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Primary care availability affects antibiotic consumption: Evidence using unfilled positions in Hungary

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MŰHELYTANULMÁNYOK

DISCUSSION PAPERS

MT-DP – 2018/10

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– Evidence using unfilled positions in Hungary**

ANIKÓ BÍRÓ – PÉTER ELEK

Discussion papers
MT-DP – 2018/10

Institute of Economics, Centre for Economic and Regional Studies,
Hungarian Academy of Sciences

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Primary care availability affects antibiotic consumption

– Evidence using unfilled positions in Hungary

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June 2018

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Anikó Bíró – Péter Elek

Abstract

Using administrative data from Hungary, we analyse the effect of general practitioner (GP) care availability on the consumption of antibiotics. We exploit the geographical and time variation in unfilled GP positions as a source of exogenous variation in the availability of primary care. According to our estimates from fixed effects panel regressions, if the single GP position of a village becomes unfilled, the days of therapy (DOT) as well as public expenditures on antibiotics decrease by 3.2-4.1%. The negative effect on antibiotic consumption is stronger in smaller settlements, in settlements where secondary care is less available, and where antibiotics were previously overprescribed. The quality of prescribing behaviour measured by the ratio of narrow-spectrum to broad-spectrum antibiotics deteriorates significantly as a consequence of worse primary care availability. The number of GP consultations decreases by 9.8%, but prescribed antibiotic DOT per GP visit goes up by 7.2%.

JEL: C23, I10, I11

Keywords:

Administrative panel data, Antibiotics, Primary care availability, Quality of antibiotic prescription, Unfilled general practices

Research ethics

The research was approved by the Research Ethics Committee of the Hungarian Medical Research Council.

Acknowledgements

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Az alapellátás elérhetősége befolyásolja az antibiotikum-fogyasztást – Eredmények betöltetlen magyarországi praxisok alapján

Bíró Anikó – Elek Péter

Összefoglaló

Magyarországi adminisztratív adatok felhasználásával vizsgáljuk a háziorvosi ellátás elérhetőségének hatását az antibiotikum-fogyasztásra. A betöltetlen háziorvosi praxisok földrajzi és időbeli variabilitását használjuk az alapellátás elérhetőségének exogén változékonyságaként. Fix hatású panelregressziós becsléseink alapján, ha egy község egyetlen háziorvosi praxisa betöltetlenné válik, akkor az antibiotikum terápiás napok száma (days of therapy – DOT) és a közösségi kiadások 3,2–4,1%-kal csökkennek. Az antibiotikum-fogyasztásra kifejtett negatív hatás erősebb azokon a kisebb településeken, ahonnan a szakellátás kevésbé elérhető, valamint ott, ahol korábban antibiotikum-túlfogyasztás volt észlelhető. A felírás minőségének indikátora (amelyet a szűk és a tág spektrumú antibiotikumok fogyasztásának egymáshoz viszonyított arányával mérünk) szignifikánsan romlik az alapellátáshoz való rosszabb hozzáférés hatására. A háziorvosi vizitek száma 9,8%-kal csökken, míg az egy vizitre eső antibiotikum-felírás DOT-ban mérve 7,2%-kal nő.

JEL: C23, I10, I11

Tárgyszavak: adminisztratív paneladatok, alapellátás elérhetősége, antibiotikumok, antibiotikum-felírás minősége, betöltetlen háziorvosi praxisok

Primary care availability affects antibiotic consumption

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Anikó Bíró* Péter Elek†

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Using administrative data from Hungary, we analyse the effect of general practitioner (GP) care availability on the consumption of antibiotics. We exploit the geographical and time variation in unfilled GP positions as a source of exogenous variation in the availability of primary care. According to our estimates from fixed effects panel regressions, if the single GP position of a village becomes unfilled, the days of therapy (DOT) as well as public expenditures on antibiotics decrease by 3.2 – 4.1%. The negative effect on antibiotic consumption is stronger in smaller settlements, in settlements where secondary care is less available, and where antibiotics were previously overprescribed. The quality of prescribing behaviour measured by the ratio of narrow-spectrum to broad-spectrum antibiotics deteriorates significantly as a consequence of worse primary care availability. The number of GP consultations decreases by 9.8%, but prescribed antibiotic DOT per GP visit goes up by 7.2%.

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Keywords: administrative panel data, antibiotics, primary care availability, quality of antibiotic prescription, unfilled general practices

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1 Introduction

”Antibiotic resistance is one of the most significant threats to patients’ safety in Europe. It is driven by overusing antibiotics and prescribing them inappropriately.” [National Health Service, 2018] According to Van Boeckel et al. [2014], global consumption of antibiotic drugs increased by 35% between 2000 and 2010. As Blaser [2011] also points out, antibiotics can be life-saving, however, overuse of them can increase the susceptibility to infections and disease. Marton et al. [1991] show alarming evidence for high incidence of antibiotic resistance in Hungary.

In this paper, using data from Hungary, we analyse how access to primary care influences the consumption of antibiotics. As a source of exogenous variation in primary care availability, we use information on unfilled general practitioner (GP) positions.

