM). The first stages involved community-wide door-to-door canvassing and screening to identify existing chronic-disease patients and reduce under-diagnosis. Over time, newly diagnosed patients were identified and referred to the program after being diagnosed during a physical check-up or hospital visit. Once identified, all such patients were invited to enroll in the primary care management program; enrollment is voluntary, and patients were free to continue to access care through hospital outpatient departments without primary care management if they so desire. Those who chose to enroll in the program were assigned to a responsible physician, usually a physician employed at the local public grassroots clinic such as a village clinic or township health center. That doctor was required to meet with each assigned hypertension or diabetes patient quarterly at minimum, record vital stats, monitor blood pressure and blood glucose, and provide drug and lifestyle guidelines, with no extra costs to enrolled patients.

Financially, the program was funded by the government essential public health service (jiben gonggong weisheng fuwu) budget: 45 RMB (approximately 7.2 USD) per resident, which covers chronic-disease management and other public health programs. The budget was then assigned to the local township health centers, the employer of all physicians working in the surrounding grassroots clinics. The township health center required those primary care doctors to provide the management service to all patients enrolled in the program who resided in nearby villages.

[9] The exchange rate between US dollars and Chinese RMB in this paper is set to 100 USD = 622.84 RMB, which is the exchange rate in 2015. Source: National Bureau of Statistics of China: http://data.stats.gov.cn/easyquery.htm?cn=C01&zb=A060J&sj=2017. Accessed on November 29 2018.

[10] See the article by China's Minister of Health (Chen, Zhu. "Launch of the health-care reform plan in China." The Lancet 373.9672 (2009): 1322-1324) and the associated policy announcement at http://www.gov.cn/ztzl/ygzt/content_1661065.htm.

Similar to other parts of Zhejiang province, Tongxiang participates in ongoing programs for skill upgrading and training for primary care providers. Moreover, the provincial CDC used national clinical guidelines to develop a hypertension treatment guideline in 2009 and a diabetes treatment guideline in 2012, and Tongxiang has adopted and disseminated these guidelines to their townships to implement in all the health centers.

In addition, Tongxiang's primary care physicians receive incentives on both extensive and intensive margins to encourage residents to enroll in the management program. Extensively, the chronic-disease management program together with other public health programs became a job requirement for their salaries from their employer, the public township health centers. Intensively, the administrator of the program, Tongxiang county CDC, also evaluates each township's performance and rewards each center both financially and reputationally. Since 2013, the Tongxiang CDC started to evaluate township health centers through reviewing and auditing performance. The two key indicators are how well each township meets the target for management rate (# patients managed /# possible patients) and the target for management quality rate (# patient who surpass management guidelines/# patients managed). The CDC randomly calls patients or their family members to confirm the above two indicators. The ranking results assigned to each township health center are disseminated within the public healthcare system as a reputational incentive. In addition, since 2014, the township health centers ranked among the top 3 overall and the bottom 3 overall have a 30% payment difference in the per-capita payments: 51 RMB per capita (top 3 towns) vs 39 RMB per capita (bottom 3); these overall rankings are based on each township health center's total performance score for all basic health services, with chronic-disease management accounting for 10% of the total score.

2.2 Data Description

The backbone of the project is the unique administrative data collected by Tongxiang and Zhejiang CDC—the database that links health insurance claims, primary care service logs, and basic health information for all residents. These three sets of data are rarely linked and analyzed in combination in China healthcare research. We focus on the agricultural *hukou* residents in this project.[11]

The medical claims for the study period 2011-2015 include all health insurance claims of individuals who enrolled in the chronic-disease management programs for hypertension or diabetes any time during the study period and all their health service logs under the management program.[12] Primary care service logs in 2015 detail every primary care service provided during every encounter between a doctor and a patient in either the hypertension or diabetes program. These encounters can take various forms including checkups

[11] We thank Zhejiang provincial CDC, Tongxiang county CDC, and Tongxiang county bureau of social security to collect, share, and answer all the questions about the data.

[12] Individuals are invited to enroll in the program appropriate for their most serious diagnosis; therefore, individuals diagnosed with both hypertension and diabetes are enrolled in the diabetes management program, which also monitors blood pressure.

by phone, home visits, and primary care visits to local clinics. The basic health information database collects demographic information of all residents as solicited by primary care doctors and nurses during community canvassing, screening and outreach programs, including each household member's age, gender, and educational attainment.[13]

The following key variables are used in the analysis. Demographic variables such as 2015 age, gender, and education level come directly from the basic health information database. Health care utilization and spending, including inpatient visits, inpatient and outpatient expenditure and out-of-pocket costs, are calculated using the medical insurance claims that cover all medical bills under the universal public health insurance program, measured in RMB. Most Chinese only have access to a single public insurance program based on their residence locality and *hukou*; such insurance programs cover more than 90% of Chinese (WHO 2015, World Bank 2016). In China, hospitals and clinics are divided into tiers by their quality and coverage of different clinical specialties. We define a specialist visit as a visit to a Tongxiang county-level hospital (or higher-tier hospitals) based on the visit date recorded in the medical claims. Similarly, a visit is classified as a primary care visit if, based on the visit date recorded in the medical claims, the patient received treatment at a township health center or village clinic in 2011 or 2015. A primary care visit also arises when a patient receives management services (at a village clinic or township health center, or at home) as recorded in the primary care service visit log, which we have for the year 2015. Such primary care management visits are not recorded in medical claims (because they are funded through the CDC budget, not insurance, as discussed above); therefore, our linked claims and service log data provide a more comprehensive picture of primary care than any study that relies solely on medical claims. Multiple visits on one date will be considered a single visit. Inpatient utilization is measured by an indicator for whether a patient was admitted as an inpatient in that year. Days covered by hypertension and diabetics drugs are defined by using prescription information for the 3 most common drugs found in the insurance claims and dividing the total prescribed amount by usage.[14] The percentage of drug coverage is calculated as the covered days divided by the number of days in 2015 after the patient's 1st prescription date. These measures of medication adherence are only available for 2015, since the 2011 medical claims lack the prescription information needed for defining them.

Our analytic sample is restricted to agricultural *hukou* residents who were age 40+ in 2015 and were alive as of the end of 2014. We do not consider urban *hukou* residents because they have access to different jobs, housing, local public goods, and social protection policies throughout their lifetime.

[13]The collection and analysis of this unique dataset was approved by Institutional Review Boards at both the Zhejiang Provincial CDC and Stanford University, and the data was de-identified prior to analysis.

[14]The top 3 most frequently prescribed hypertension drugs in 2015 were hypertension Telmisartan, Irbesartan, and Amlodipine Besylate. The top 3 for diabetics were Gliclazide, Metformin Hydrochloride, and Repaglinide. We calculate the dosage of each prescription and divide by doctors' recommended usage if existed, or otherwise the average recommended usage for each drug to get the number of days covered. If the total covered days exceed 2015.12.31, only those in 2015 will be counted.