Hungary had the 9th lowest per capita consumption of antibiotics for systemic use out of 30 EU/EEA countries in 2016 (the defined daily dose – DDD per 1,000 inhabitant-days

was 15.4 in Hungary, 21.9 in the EU/EEA, see European Centre for Disease Prevention and Control [2017]). However, quality indicators of antibiotic prescribing behaviour do not show such a bright picture. The ratio of broad-spectrum antibiotics – more probably responsible for emerging antibiotic resistance – to narrow-spectrum antibiotics in community consumption is the second largest in the EU/EEA [ECDC et al., 2017]. Similarly, Adriaenssens et al. [2011b] report that out of the 12 antibiotics quality indicators such as the seasonal variation of prescriptions or the use of certain broad-spectrum medications, Hungary is in the worst quartile of EU/EEA countries in five cases and in the second worst quartile in four cases. Specifically, Juhasz et al. [2013] report some inappropriateness of antibiotic treatment in acute cystitis in the country. Partly responding to these results, the prescription rate of antibiotics has become part of the primary care indicator system in Hungary since 2011 [National Health Insurance Fund Administration, 2014].

It is of policy importance to analyse how access to outpatient care – especially to primary care – influences the demand for antibiotics, but little is known about this issue. Limited access to primary care is likely to lead to fewer consultations, hence lower access to prescriptions. However, it can also have opposite effects since as Lundkvist et al. [2002] argue, if GPs spend more time with their patients the prescription of antibiotics can be reduced. Filippini et al. [2006] find that the density of physicians is positively related to outpatient antibiotic consumption in the Switzerland. Masiero et al. [2010] arrive at similar conclusions, based on data from 17 European countries. Matuz et al. [2006] document regional variations in antibiotic consumption in Hungary, but find no relations between antibiotic use and the density of pharmacies or the number of enrolled patients per GP. Based on more detailed administrative data covering later periods, and using unfilled positions as a source

of exogenous variation in GP care availability, we find differing results.

The literature shows evidence that geographical distance to health care facilities negatively affects health care use (Haynes and Bentham [1982], Hyndman et al. [2000], among others). Also, using a quasi-experimental setting in Hungary, Elek et al. [2015] find that geographical accessibility increases the demand for outpatient specialist care. If better access (both in terms of geographical distance and times of availability) increases the visits to GPs, and pharmaceutical consumption is conditional on having obtained a prescription, then GP access is likely to influence the use of pharmaceuticals.

Our results indicate that unfilled general practices have a moderate, but statistically significant negative effect on the use of antibiotics. The effect is stronger in smaller settlements, in settlements where secondary care is less available, and where antibiotics were previously overprescribed. We also find evidence that the quality of outpatient antibiotic use deteriorates significantly as a consequence of worse primary care availability.

2 Institutional background

In Hungary, the municipalities are responsible for the provision of primary care. The majority of primary care services are provided by general practitioners (family physicians or family paediatricians). Local governments designate primary care districts to the GPs, who are not allowed to refuse patients from their primary care district. On the other hand, patients have the right to choose their GP. GPs work in single handed practices, group practices are generally not allowed. To work in a primary care district with a territorial supply obligation, family doctors must purchase a licence. Thus practices can be bought and sold,

while local governments still keep a control over who serves as a GP. GP care is provided for free, and at least in principle, GPs act as gatekeepers. However, several specialist care services can be accessed without the referral of a GP (e.g. dermatology, ear, nose and throat diseases, gynaecology, traumatology). GPs' financing is mostly based on capitation, with some supplements depending e.g. on the age composition of the patients and the type of settlements covered. (This summary of primary care in Hungary is based on Gaál et al. [2011] and Rurik [2012].) In 2015, there were 6,277 practising GPs in Hungary, the average number of patients per GP was 1,566. For comparison, there are 3,155 settlements in Hungary, and the total population is around 9.8 million [Hungarian Central Statistical Office, 2018].

A severe problem of the Hungarian primary care system is that around 5% of the GP practices are unfilled. The lack of supply of GPs (or family physicians) is not unique to Hungary, see for example, Bland and Isaacs [2002] and Spence [2016]. The high ratio of unfilled GP positions in Hungary is despite the fact that the government offers high financial subsidies if a GP takes up a practice that has been unfilled for at least 6 months. The unfilled practices are mostly located in remote, less developed areas of the country. If a practice becomes unfilled it will be partly covered by GPs of neighbouring primary care districts. Hence, on the one hand, deputy GPs in the remote areas have to travel a lot, so as to provide some care at the unfilled practices. On the other hand, patients in unfilled districts cannot access a GP locally every day of the week. If they need to see a GP when the deputy GP is not around, they have to travel to another district (typically to another settlement).

3 Data and descriptive statistics

3.1 Unfilled practices

We obtained the list of filled and unfilled general practices from the National Health Insurance Fund Administration (NHIFA) for the time between 2004-2017.¹ We know the zip code of the site of the practice, the list of settlements the practice caters for, and the start and end date (month) of the practice having been unfilled. In those settlements where there is only one general practice, we exactly know whether it is unfilled or not in a given month. However, our information is less precise in settlements (mainly towns and cities) where more than one general practice is available. We know if some of them are unfilled, but cannot identify the exact part of the settlement that is not covered by GP care. Because of this data limitation, we focus our analysis on villages. As descriptive statistics will show, the majority of unfilled general practices are in the countryside, the lack of GP care availability is typically an issue in the villages.

Our main explanatory variable on the settlement level will be the ratio of the unfilled practices relative to the total number of practices (filled plus unfilled) covering the given settlement. Most (around 77%) of villages are covered by a single practice only, thus if a GP position is unfilled there then the ratio of unfilled practices equals one.²

Figure 1 displays the number of unfilled general practices between 2004 and 2017. A steady increase can be observed from 2008 up to 2016: during these years the number of unfilled practices as well as their share among all practices more than doubled from 150

¹These data were provided to us by the NHIFA free of charge in the framework of secondary use of public data.

²Most of the villages (72.5%) are covered by practices that cater for adults and children as well. 18.3% of the practices covering villages cater for adults only, and 9.2% for children only.

(2.3%) to 350 (5.5%). Based on the (censored) data covering years 2004-2017, the observed mean duration of a practice being unfilled is 4.9 years, the median is 3.3 years.

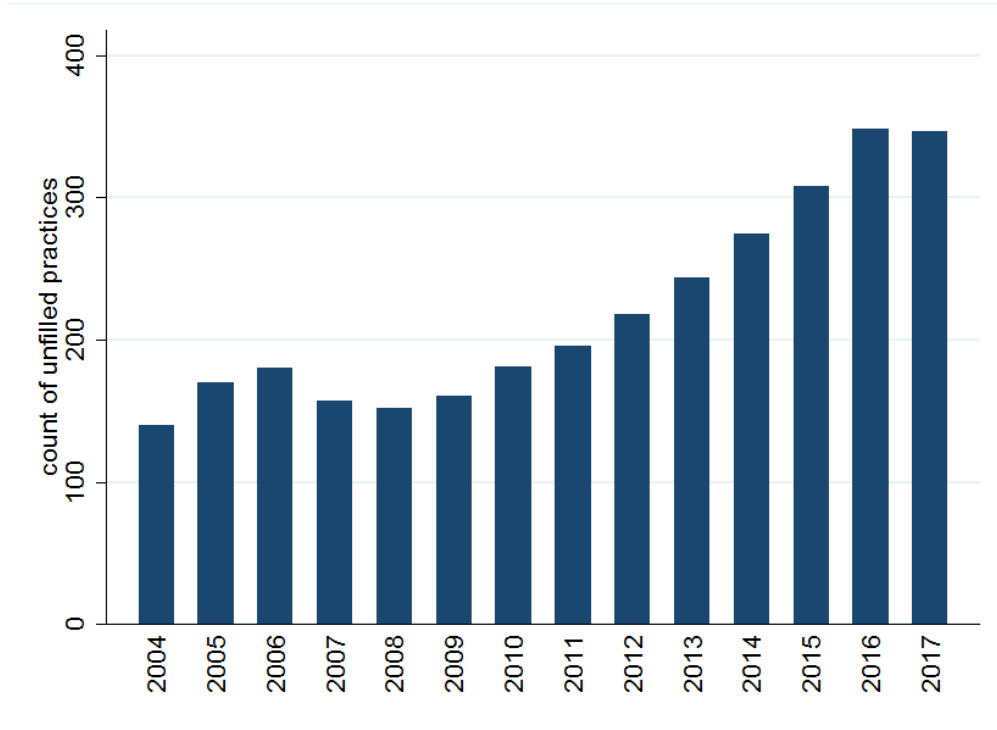


Figure 1: Number of unfilled general practices in December of a given year (data source: NHIFA)

Figure 2 shows the spatial distribution of settlements with unfilled general practices as of December 2015. While unfilled practices are scattered all over Hungary, their distribution is more dense in the Eastern part of the country, especially in the poorer North-Eastern part.

Throughout the paper we will also use the T-STAR municipal statistical system of the Central Statistical Office (CSO) of Hungary, which contains wide-range annual settlement-level demographic and socio-economic data on all settlements in the country. By merging the data on unfilled practices to T-STAR we see that between years 2010-2015 (in the period upon which our main antibiotic analysis will be based), about two-third of unfilled general practices were in villages, and the share of unfilled practices increased from 5.8% to the