Tables 1 shows the summary statistics of our patient sample. There were 75,275 patients with hypertension over the age of 40 enrolled in the managed program possessing a rural *hukou*. As shown in Table 2, these patients had an average age of 65.43 and 48% were male. The enrolled patient population of our sample is older than the average hypertensive in China (59.5 among men and 61.4 among women; He et al. 2009), consistent with the challenge of attracting working-age patients to primary care for management of their chronic conditions. In 2011, hypertension patients had an average of 6.10 medical visits including specialist and primary care clinic visits, compared to 11.35 in 2015. Of all the patients, 7% had an inpatient visit in 2011, whereas 14% had an inpatient visit in 2015. Like the number of inpatient visits, expenditure also increased. In 2011, patients had an average health expenditure of 1518.32 RMB, 946.12 of which was out-of-pocket (OOP) costs [15]; this is compared to an average expenditure of 3422.36 RMB and 1745.04 in OOP costs in 2015. Among the 14,412 individuals with diabetes over the age of 40 with a rural *hukou* who enrolled in the primary care management program, the average age was 62.01, and 42% were male. On average these patients had 7.76 visits in 2011, compared to 16.04 in 2015. In 2011, their average expenditures totaled 2598.49 RMB (1565.47 being OOP costs), rising in 2015 to an average of 5810.08 RMB (with 2832.41 RMB OOP).

The enrolled residents by the end of 2015 represented a high share of diagnosed NCD patients. Tongxiang CDC, in collaboration with local healthcare providers, tracks all patients who are diagnosed for diabetes at local hospitals or through physical check-ups. By the end of 2015, 91% of diagnosed rural *Hukou* patients aged 40+ had enrolled in the diabetes management program. Additionally, the diagnosis rates of hypertension and diabetes among rural populations in Tongxiang are also similar as the rest of the country. From CHARLS, a national representative survey of China, 22% of rural *Hukou* residents aged 45+ were diagnosed for hypertension in China by 2013; in comparison, 25% of similar population in Tongxiang were enrolled in the hypertension management program by 2015, although we do not know the exact diagnosis rate. For diabetes, 5% of rural *Hukou* residents aged 45+ were diagnosed in China by 2013, compared to 6% of the similar population diagnosed for diabetes in Tongxiang by 2015.

Figure A.1 shows the percentage of enrolled patients by their enrollment years. There are very few people who enrolled prior to 2010 under pilot programs. The majority of patients enrolled between 2010 and 2013, representing the stock of existing chronic-disease patients. Individuals enrolling after 2013 were mostly incident cases of hypertension or diabetes newly diagnosed in the year they enrolled in the primary

[15] All expenditure terms in 2011 are adjusted to 2015 RMB using rural residents' Consumer Price Index in health care service from National Bureau of Statistics of China, http://data.stats.gov.cn/easyquery.htm?cn=C01.Accessed on November 29 2018.

Table 1: Summary Statistics for Enrolled Patients

Panel A: Enrolled Hypertension Patients (N=75,275)

Year	Age (in 2015)	Male	Educ	1(Inpatient)	Expenditure	Inpatient Expenditure	Outpatient Expenditure	Out-of-pocket Expenditure	# Specialist Visits	# Primary Care Clinic Visits	# Primary Care Management Visits	# HP-Drug Covered Day	% HP-Drug Covered Day
2011	65.43	0.48	Primary School	0.07	1518.32	779.11	739.21	946.12	1.40	4.70			
				(0.26)	(5271.56)	(4774.44)	(1497.48)	(2903.17)	(3.20)	(5.77)			
2015	(10.94)	(0.50)		0.14	3422.36	2112.16	1310.20	1745.04	1.96	9.39	6.60	87.61	0.30
				0.35)	(10584.29)	(9912.25)	(2291.81)	(4993.84)	(3.83)	(8.74)	(3.92)	(118.75)	(0.38)

Panel B: Enrolled Diabetic Patients (N=14,412)

Year	Age (in 2015)	Male	Educ	1(Inpatient)	Expenditure	Inpatient Expenditure	Outpatient Expenditure	Out-of-pocket Expenditure	# Specialist Visits	# Primary Care Clinic Visits	# Primary Care Management Visits	# DB-Drug Covered Day	% DB-Drug Covered Day
2011	62.01	0.42	Primary School	0.11	2598.49	1205.28	1393.21	1565.47	3.37	4.39			
				(0.31)	(6994.17)	(6245.56)	(2083.57)	(3911.38)	(5.44)	(6.00)			
2015	(10.42)	(0.49)		0.20	5810.08	3236.91	2573.17	2832.41	4.68	11.36	8.87	129.71	0.41
				(0.40)	(14409.96)	(13517.86)	(3220.55)	(6402.15)	(6.32)	(11.66)	(5.89)	(139.61)	(0.42)

Notes: The table shows the demographic characteristics and medical utilization in 2011 and 2015, among all hypertension and diabetic patients enrolled by 2015. All expenditure amounts are adjusted to 2015 RMB. Panel A shows the summary statistics for 75,275 hypertension patients and Panel B shows for 14,412 diabetic patients. The average statistics are presented for each variable except education, of which the median is displayed as it is a categorical variable. Standard deviations are shown in parentheses. Outpatient and inpatient expenditure include drug expenditure in its respective setting.

care management program.

3 Empirical Strategy

3.1 Study Design

The research question we are interested in is whether rural primary care services are effective in managing chronic-disease patients. A direct analysis looking at patient outcomes and the intensity of management may not be appropriate due to patient selection and other confounding factors that co-determine a patient's decision to receive primary care management and her health outcomes.

To tackle the potential endogeneity problem, we utilize a boundary discontinuity approach. In Tongxiang, some villages are located next to each other and belong to different townships. Residents in these villages are similar in observed characteristics. They also enjoy exactly the same health insurance policies and access to any hospitals in Tongxiang at will. Comparison within the boundary villages allows us to isolate the same health demand factors and other health services available beyond primary care. The primary care management services, however, are administrated at the local township level. Because management in different townships provides different treatment intensity for otherwise similar residents with chronic disease, we may isolate the effects of chronic-disease treatment intensity on health outcomes.[16]

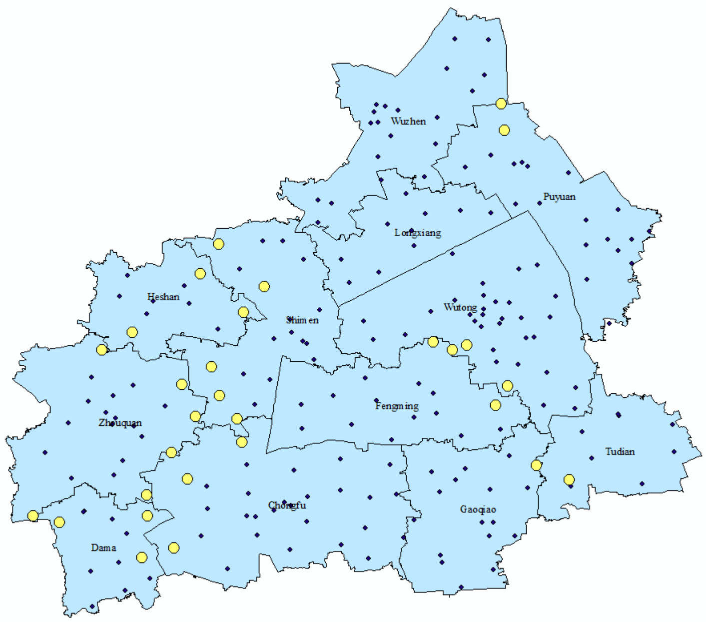
Of course, individuals who seek care in village clinics and the township health center may receive a range of primary care services beyond those specified in the chronic disease management program, including community outreach. A caveat is that the effects we find may reflect these other primary care services and need not be limited to the chronic-disease management program , although the latter was the largest policy change in Tongxiang during the study period.

Figure 1 shows the 14 pairs of villages that we consider as neighboring villages. We identify them by restricting to villages of which the centroids are located within 2km of each other (according to Google Maps) yet belong to different townships. We exclude pairs in which one village belongs to a traditionally rural township and the other belongs to an urban township.

To measure the intensity of primary care management, we proxy it by using management duration for an average patient. First, we estimate the following regressions for all managed patients in all townships:

[16] Those with agricultural *hukou* have allocated land holdings in a given village within a given township both for living and farming, and rarely move except for marriage or migrating to urban areas for schooling or work. The vast majority of older individuals such as those in our sample remain resident in the same county and village over a lifetime. According to nationally representative data for 2010-11, the percentage of Chinese adults 45 and older who still reside in the same county in which they were born was 90 percent, with fully 58 percent of rural residents still residing in the same village in which they were born (Smith et al. 2013). Moreover, residents are unlikely to know much about the management intensity in neighboring townships since the rankings we discuss are not disseminated publicly but only among the primary care workforce.

Figure 1: Illustration of Boundary Discontinuity



Notes: The above figures illustrate the boundary discontinuity of our research. Each black line shows a township border and each yellow dot is the google map location of each neighboring village. We identify 14 pairs of neighboring villages by restricting to villages that are located within 2km of each other yet belong to different townships. We exclude pairs in which one village belongs to a traditionally rural township and the other belongs to an urban township.

$$t_i^{d\in\{hp,db\}} = X_i'\beta^d + \eta_i^d,$$

where t_i^d is the duration of management for hypertension ($d = hp$) or diabetic ($d = db$) patient i by 2015. This regression is separately run for hypertension and diabetic patients. X_i includes age, gender, and years of schooling. The residual $\hat{\eta}_i$ is the characteristics-controlled management duration. Next, for each township k, we average over the residuals to construct the management intensity in each township k and village j, l_k^d and l_j^d. The average management duration for the residents of disease d within a township and a village are our measures of management intensity:

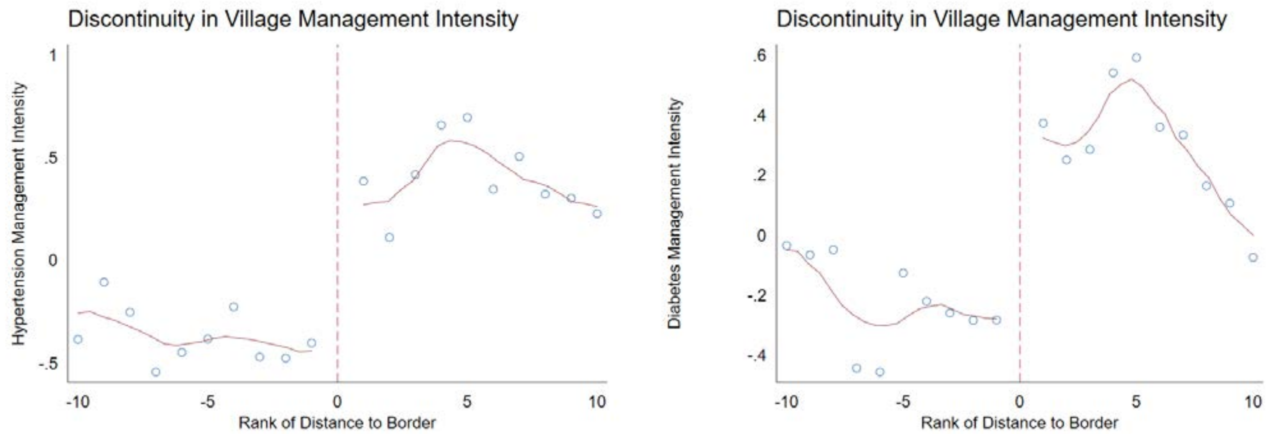
$$l_j^d = \frac{1}{n_j^d} \sum_{i\in j^d} \hat{\eta}_i^d,$$

$$l_k^d = \frac{1}{n_k^d} \sum_{i\in k^d} \hat{\eta}_i^d.$$

Figure 2: Binscatter Plot of Village-Level Management Durations vs Distance to Township Boundary

(a) Hypertension Management

(b) Diabetes Management



Notes: The above figures plot the "jumps" of management duration for hypertension (Panel A) and diabetes (Panel B) across township boundaries. Panel A uses hypertension management durations among each hypertension patient. Panel B uses diabetes management durations among each diabetic patient. Consider a pair of nearby villages j and j', belonging to townships k and k'. We order all the villages in the two towns by distance ranks to the boundary and put the township with lower township-level management duration l_k to the left of red line and the township with higher $l_{k'}$ on the right. The absolute value of the x axis shows the rank of distance of a village to the township boundary. The y-axis shows the village level management duration l_j. Since we have 14 pairs of adjacent villages, the graphs are then binscattered at each distance-to-boundary level for a village. If there are more than 10 villages in a township, the ranks of village-to-boundary are scaled down to deciles. The solid red line is the kernel fit of binscattered dots.

The validity of the study design requires discontinuity in management intensity. We perform the following steps to show the "jump" across township boundaries. Figure 2 plots the average village-level management duration of enrolled hypertension and diabetic patients, binscattered at the rank of village-distance-to-township-boundaries within all adjacent township pairs. The details of construction are as follows. Consider a pair of nearby villages j and j', belonging to townships k and k'. We order all the villages in the two townships by distance ranks to the boundary. Put the township with lower township-level management duration l_k to the left of the red line and the one with higher $l_{k'}$ on the right. The absolute value of the x axis shows the rank of distance of a village to the township boundary. The y-axis shows the village-level management duration l_j. Since we have 14 pairs of adjacent villages, the graphs are then binscattered at each distance-to-boundary level for a village. As one can see, on average, across the boundaries, adjacent villages have about a 1 year difference in management duration for hypertension patients and about a 0.5 year difference in management duration for diabetic patients, even controlling for observables.

We examine what factors of a township may determine the township-level management durations. Using observed characteristics, we estimate the following resident i level regression among all residents aged 40+:

$$l_{k(i)}^d = \beta_0^d + \beta_1^d x_i + \epsilon_i^d. \tag{1}$$

The regression results are displayed in Table 2. Notice that the null results of age, gender, and education are not mechanical. When constructing characteristic-controlled management duration $\hat{\eta}_i$ and thus l_k, we only use the sample of enrolled patients. In equation (1), we use the age/gender/education characteristics of all residents in each township to measure township-level average characteristics rather than those of patients. The only two variables that significantly explain township management duration are the number of physicians per capita who recruited and managed cases with hypertension and diabetes in each township, suggesting that the stock of local physicians significantly improves management intensity.

Other factors may also explain management intensity but are difficult to measure, such as the characteristics of local leaderships (i.e., who decided how many physicians to hire and allocate to chronic disease management in each year, for example). In appendix A2, we also find that perhaps reputational incentives from the rankings of primary care management of each township promote management intensity, although the results are only suggestive.

3.2 Main Regression

The main regression includes all patients living in the bordering villages and estimates a cross-sectional patient i level regression for each disease:

$$y_i^d = \beta_i^d rank(l_{k(i)}^d) + \sum_{p \in 1..14} \alpha_p^d B_{p(i)} + \epsilon_i^d, \tag{2}$$

where y_i^d is the healthcare utilization of enrolled patient i for hypertension $d = hp$ or diabetics $d = db$. $rank(l_{k(i)}^d)$ ranging from 1 to 12 (the higher the better) captures the management intensity of disease d in township k that i resides in. We use rank for easier interpretation of findings. $B_{p(i)}$ is an indicator that is 1 if i resides in the pth adjacent village pair across township boundaries and 0 otherwise. The regression framework captures within a village-pair boundary, how different management intensity affects patient i's healthcare utilization.