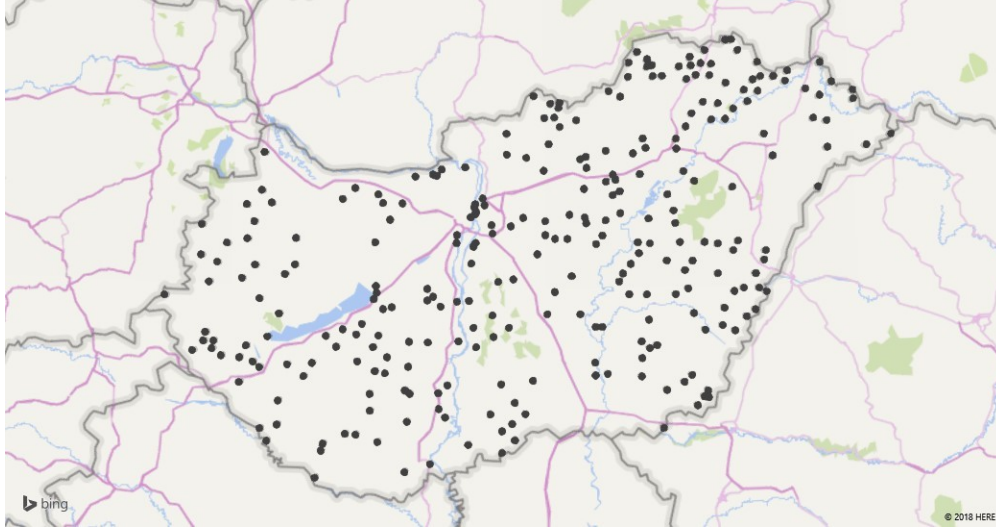


Figure 2: Spatial distribution of settlements with unfilled general practices, December 2015 (data source: NHIFA)

substantial 10.9% in this settlement category. Restricting the analysis to villages, we estimate a simple linear model to determine the factors that influence the ratio of unfilled practices among all practices covering a given settlement.³ According to Table 1, the ratio of unfilled practices substantially increases with the young-age and old-age ratio (population aged 0-5 and 60+ divided by the total population, respectively) and with the rate of unemployment (population registered as unemployed divided by the population aged 18-59). Unfilled GP positions are less frequent in villages with a larger population and with a higher number of private firms per capita. The effect of the number of cars per capita and of the ratio of the population with prescription exemption certificate is not significant.⁴ Altogether this analysis suggests that unfilled general practices are less common in the more affluent villages.

³Note that this variable, used throughout the paper, takes into account the catchment areas of the practices, hence those small villages that are normally covered by a practice in a neighbouring settlement, are also included.

⁴We use the latter indicator as a composite measure of disadvantaged status, as eligibility to such certificate is based on income and health care need.

	ratio of unfilled general practices	
log of population size	-0.0119***	[0.00378]
age 0-5 ratio	1.055***	[0.358]
age 60 plus ratio	0.333***	[0.0830]
unemployment rate	0.385***	[0.0635]
prescription exemption rate	0.113	[0.0992]
cars per capita	-0.0190	[0.0200]
firms per capita	-0.199***	[0.0454]
year effects		Yes
number of observations		16,318
number of settlements		2,810
mean of outcome variable		0.0636

Cluster-robust standard errors in brackets, *** p<0.01, ** p<0.05, * p<0.1
Settlement-year level NHIFA and T-STAR data,
weighted by the population of settlements, years: 2010-2015

Table 1: Linear regression of unfilled general practices on settlement characteristics

3.2 Consumption of antibiotics

We obtained data on the use of antibiotics from the National Healthcare Services Centre (NHSC) of Hungary through an agreement between the NHSC and the Institute of Economics, Centre for Economic and Regional Studies of the Hungarian Academy of Sciences. The data cover pharmaceuticals in the ATC (Anatomical Therapeutic Chemical) group "J01" (antibiotics with systemic use) that were purchased through pharmacies, hence only relate to the ambulatory setting and exclude hospital care. Only prescription drugs are recorded (over-the-counter sales are excluded) but this is not a limitation because of the prescription-only status of antibiotics in Hungary.⁵ Our data cover prescriptions both in primary care and specialist outpatient care, hence we will measure the overall effect on the use of antibiotics, taking into account a possible substitution from primary care to specialist outpatient care when a general practice becomes unfilled.

⁵As Matuz et al. [2007] document, some non-prescription sales do occur but they constitute only around 2% of all sales.

The NHSC data set covers years 2010-2015. It provides information on the name, identifier code and detailed ATC code of the antibiotic medication, the date of the purchase, the amount purchased, the associated social security payment and out-of-pocket payment. It also includes the zip code of the patient's address, the patient's year of birth and gender, and the ICD (International Statistical Classification of Diseases) code of the diagnosis for which the prescription was given. Using the zip codes, we construct monthly indicators of antibiotic use (days of treatment [DOT], social security payment and out-of-pocket payment of all antibiotics and of various subcategories) on the settlement level. To examine heterogeneity, we also define monthly indicators by settlement, age group and gender.

To generate descriptive statistics and to relate the consumption of antibiotics to total pharmaceutical consumption, we also use publicly available county-level statistics on pharmaceutical sales from the NHIFA [National Health Insurance Fund Administration, 2018].⁶ Similarly to the NHSC data above, only prescribed pharmaceutical purchases in public pharmacies are included in these statistics.