The identification assumption is that, within a village-pair boundary, no other unobserved factors affect a resident's average healthcare utilization in a high management intensity village compared to a low intensity village, other than the management program. A balance-check of resident characteristics will increase our confidence that such an assumption is valid. We specify the following individual-level regression among all residents living in the boundary villages in 2015:

$$rank(l_{k(i)}^d) = X_i' \gamma^d + \sum_{p \in 1..14} \alpha_p^d B_{p(i)} + \epsilon_i^d, \tag{3}$$

Table 2: Estimation Results of Equation (1)

Panel A: Hypertension Management Duration

VARIABLES	(1) $l_{k(i)}$	(2) $l_{k(i)}$	(3) $l_{k(i)}$	(4) $l_{k(i)}$	(5) $l_{k(i)}$
Age	0.000631				
	(0.000802)				
Male		-0.00228			
		(0.00225)			
Years of Schooling			0.00190		
			(0.00614)		
# Case Opening HP Physicians				1,211***	
				(317.6)	
# Case Opening DB Physicians					1,301***
					(278.9)
Observations	337,507	337,507	312,147	337,507	337,507
R-squared	0.000	0.000	0.000	0.325	0.385

Panel B: Diabetes Management Duration

VARIABLES	(1) $l^{db}_{k(i)}$	(2) $l^{db}_{k(i)}$	(3) $l^{db}_{k(i)}$	(4) $l^{db}_{k(i)}$	(5) $l^{db}_{k(i)}$
Age	0.000434				
	(0.000597)				
Male		-0.00108			
		(0.00144)			
Years of Schooling			0.00145		
			(0.00495)		
# Case Opening HP Physicians				1,010***	
				(261.5)	
# Case Opening DB Physicians					1,124***
					(227.8)
Observations	337,507	337,507	312,147	337,507	337,507
R-squared	0.000	0.000	0.000	0.325	0.385

Notes: The table above shows the estimation results of equation (1). The sample includes all residents in Tongxiang who were alive by the end of 2014 and aged 40+ in all towns. Each observation is at the resident level. Panel A uses the management durations for hypertension as the LHS and Panel B uses diabetics as the LHS. Standard errors are clustered at the township level.

Table 3: Estimation Results of Equation (3)

VARIABLES	(1) rank(l_k^{hp})	(2) rank(l_k^{db})
Years of Schooling	0.0378	0.0453
	(0.0552)	(0.0535)
Male	-0.0573	-0.0716
	(0.0618)	(0.0628)
Age	0.0104	0.0121
	(0.0105)	(0.0101)
Observations	52,078	52,078
R-squared	0.492	0.510
Boarder FE	Yes	Yes
F test	0.771	0.932
Prob > F	0.520	0.438

Notes: The table above shows the estimation results of equation (3). The sample includes all rural residents in the 14 pairs of boundary villages who were alive by the end of 2014 and aged 40+. Observations are at the individual level. The dependent variable is the rank of township's primary care management intensity measured as the average residual of management duration for hypertension and diabetics. The F test are a joint F test for all the RHS regressors. Standard errors are clustered at the village level.

where X_i includes education, age, and gender and we hope the characteristics are similar across villages within a boundary. Table 3 show the result of the balance checks. We see that resident education, gender, and age do not predict the rankings of hypertension and diabetes management intensity. Resident characteristics are balanced across villages within a village-pair, enhancing confidence in the validity of our geographic discontinuity study design.

In Table 4, we estimate equation (1) for healthcare utilization in 2015. We observe four statistically significant results: a township with higher management intensity is associated with more primary care visits, fewer specialist visits, lower inpatient rates, and lower inpatient spending. Comparing a township ranked 1^{st} to one ranked 11^{th}, the differences in inpatient admissions among hypertension patients are about $0.0018 * 10 = 0.018$, which is about 13% of the average inpatient admission rate among hypertension patients. In Table A.1, we estimate equation (1) for healthcare utilization in 2011 as a placebo test since most of the patients were not yet managed or just managed for a very short amount of time. We observe no statistical differences in any of utilization measures with respect to ex-post management intensity. In Table A.2, we use the differences in health utilization between 2015 and 2011 as the dependent variable to capture changes in health that may underly these utilization changes. The general patterns still persist. A township with higher management intensity is associated with more primary care visits, fewer specialist visits, decrease in inpatient utilization, and decrease in total health expenditures, relative to a township with lower management intensity. These results suggest that primary care chronic-disease management in rural Tongxiang county reduces health spending and avoidable hospital admissions for ambulatory-care sensitive conditions such as hypertension and diabetes, indicating better health outcomes in terms of chronic disease control.

To understand potential mechanisms behind these findings, we gathered and coded data on medication adherence. For individuals with high blood pressure and diabetes, regular and consistent adherence to antihypertensive and anti-diabetic drugs can be crucial for preventing complications, yet individuals without salient symptoms often exhibit poor adherence. Improving medication adherence is therefore one primary mechanism through which primary care management can enhance health outcomes and reduce avoidable admissions for acute sequelae.

To test this hypothesis, we identified hypertension and diabetic drugs from the medical claims. We only focus on the three most common formulas in the data—Telmisartan, Irbesartan and Amlodipine for anti-hypertensive medication and Gliclazide, Metformin Hydrochloride, and Repaglinide for anti-diabetic medication. Table 4 columns 8 and 9 report results of our main regression with anti-hypertensive and anti-diabetic drug usage in 2015 as the dependent variable. The results support our hypothesis of improved adherence as an important mechanism underlying the pattern of utilization we observe: patients residing in a village with higher-ranked management intensity exhibit a higher drug possession rate, measured either by the number or the percentage of drug-covered days. For example, comparing the two townships that are ranked 1^{st} and 11^{th},the difference in the number of days in possession of an anti-hypertensive drug was about 25 days, which was 29% of the average anti-hypertensive drug possession days from Table 1. For anti-diabetic medication, the difference was 14% of the average anti-diabetic drug possession days. These empirical results suggest that the village doctors may have significantly increased medication adherence among patients through regular interactions with them.

4 Robustness

We use a leave-1-out measure of township management intensity to mitigate the potential concern that unobserved differences in health demand of adjacent villages may explain the differences in township management duration. That is, for each village j in township k, we first calculate for each disease d,

$$l_{k(j)}^{d,-j} = \frac{1}{n_{k \setminus j}} \sum_{i \in k, i \notin j} \hat{\eta}_i^d,$$

that is, the leave-village-j out average of η_i^j, the observables-adjusted management duration for each patient i residing in township k but not in village j. Then we use $\text{rank}(l_{k(j)}^{d,-j})$ for each village normalized to 1 to 12 as the township-level management intensity of village j in disease d. Then, similar to the main specification (2),

Table 4: Regression Results for Equation (2): Healthcare Utilization in 2015

Panel A: Enrolled Hypertension Patients

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
VARIABLES	1(Inpatient)	Expenditure	Inpatient Expenditure	Outpatient Expenditure	# Specialist Visits	# Primary Care Clinic Visits	# Primary Care Management Visits	# HP-Drug Covered Day	% HP-Drug Covered Day
rank($l_{k(i)}$)	-0.00181***	-14.51	-17.28**	2.770	-0.0434***	-0.0205	0.0130	2.477	0.00808
	(0.000650)	(10.72)	(6.286)	(5.916)	(0.0137)	(0.125)	(0.0492)	(1.462)	(0.00491)
Observations	12,517	12,517	12,517	12,517	12,517	12,517	12,517	12,517	12,517
R-squared	0.002	0.002	0.001	0.008	0.033	0.054	0.018	0.028	0.027
Border FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sample	hp Patients	hp Patients	hp Patients	hp Patients	hp Patients	hp Patients	hp Patients	hp Patients	hp Patients