Based on the NHIFA data, throughout years 2010-2015, the average per capita annual expenditures on prescribed pharmaceuticals (social security plus out-of-pocket payments) were around 148 EUR (44,300 HUF). Expenditures on antibiotics accounted for 3.0% of total prescribed pharmaceutical expenditures. Per capita annual expenditures on antibiotics were around 4.5 EUR (1,350 HUF), of which 30% were paid by the social security. Antibiotic consumption is strongly seasonal: compared to the summer months, expenditures more than double in the winter. The average days of therapy (DOT) of antibiotics was 14.2 per 1,000

⁶Since they come from the same administrative sources, the NHSC and NHIA antibiotic consumption data are very similar both in their levels and in their county-level variation (the correlation is above 0.95).

inhabitant-days throughout years 2010-2015, without major time trend (15.1 in 2010, 14.8 in 2015).

Table 2 shows descriptive statistics of antibiotic use by gender and age. On average, antibiotic DOT per 1,000 inhabitant-days is higher for women than for men (by 23%), and higher for children than for adults, but the age differences are more pronounced for men than for women. Gender differences are partly due to the common use of antibiotics for the treatment of urinary tract infections among women.

age group	males			females		
	mean	SE	median	mean	SE	median
0-5	18.43	0.03	16.64	17.10	0.03	15.18
6-17	17.25	0.03	14.75	17.79	0.03	15.50
18-39	10.41	0.01	9.78	15.39	0.02	14.85
40-59	9.12	0.01	8.75	13.83	0.02	13.47
60-	13.91	0.02	13.35	13.54	0.02	13.19
Total	11.97	0.01	10.68	14.77	0.01	14.03

Statistics weighted by the size of each settlement-gender-age group
 SE is the standard error of the mean
 NHSC data, years 2010-2015

Table 2: Average antibiotic DOT per 1,000 inhabitant-days by gender and age

There is a non-negligible variation in per capita antibiotic consumption across counties (Figure 3). In line with Matuz et al. [2006], the use of antibiotics tends to be higher in the poorer areas (Eastern, North-Eastern and Southern Hungary).

3.3 GP care use

Finally, the T-STAR database contains annual settlement-level data on GP care use, constructed by adding up the visits to all GPs based in a given settlement. Thus if a practice caters for several settlements then all the visits are attached to the basis settlement. Due

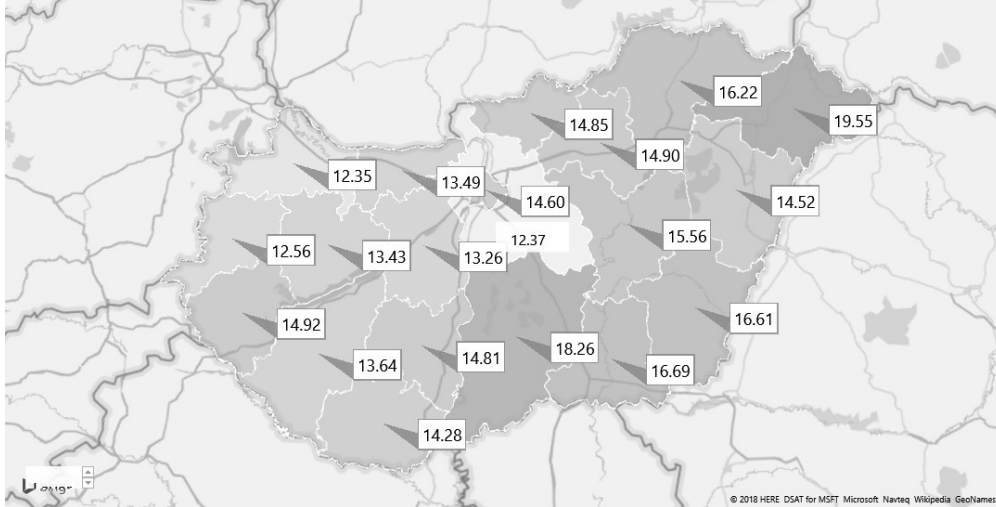


Figure 3: Average antibiotic DOT per 1,000 inhabitant-days by county (data source: NHIFA, year 2015)

to this limitation, we take the following steps to generate the annual per capita number of GP visits. First, using the register of general practices, for each settlement we identify the settlement that provides the GP care (this is important for small villages, which do not host a health centre). Second, we calculate the population of the catchment area of the general practices of a given settlement, using the population statistics from T-STAR. Finally, we divide the number of GP visits with the estimated population to construct the per capita indicator on the catchment area level.

Within villages over years 2010-2015, the annual per capita number of GP visits was 8.0.