Panel B: Enrolled Diabetic Patients

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
VARIABLES	1(Inpatient)	Expenditure	Inpatient Expenditure	Outpatient Expenditure	# Specialist Visits	# Primary Care Clinic Visits	# Primary Care Management Visits	# DB-Drug Covered Day	% DB-Drug Covered Day
rank($l_{k(i)}$)	-0.00202	1.513	-19.31	20.83	-0.114***	0.402**	0.146**	1.755**	0.00546*
	(0.00190)	(33.18)	(18.45)	(22.22)	(0.0229)	(0.157)	(0.0563)	(0.848)	(0.00277)
Observations	3,065	3,065	3,065	3,065	3,065	3,065	3,065	3,065	3,065
R-squared	0.010	0.006	0.007	0.009	0.039	0.055	0.040	0.053	0.054
Border FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sample	db Patients	db Patients	db Patients	db Patients	db Patients	db Patients	db Patients	db Patients	db Patients

Notes: The table above shows the estimation results of 2 using health utilization in 2015 as the dependent variables. The sample includes all enrolled chronic-disease patients aged 40+ in the 14 pair of adjacent villages located in different townships. An observation is at the patient level. Panel A) use enrolled hypertension patients only and Panel B) use diabetics patients only on the boundaries. The number of primary care visits in 2015 are broken down into visits in clinics that are recorded in the insurance claims and visits from the management logs that are not recorded in the insurance claims. All expenditures are winsorized at 95th percentile within our claim sample during that year among the aged 40+ and agricultural *hukou* chronic-disease patients. Standard errors are clustered at the village level.

we run the following regressions using the leave-j-out measures of management durations using all patients i residing in any of the 14 pairs of nearby villages:

$$y_i^d = \beta_i rank(l_{k(i)}^{d,-j(i)}) + \sum_{p \in 1..14} \alpha_p^d B_{p(i)} + \epsilon_i^d. \quad (4)$$

The estimation results are very similar to those reported earlier and are displayed in Tables A.3, A.4, and A.5.

5 Welfare implications

We undertake a back-of-the-envelope welfare calculation to understand the impacts of the chronic-disease management program.

Since the central government allocated fiscal funds of 45 RMB per capita in 2015 to support essential population health services, and 10% of the ranking score for those services is assigned to chronic-disease management, we assume that 10% of the 45 RMB per capita funding goes to chronic-disease management. Since there were about 687k residents in Tongxiang county, the total cost of the program for one year is calculated as follows:

$$Cost^{2015} = 10\% \cdot 45 \cdot 687k = 3.09 \text{ Million RMB.}$$

Our analyses imply that relative reduction in overall medical spending is one of the benefits of the program. Suppose the last-ranked township exhibits virtually no effect on spending, and the 6th-place township represents the average effect. Using the estimates from Table 4, the cost saving in 2015 for the average effect is $14.5 * 6 = 87$ RMB per hypertension patient. Thus, the benefit of managing 72,000 hypertension patients alone in 2015 would be

$$Benefit^{2015} = 97 * 72k = 6.26 \text{ Million RMB.}$$

This estimation of saved medical expenditures arguably represents a lower bound of the benefits of the program, as we have not considered any cost savings from managing diabetes nor the potential value of improving quality of life and survival for individuals with either or both chronic diseases we study.

6 Discussion and Conclusion

Our study contributes evidence on the potential for strengthened primary care to provide accessible, affordable, and decent quality management of common chronic diseases, thereby reducing use of specialist and inpatient services in China. Localities elsewhere in Zhejiang and other urban areas (such as Shanghai and Xiamen) have strengthened primary care over decades with some success, but there is little evidence of effective interventions in rural areas to date. We fill this gap with unique data for over 70,000 rural Chinese suffering from either hypertension or diabetes and who have voluntarily enrolled in a primary care management program in southeast China. Our study design uses variation in management intensity generated by administrative and geographic boundaries—regression analyses based on 14 pairs of villages within two kilometers of each other but managed by different townships. Utilizing this plausibly exogenous variation, we find that patients residing in a village within a township with more intensive primary care management, compared to neighbors with less intensive management, had more primary care visits, fewer specialist visits, fewer hospital admissions, and lower inpatient spending. No such effects are evident in a placebo treatment year.

Exploring the mechanism, we find that patients with more intensive primary care management exhibited better drug adherence as measured by filled prescriptions. This is important, because non-adherence to anti-hypertensive and anti-diabetic medication regimens is a leading cause of preventable complications such as heart disease and stroke. Drug non-adherence—which includes missed doses, unfilled prescriptions, and other forms of under-utilization—is especially common for asymptomatic diseases, often associated with poor primary care, and can be improved with interventions (Conn et al. 2016). Numerous studies confirm adherence problems among NCD patients in China. For example, Pan et. al (2017) present a cross-sectional survey of antihypertensive drug adherence in Xi'an in northwestern China, showing that only 35% of patients adhered to prescribed therapy. In a teaching hospital in Shanghai, Yue et. al (2014) found only 52% of hypertension patients exhibited good adherence to antihypertensive drugs. Given a significant association between patient understanding of hypertension and drug adherence, the authors advocate for greater patient education to offset low antihypertensive drug adherence in China. Wong et. al (2014) find a significant association between a greater number of co-morbidities and poor antihypertensive drug adherence in Henan, China.

Most previous evidence comes from urban China, but these studies do support our posited mechanism for the reduced spending and improved health (as measured by fewer hospitalizations) that we find flowed from better primary care management. And better adherence is especially important for rural Chinese with chronic disease, given low rates of disease control. For example, Lu et al. (2017) find that only 6.1% of rural individuals with hypertension had their blood pressure under control. Although physicians in China have long had financial incentives to prescribe medications because clinics derived revenue from drug dispensing (Currie et al. 2010, 2014), China has removed that 'drug mark-up' revenue from government-owned primary care providers since national health reforms in 2009. Moreover, any such incentive was not differential across the townships in our study, so cannot explain the pattern of adherence improvements that we observe.

Our findings of a causal effect imply that appropriately aligning primary care providers' incentives and knowledge with the goal of convincing patients to adhere to medications can contribute to better health and reduced medical spending, improving welfare. Indeed, our back-of-the-envelope estimate suggests that the resource savings from the Tongxiang primary care management program, in terms of avoided inpatient admissions, substantially outweighed the fiscal costs of the program.

Our measure of primary care management intensity captures the patient-years of enrollment in the NCD-control component of the essential population health services package. This intensity measure presumably captures the efforts of village doctors and township health center staff to convince community residents of the desirability and effectiveness of regular community-level management of their conditions, relative to regular management through county hospital outpatient department visits (or lack of management until complications develop). Of course our management intensity metric could also capture patient-to-patient spillover effects within the village—letting others know about the program and persuading each other of its benefit.