4 Methods

In our baseline analysis we estimate the effect of unfilled general practices on antibiotic consumption, using the settlement-month panel of antibiotic DOT and expenditures, which was created from the NHSC data. We restrict the analysis to villages and estimate the

following panel model:

$$antibiotics_{st} = \gamma_0 + \gamma_u unfilled_{st} + \gamma_d D_t^{date} + \gamma_h h_{st} + \nu_s + \varepsilon_{st}, \quad (1)$$

where s indicates settlements and t the time measured in months. In various model specifications the outcome variables ($antibiotics_{st}$) are the level and logarithm of antibiotic DOT per 1,000 inhabitant-days as well as the level and logarithm of expenditures per 1,000 inhabitants.⁷ In addition to total expenditures, we also analyse social security and out-of-pocket payments separately. Also, as quality indicators, we examine various subcategories of antibiotic consumption. Our main explanatory variable is the ratio of unfilled general practices among all practices covering settlement s in month t ($unfilled_{st}$).

As control variables we include time fixed effects (D_t^{date}) and various settlement-level indicators (h_{st}) of health need and health care supply from the T-STAR database. We proxy health needs with the age-gender distribution of the settlement and with socio-economic factors (local unemployment rate and prescription exemption rate). The supply of health care beyond primary care is measured by the local (micro-regional) specialist outpatient capacities (annual specialist outpatient hours per 1,000 inhabitants) and with the presence of a pharmacy in the settlement. We estimate equation (1) with settlement-level fixed effects (ν_s), which capture all time-invariant characteristics of the settlements. We use the (time-averaged) population of the settlements as weights in our estimation because the dependent variables are calculated on per capita basis and hence the models are inherently heteroscedastic.

⁷The monthly settlement-level DOT or expenditures are zero only for a tiny fraction of observations, hence the logarithms are missing only in very few cases.

We also investigate effect heterogeneities. First, we analyse how the population size, the availability of secondary care and the socio-economic conditions in a settlement influence the estimated effect of unfilled general practices on antibiotic use. Therefore, we extend equation (1) with interaction terms between the ratio of unfilled general practices ($unfilled_{st}$) and the logarithmic value of population size, normalized to 1,000 inhabitants. We also interact the ratio with the micro-regional specialist outpatient hours per 1,000 inhabitants (population-weighted mean=1.22, SD=0.80), with the binary indicator of the presence of a pharmacy in the settlement (weighted proportion=0.775) and, to capture the socio-economic conditions, with settlement-level unemployment rate (weighted mean=0.105, SD=0.071) and with the prescription exemption rate (weighted mean=0.039, SD=0.025).

Second, we analyse effect heterogeneities according to the initial consumption level of antibiotics. Our aim is to understand if the negative estimated effect of unfilled practices originates from settlements where the use of antibiotics was relatively high, conditional on health care need (captured by a set socio-economic indicators) and health care supply. To do so, first we estimate a cross-sectional regression of the annual antibiotic use in year 2010, and generate the residuals:

$$antibiotics_{s,2010} = \gamma_0^{2010} + \gamma_u^{2010} unfilled_{s,2010} + \gamma_h^{2010} h_{s,2010} + \varepsilon_{s,2010}. \quad (2)$$

The outcome variable in equation (2) is the logarithm of the annual antibiotic DOT in 2010, and settlement-level controls (h_s) are the same as in equation (1). The generated residuals have a standard deviation of 0.35 (with zero mean). Then, we re-estimate equation (1), with adding the interaction term between the ratio of unfilled practices and the year

2010 residual of equation (2). Here we use data for years 2013-2015, so that we can interpret the interaction term as the heterogenous effect according to the baseline use of antibiotics.

Third in our heterogeneity analysis, we investigate how the estimated effects vary across age groups and gender. Here, we split the settlement level monthly antibiotic consumption according to these variables and then estimate a version of equation (1) on each age group and gender specific subsample:

$$antibiotics_{agst} = \delta_0^{ag} + \delta_u^{ag} unfilled_{st} + \delta_d^{ag} D_t^{date} + \delta_h^{ag} h_{st} + \nu_{ags} + \varepsilon_{agst}, \quad (3)$$

where index a stands for age category, g for gender, s for settlement and t for monthly time. Now, the coefficient δ_u as well as the coefficients of the time and of the control variables vary with age and gender, and ν_{ags} stands for age, gender and settlement specific fixed effects.

Finally, to investigate the mechanisms of how unfilled practices affect the use of antibiotics, we estimate the impact of the ratio of unfilled practices on the annual number of GP visits, and on antibiotic prescriptions per GP visit. We use the settlement-level (more precisely, GP catchment area level) GP care use statistics as described in section 3.3 and restrict the analysis to villages. We estimate the following fixed effects model:

$$\ln y_{st} = \beta_0 + \beta_u unfilled_{st} + \beta_d D_t^{date} + \beta_h h_{st} + \nu_s^{GP} + \varepsilon_{st}^{GP}. \quad (4)$$

The notations and the explanatory variables are essentially the same as in equation (1). Since the data are on the annual level, the time dummies are year dummies now. The dependent variables ($\ln y_{st}$) are the logarithm of the per capita annual number of GP visits and the logarithm of the ratio of antibiotic prescriptions to GP visits.

5 Results

5.1 Effects on the use of antibiotics

5.1.1 Baseline results

The estimation results of equation (1) are reported in Table 3. The logarithmic models show that when the single general practice covering a village becomes unfilled, then antibiotic DOT decreases by 3.2% and total antibiotics expenditures by about 2.5%. The negative effect is driven by social security expenditures (-4.1%) rather than out-of-pocket payments (-0.9%), indicating a stronger effect on antibiotic use that is subsidised by the social security to a higher extent (e.g. usage based on prescription exemption). In nominal terms, the magnitude of the decreasing effect is around 14.2 EUR per 1,000 inhabitants in a month, most of which (11.2 EUR) comes from decreasing social security expenditures. DOT per 1,000 inhabitant-days decreases by about 0.6 as the ratio of unfilled practices increases from zero to one.

Specification checks (not shown here in detail) reveal that above the contemporaneous effect, past and future (i.e. previous and next year's) unfilled status of the general practice have no significant effect on antibiotic use. Thus, we find no evidence for adjustment in antibiotic use after the immediate negative effect of a practice becoming unfilled. We also do not see evidence that people would adjust their antibiotic use in anticipation of a practice becoming unfilled.

5.1.2 Heterogeneity analyses

The estimation results, reported in the first column of Table 4, suggest that the negative effect of unfilled practices originates from smaller settlements. As the normalized logarithmic

	monthly expenditures, EUR/1,000 inhabitants			DOT per 1,000 inhabitant-days
	total	social security	out-of-pocket	
ratio of unfilled practices	-14.16*** [4.832]	-11.22*** [3.694]	-2.944 [2.456]	-0.555*** [0.149]
number of observations	164,868	164,868	164,868	164,868
number of settlements	2,320	2,320	2,320	2,320
mean of outcome variable	378.12	121.71	256.41	14.62
	log of per capita expenditures			log of per capita DOT
	total	social security	out-of-pocket	
ratio of unfilled practices	-0.0253*** [0.00963]	-0.0414*** [0.0128]	-0.00933 [0.00880]	-0.0323*** [0.00941]
number of observations	164,415	164,415	164,362	164,415
number of settlements	2,320	2,320	2,320	2,320

Cluster-robust standard errors in brackets, *** p<0.01, ** p<0.05, * p<0.1

Controls: settlement and monthly date fixed effects, settlement level controls (see text)

Settlement-month level NHSC data, weighted by the population of settlements,
years: 2010-2015

Table 3: Effect of the ratio of unfilled general practices on antibiotic use, fixed effects models

population size is zero for a settlement of around 1,000 inhabitants, if the general practice in a settlement of this size becomes unfilled, that implies a 3.8% decrease in antibiotic consumption. In smaller settlements the effect is even larger. For example, in a village with a population size of 250, the estimated effect of a single practice becoming unfilled on the per capita antibiotic DOT is -9%.

Turning to the second column of Table 4, the results indicate that it is not the small population size *per se* that increases the effect of unfilled practices, but rather the poorer supply of health care services (as captured by the availability of specialist care and pharmacies). Lower supply of specialist care implies less opportunity for substitution of primary care, leading to the stronger effect of the availability of primary care on antibiotic use. Meanwhile, there is no effect heterogeneity according to socio-economic conditions measured by the local unemployment rate and the prescription exemption rate.

The results reported in the third column of Table 4 suggest that a major fraction of the negative effect of unfilled practices originates from settlements where the baseline use of antibiotics was comparatively high. In settlements where the initial use of antibiotics was higher by one standard deviation (by 0.35 on logarithmic scale), the negative effect is stronger by 4.1 %points, comparable with the magnitude of the average effect.

	log of per capita DOT		
ratio of unfilled practices	-0.0383***	-0.0662***	-0.0300**
	[0.00880]	[0.0225]	[0.0131]
× log of population size (ln(population/1,000))	0.0352***	0.0162	
	[0.0125]	[0.0170]	
× specialist outpatient hours in micro-region /1,000 inhabitants		0.0147*	
		[0.00761]	
× pharmacy present in settlement		0.0444*	
		[0.0246]	
× unemployment rate in settlement		-0.0713	
		[0.0926]	
× prescription exemption rate in settlement		-0.163	
		[0.238]	
× residual of antibiotic use in 2010			-0.116**
			[0.0513]
number of observations	164,415	164,415	81,052
number of settlements	2,320	2,320	2,274

Cluster-robust standard errors in brackets, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Controls: settlement and monthly date fixed effects, settlement level controls (see text)

Settlement-month level NHSC data, weighted by the population of settlements,

years: 2010-2015 (2013-2015 for third column)

Table 4: Heterogeneous effect of the ratio of unfilled general practices, fixed effects models

Next, we turn to the heterogeneity analysis by age and gender. The estimation results are reported in Table 5. For all age groups and both genders, the estimated effect of unfilled practices on antibiotic DOT is either statistically not significant, or significantly negative, in the range of -3.9% to -5.9% . On average, the negative effect is similar across the two genders, and weaker within the youngest age category.