Any such spillovers reinforce the positive effects from village management, indirectly amplifying physician effort through positive interaction among neighbors. We find statistically significant causal effects of differing management intensity in neighboring villages despite any such spillovers across township boundaries. This empirical evidence supports the effectiveness of chronic disease management programs as part of broader regional initiatives to address population health, not merely as adjuncts to health insurance. Note that the program in Tongxiang worked across that region to improve population health starting with community screening for NCDs, reducing underdiagnosis and enhancing primary and secondary prevention with management of incident cases. Rarely have regional primary care strengthening programs been assessed in rural areas of LMICs, despite their importance in many high-income countries. For example, studies show the association between regional management initiatives and reduction in age- and sex-adjusted hospitalization rates for targeted ambulatory care-sensitive conditions (e.g. Tanenbaum et al. 2018).

Aligning provider incentives with health system goals was a key component of program effectiveness in the Tongxiang case. While providing some resources and training, the studied program mostly relied on supply-side incentives and augmented workload, while allowing patients to choose between primary care with no additional out-of-pocket payment or hospital-based care previously available under insurance. Like most of China, policymakers eschewed mandatory referrals or strict gatekeeping. Our study suggests that ongoing reform in China that relies more on primary care may be promising.

China's health policymakers continue to experiment with incentive reforms to improve the efficiency and sustainability of its universal health coverage, such as through provider payment reforms (Jian et al. 2015, Powell-Jackson et al. 2015) and strengthening primary care, including introduction and nationwide implementation of a voluntary "family doctor" system. The success of these efforts will rest partially on the appropriate crafting of incentives for primary care providers. In Tongxiang, the program initially rewarded effort in enrolling new patients; but gradually as the program enrolled the stock of existing NCD patients in the community—all but those most devoted to hospital-based management—the incentive structure needed to shift to focus on quality of care for those patients rather than the number of new patients.

Some other localities, such as Beijing's eastern district and some other (mostly urban) localities in Jiangsu, Zhejiang, Fujian and Guangdong, have experimented with innovative strategies of multiple-indicator evaluation systems for teams of providers serving empaneled patients. By linking those evaluation results to individual- and team-based bonuses, these primary care initiatives strive to provide a balanced and transparent system of rewarding providers who deliver high value primary care to their community members. Of course, some patients still prefer management by hospital-based physicians, and not all of the primary care targets specified by the monitoring systems align directly with what patients demand or value. Xiamen has developed a well-known team-based model that includes a health manager ("jiankang guanli shi") working with a general practitioner and any specialists the patients may need. Many localities are also experimenting with iphone apps to promote healthy lifestyles, self-management of chronic disease, or adherence to clinical recommendations. And many are thinking of ways to enrich the benefit package associated with signing up for the family doctor system, to attract patients into first-contact care at the primary care level. Such services include not only access to specialist referrals when needed but also easier prescription refills, home-based care for the disabled, and so on. Ultimately it will be important to assess whether such programs do achieve better convenience and lower cost without sacrificing quality of care, and especially to focus on rural areas, where the quality of primary care has been especially problematic.

Experiments with regional integration of primary care with hospitals into integrated care groups (such as Luohu district of Shenzhen in southern China) represent one mechanism to reinforce quality improvement in primary care with supply-side incentives (e.g. partial capitation payment to the integrated hospital and primary care group) to encourage patients to receive management in primary care. Future research on these integrated care experiments will reveal if they can complement NCD management in primary care without suffering from problems of underprovision under capitation or market power from lack of provider competition.

In sum, this study provides empirical evidence of the causal effects of primary care for improving health outcomes as measured by avoidable hospitalizations and reducing total medical spending for patients with hypertension and diabetes. This evidence from a relatively high per capita income part of rural China suggests that further efforts to strengthen primary care hold considerable promise for improving the control of chronic disease in rural areas as China develops, and the quality, efficiency, and convenience of basic healthcare services in other LMICs as well. Further research employing geographic discontinuities could be valuable for assessing the ongoing efforts to improve the quality and accountability of primary care in disparate settings within China and other LMICs around the globe.

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Appendix

A1 Tongxiang Public Health Insurance

Tongxiang *hukou* residents as well as full-time students are eligible to enroll in the Tongxiang resident insurance plan, which provides access to medical care are all local village and township-level public clinics, 12 Tongxiang county-level hospitals, and selected city-level hospitals in Zhejiang province and Shanghai. In 2015, the plan provided access to primary care with a co-insurance rate of 50% at local community health centers (village and township levels), in contrast to 90% at county- or city-level hospital outpatient departments. The coverage of inpatient admissions is relatively generous. For example, in 2015 the co-insurance rate patients paid for an inpatient admission at a township health center was 15% and at a hospital was 35%. Pharmaceutical expenditures are covered as well in the program. To enroll in the program, a resident in 2015 needed to pay 260 RMB (41.7 USD) for the annual premium and the local government would supplement the premium with 540 RMB (86.7 USD) per resident. In 2012, more than 95% of eligible residents enrolled in this program.

Eligibility to enroll in the Tongxiang employee insurance plan is restricted to employees who contribute towards social security benefits (i.e., formal sector employees) and eligible retired employees who have contributed to social security for enough time. The program is more generous than the resident insurance plan. In 2015, for employees that are not retired, the plan provided access to primary care with co-insurance rates of 30% at local community health centers (village and township levels) and 50% at county- or city-level hospital outpatient departments. The co-insurance rate patients paid for an inpatient admission at a township health center was 10% and at a hospital was 20%. The co-insurance rates were even lower for a retired employee.

The rural residents in Tongxiang are traditionally farmers who do not have formal employment and mostly enroll in the resident insurance program. The overall enrollment rate for private health insurance plans among Chinese residents is low and in general concentrated among the richer population. This paper focuses on the rural residents only, which constitute the majority of the Tongxiang population and are more homogeneous in demographics.

A2 Reputational Incentives and Management Intensity

The county-level CDC evaluates each township's population health service work each year, using a standardized evaluation metric with sub-components for each area of public health, such as vaccinations and NCD management. We obtained the Tongxiang CDC ranks and detailed scores assigned to each township for their public health programs during 2014-2016. In the calculation of the final score, 10% is based on performance of the chronic-disease management program. At the township-year level, we consider the following township(k)-year(t) level panel regression:

$$n_{kt} = \alpha r_{kt} + \chi_k + Y_t + \epsilon_{kt}, \tag{5}$$

where n_{kt} is the rank of # newly managed chronic-disease (both hypertension and diabetic) patients per capita in each township in year t, the higher the better, to reflect current year effort. r_{kt} is the rank of chronic-disease scores in the total score calculation, measured in the previous year, current year, and future year. Figure A.2 plots the residuals of n_{kt} against the residuals of r_{kt}, controlling for χ_k and Y_t, the township and year fixed effects. As we can see, past year rankings negatively affect the current year effort—the worse a township does in the past year, the better they perform in the current year. The relationship diminishes when regressing current year effort on current year ranking or future year ranking, suggesting mean-reversion is perhaps not the driving force. These results suggestively indicate that perhaps past reputation affects a township's employees' effort. One should notice that these results are only suggestive due to the small number of observations and other possible confounding factors.

Additional Tables and Figures

Table A.1: Regression Results for Equation (2): Healthcare Utilization in 2011

Panel A: Enrolled Hypertension Patients

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	1(Inpatient)	Expenditure	Inpatient Expenditure	Outpatient Expenditure	# Specialist Visits	# Primary Care Clinic Visits
rank($l_{k(i)}$)	0.000747	2.311	3.471	-1.160	-0.0175	-0.0339
	(0.00115)	(9.742)	(5.987)	(3.978)	(0.0162)	(0.112)
Observations	12,517	12,517	12,517	12,517	12,517	12,517
R-squared	0.002	0.007	0.002	0.015	0.049	0.061
Border FE	Yes	Yes	Yes	Yes	Yes	Yes
Sample	hp Patients	hp Patients	hp Patients	hp Patients	hp Patients	hp Patients

Panel B: Enrolled Diabetic Patients

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	1(Inpatient)	Expenditure	Inpatient Expenditure	Outpatient Expenditure	# Specialist Visits	# Primary Care Clinic Visits
rank($l_{k(i)}$)	-7.91e-05	9.696	3.700	5.996	-0.0297	0.00347
	(0.000960)	(13.40)	(5.569)	(9.436)	(0.0352)	(0.104)
Observations	3,065	3,065	3,065	3,065	3,065	3,065
R-squared	0.003	0.020	0.007	0.025	0.076	0.055
Border FE	Yes	Yes	Yes	Yes	Yes	Yes
Sample	db Patients	db Patients	db Patients	db Patients	db Patients	db Patients

Notes: The table above shows the estimation results of 2 using health utilization in 2011 as the dependent variables. All expenditure amounts are adjusted to 2015 RMB. The sample includes all enrolled chronic-disease patients aged 40+ in the 14 pair of adjacent villages located in different townships. An observation is at the patient level. Columns 1-6 use enrolled hypertension patients only and Panel B) use diabetics patients only on the boundaries. All expenditures are winsorized at 95th percentile within our claim sample during that year among the aged 40+ and agricultural *hukou* chronic-disease patients. Standard errors are clustered at the village level.

Table A.2: Regression Results for Equation (2): Differences in Healthcare Utilization

Panel A: Enrolled Hypertension Patients

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Δ 1(Inpatient)	Δ Expenditure	Δ Inpatient Expenditure	Δ Outpatient Expenditure	Δ # Specialist Visits	Δ # Primary Care Clinic Visits
rank($l_{k(i)}$)	-0.00256*	-16.82**	-20.75***	3.930	-0.0259**	0.0134
	(0.00142)	(7.753)	(6.784)	(3.404)	(0.0107)	(0.118)
Observations	12,517	12,517	12,517	12,517	12,517	12,517
R-squared	0.001	0.001	0.001	0.004	0.009	0.039
Border FE	Yes	Yes	Yes	Yes	Yes	Yes
Sample	hp Patients	hp Patients	hp Patients	hp Patients	hp Patients	hp Patients

Panel B: Enrolled Diabetic Patients

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Δ 1(Inpatient)	Δ Expenditure	Δ Inpatient Expenditure	Δ Outpatient Expenditure	Δ # Specialist Visits	Δ # Primary Care Clinic Visits
rank($l_{k(i)}$)	-0.00194	-8.183	-23.01	14.83	-0.0844***	0.398***
	(0.00173)	(22.82)	(16.48)	(14.95)	(0.0174)	(0.119)
Observations	3,065	3,065	3,065	3,065	3,065	3,065
R-squared	0.010	0.009	0.010	0.003	0.013	0.035
Border FE	Yes	Yes	Yes	Yes	Yes	Yes
Sample	db Patients	db Patients	db Patients	db Patients	db Patients	db Patients

Notes: The table above shows the estimation results of 2 using differences between health utilization in 2015 and in 2011 as the dependent variables. All expenditure amounts are adjusted to 2015 RMB. The sample includes all enrolled chronic-disease patients aged 40+ in the 14 pair of adjacent villages located in different townships. Columns 1-6 use enrolled hypertension patients only and Panel B) use diabetics patients only on the boundaries. An observation is at the patient level. All expenditures are winsorized at 95th percentile within our claim sample during that year among the aged 40+ and agricultural *hukou* chronic-disease patients. Standard errors are clustered at the village level.

Table A.3: Regression Results for Equation (4): Healthcare Utilization in 2015

Panel A: Enrolled Hypertension Patients

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
VARIABLES	1(Inpatient)	Expenditure	Inpatient Expenditure	Outpatient Expenditure	# Specialist Visits	# Primary Care Clinic Visits	# Primary Care Management Visits	# HP-Drug Covered Day	% HP-Drug Covered Day
rank($l_{k(i)}$)	-0.00196**	-17.49	-19.83***	2.337	-0.0477***	-0.0314	0.0236	1.250	0.00403
	(0.000821)	(11.50)	(6.696)	(6.744)	(0.0154)	(0.143)	(0.0530)	(1.470)	(0.00485)
Observations	12,517	12,517	12,517	12,517	12,517	12,517	12,517	12,517	12,517
R-squared	0.002	0.002	0.001	0.008	0.033	0.054	0.018	0.025	0.025
Border FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sample	hp Patients	hp Patients	hp Patients	hp Patients	hp Patients	hp Patients	hp Patients	hp Patients	hp Patients

Panel B: Enrolled Diabetic Patients

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
VARIABLES	1(Inpatient)	Expenditure	Inpatient Expenditure	Outpatient Expenditure	# Specialist Visits	# Primary Care Clinic Visits	# Primary Care Management Visits	# DB-Drug Covered Day	% DB-Drug Covered Day
rank($l_{k(i)}$)	-0.00368**	-21.34	-34.31**	12.97	-0.111***	0.210	0.0770	1.537	0.00413
	(0.00138)	(30.96)	(14.65)	(22.34)	(0.0222)	(0.168)	(0.0591)	(0.970)	(0.00314)
Observations	3,065	3,065	3,065	3,065	3,065	3,065	3,065	3,065	3,065
R-squared	0.010	0.006	0.007	0.008	0.039	0.050	0.038	0.053	0.053
Border FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sample	db Patients	db Patients	db Patients	db Patients	db Patients	db Patients	db Patients	db Patients	db Patients

Notes: The table above shows the estimation results of 4 using health utilization in 2015 as the dependent variables. The sample includes all enrolled chronic-disease patients aged 40+ in the 14 pair of adjacent villages located in different townships. An observation is at the patient level. Panel A) use enrolled hypertension patients only and Panel B) use diabetics patients only on the boundaries. The number of primary care visits in 2015 are broken down into visits in clinics that are recorded in the insurance claims and visits from the management logs that are not recorded in the insurance claims. All expenditures are winsorized at 95th percentile within our claim sample during that year among the aged 40+ and agricultural *hukou* chronic-disease patients. Standard errors are clustered at the village level.

Table A.4: Regression Results for Equation (4): Healthcare Utilization in 2011

Panel A: Enrolled Hypertension Patients

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	1(Inpatient)	Expenditure	Inpatient Expenditure	Outpatient Expenditure	# Specialist Visits	# Primary Care Clinic Visits
rank($l_{k(i)}$)	0.000590	2.923	3.499	-0.576	-0.0219	-0.0176
	(0.00132)	(11.24)	(7.131)	(4.368)	(0.0190)	(0.127)
Observations	12,517	12,517	12,517	12,517	12,517	12,517
R-squared	0.002	0.007	0.002	0.015	0.049	0.061
Border FE	Yes	Yes	Yes	Yes	Yes	Yes
Sample	hp Patients	hp Patients	hp Patients	hp Patients	hp Patients	hp Patients

Panel B: Enrolled Diabetic Patients

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	1(Inpatient)	Expenditure	Inpatient Expenditure	Outpatient Expenditure	# Specialist Visits	# Primary Care Clinic Visits
rank($l_{k(i)}$)	-0.000844	5.975	1.158	4.817	-0.0204	-0.0211
	(0.00109)	(14.02)	(6.357)	(9.573)	(0.0359)	(0.102)
Observations	3,065	3,065	3,065	3,065	3,065	3,065
R-squared	0.003	0.020	0.007	0.025	0.076	0.055
Border FE	Yes	Yes	Yes	Yes	Yes	Yes
Sample	db Patients	db Patients	db Patients	db Patients	db Patients	db Patients

Notes: The table above shows the estimation results of 4 using health utilizatoin in 2011 as the dependent variables. All expenditure amounts are adjusted to 2015 RMB. The sample includes all enrolled chronic-disease patients aged 40+ in the 14 pair of adjacent villages located in different townships. An observation is at the patient level. Columns 1-6 use enrolled hypertension patients only and Panel B) use diabetics patients only on the boundaries. All expenditures are winsorized at 95th percentile within our claim sample during that year among the aged 40+ and agricultural *hukou* chronic-disease patients. Standard errors are clustered at the village level.

Table A.5: Regression Results for Equation (4): Differences in Healthcare Utilization

Panel A: Enrolled Hypertension Patients

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Δ 1(Inpatient)	Δ Expenditure	Δ Inpatient Expenditure	Δ Outpatient Expenditure	Δ # Specialist Visits	Δ # Primary Care Clinic Visits
rank($l_{k(i)}$)	-0.00255	-20.42**	-23.33***	2.912	-0.0258**	-0.0137
	(0.00175)	(9.234)	(8.280)	(3.794)	(0.0118)	(0.148)
Observations	12,517	12,517	12,517	12,517	12,517	12,517
R-squared	0.001	0.001	0.001	0.004	0.009	0.039
Border FE	Yes	Yes	Yes	Yes	Yes	Yes
Sample	hp Patients	hp Patients	hp Patients	hp Patients	hp Patients	hp Patients

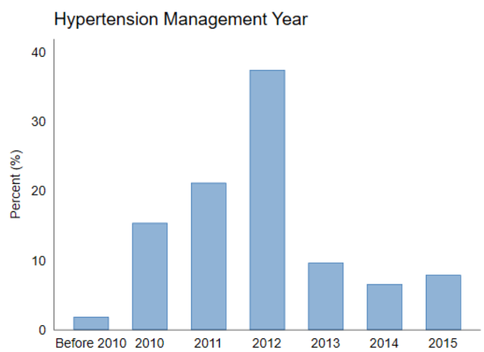
Panel B: Enrolled Diabetic Patients

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Δ 1(Inpatient)	Δ Expenditure	Δ Inpatient Expenditure	Δ Outpatient Expenditure	Δ # Specialist Visits	Δ # Primary Care Clinic Visits
rank($l_{k(i)}$)	-0.00284**	-27.32	-35.47***	8.150	-0.0910***	0.231*
	(0.00128)	(20.12)	(12.29)	(15.49)	(0.0187)	(0.132)
Observations	3,065	3,065	3,065	3,065	3,065	3,065
R-squared	0.010	0.009	0.010	0.002	0.014	0.029
Border FE	Yes	Yes	Yes	Yes	Yes	Yes
Sample	db Patients	db Patients	db Patients	db Patients	db Patients	db Patients

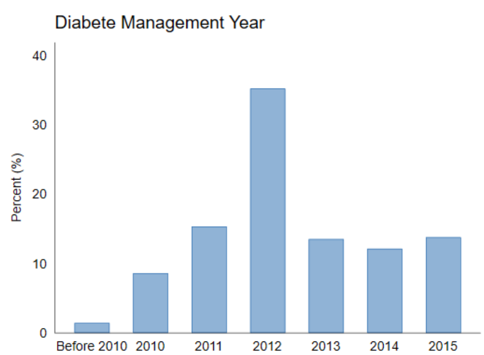
Notes: The table above shows the estimation results of 4 using differences between health utilization in 2015 and in 2011 as the dependent variables. All expenditure amounts are adjusted to 2015 RMB. The sample includes all enrolled chronic-disease patients aged 40+ in the 14 pair of adjacent villages located in different townships. Panel A) use enrolled hypertension patients only and Panel B) use diabetics patients only on the boundaries. An observation is at the patient level. All expenditures are winsorized at 95th percentile within our claim sample during that year among the aged 40+ and agricultural *hukou* chronic-disease patients. Standard errors are clustered at the village level.

Figure A.1: %New Enroll Patients by Year of Management

(a) Hypertension Management



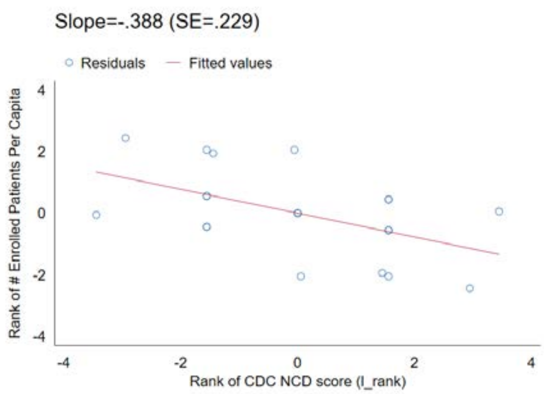
(b) Diabetics Management



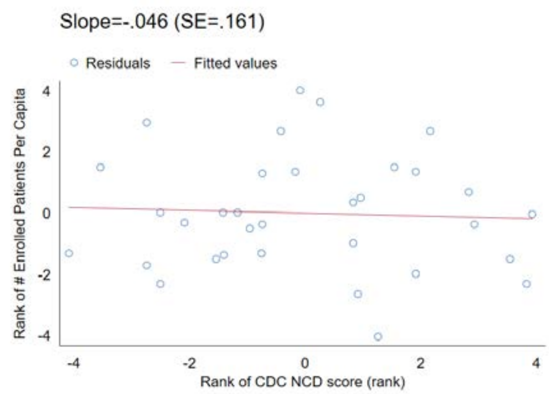
Notes: The figures above show the percentage of enrolled patients by their enrollment years. There are very few people who enrolled prior to 2010 due to pilot programs but the most majority enrolled between 2010 and 2013.

Figure A.2: Incentive Responses to Township Chronic-Disease Ranking

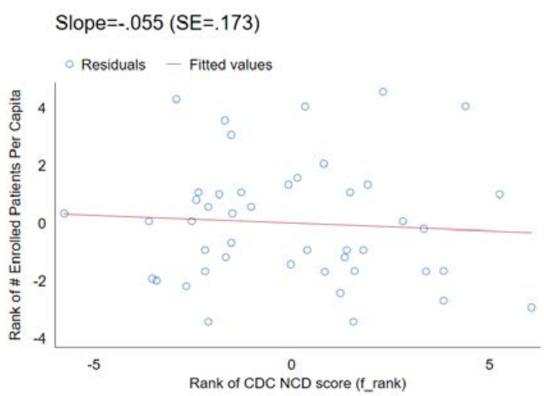
(a) Ranking of Newly Managed Patients Per Capita Vs Past Year Township Chronic-Disease Ranking



(b) Ranking of Newly Managed Patients Per Capita Vs Current Year Township Chronic-Disease Ranking



(c) Ranking of Newly Managed Patients Per Capita Vs Next Year Township Chronic-Disease Ranking



Notes: The figures above plot the residualized n_{kt} and r_{kt} controlling for township and year fixed effects from equation (5). Rankings are the higher the better. Panel A uses past year township chronic disease ranking from the CDC internal performance review. Panel B uses current year ranking. Panel C uses next year ranking. The red lines are linear fits of the scatterplots. The title includes the coefficient estimates and standard errors of $\hat{\alpha}$ from equation (5). Standard errors clustered at township levels.