The positive (albeit statistically not significant) estimated effects in the youngest age group (age 0–5) are not negligible. These results indicate that in case of a GP practice being unfilled, the deputy practitioners might be on average more likely to prescribe antibiotics for young children. This is an indicative evidence for the quality of antibiotic prescribing practices deteriorating with the lower availability of primary care, which will be further confirmed by the results reported in the next section.

log of per capita DOT		
ratio of unfilled practices	× males	× females
× age 0-5	0.0161 [0.0207]	0.0344 [0.0217]
number of observations	142,135	138,464
× age 6-17	-0.00439 [0.0178]	0.00851 [0.0185]
number of observations	145,746	146,220
× age 18-39	-0.0522*** [0.0143]	-0.0473*** [0.0126]
number of observations	144,589	149,201
× age 40-59	-0.0409** [0.0165]	-0.0593*** [0.0138]
number of observations	149,089	158,206
× age 60-	-0.0114 [0.0168]	-0.0387*** [0.0147]
number of observations	148,027	158,309

Cluster-robust standard errors in brackets, *** p<0.01, ** p<0.05, * p<0.1

Controls: settlement and monthly date fixed effects,

settlement level controls (see text)

Settlement – month – age group – gender level NHSC data,

weighted by the population in each category, years: 2010-2015

Number of settlements: 2320 in each category

Table 5: Age and gender specific effect of the ratio of unfilled general practices on antibiotic prescriptions, fixed effects models

5.2 Quality indicators

We investigate some further indicators of antibiotic use that can provide evidence whether the quality of antibiotic prescriptions is affected by the unfilled status of general practices.

First, we look at the effect of the ratio of unfilled practices on the use of narrow-spectrum versus broad-spectrum antibiotics, the reciprocal of the indicator defined by [ECDC et al., 2017].⁸ To lower the risk of antibiotic resistance, a higher value of this (reciprocal) quality indicator is desirable, but international data suggest that its value is much worse in Hungary than in the EU/EEA on average [ECDC et al., 2017]. According to fixed effects panel regressions (Table 6), the indicator decreases substantially by 0.023 (from an average level of 0.18) if a practice becomes unfilled, suggesting a quality worsening effect. The nominator (consumption of narrow-spectrum antibiotics) decreases by 7.7%, more strongly than the 1.4% and statistically not significant decrease of the denominator (broad-spectrum antibiotics).

Next, we look at the effect of unfilled practices on disease-specific antibiotic prescriptions. We analyse antibiotic prescriptions for urinary tract infections and respiratory tract infections (9% and 57% of all antibiotic prescriptions, respectively, based on NHSC data). According to Adriaenssens et al. [2011a], the largest volumes of antibiotic prescriptions are given out for these diseases in primary care, hence they can be used to track disease-specific quality of antibiotic consumption.⁹ While guidelines recommend the use of antibiotics for

⁸We define the indicator as the ratio of the consumption of narrow-spectrum penicillins, cephalosporins and macrolides (J01(CA+CE+CF+DB+FA01)) to the consumption of broad-spectrum penicillins, cephalosporins, macrolides and fluoroquinolones (J01(CR+DC+DD+(F-FA01)+MA)). We examine the reciprocal of the index used by [ECDC et al., 2017] because there are lots of zero values in the consumption of narrow-spectrum antibiotics on the settlement-month level.

⁹We exclude pneumonia from this analysis as only 2.3% of antibiotic prescriptions have this diagnosis code, and guidelines recommend the use of antibiotics. We include the following International Classification of Primary Care (ICPC) codes under respiratory tract infections: H71 - acute otitis media, R74 - acute upper respiratory infection, R75 - sinusitis, R76 - tonsillitis, R78 - bronchitis. Urinary tract infections correspond to the U71 ICPC code.

urinary tract infection, this is not the case for most types of respiratory tract infections. Therefore, assuming that unfilled practices do not influence the prevalence of diseases, we would consider an indication of improving quality of antibiotic prescribing behaviour if prescriptions for urinary tract infections remained unchanged while for respiratory tract infections decreased.

Therefore, we re-estimate equation (1) using disease-specific antibiotic prescriptions (DOT) as the dependent variable, both in levels and in logs (Table 6). We do not find substantial differences for the two disease categories (-2.3% versus -2.9%).

	DOT per 1,000 inhabitant-days			log of per capita DOT		
	quality index	broad spectrum	narrow spectrum	broad spectrum	narrow spectrum	
ratio of unfilled practices	-0.0233** [0.00951]	-0.204* [0.121]	-0.214*** [0.0748]	-0.0137 [0.0101]	-0.0771** [0.0341]	
number of observations	164,353	164,592	164,592	164,353	142,244	
number of settlements	2,320	2,320	2,320	2,320	2,320	
mean of outcome variable	0.18	11.29	1.82			
	urinary tract infections		respiratory tract infections			
ratio of unfilled practices		-0.0343 [0.0214]		-0.313** [0.131]	-0.0229 [0.0173]	-0.0287* [0.0155]
number of observations		164,868		164,868	155,483	163,636
number of settlements		2,320		2,320	2,319	2,320
mean of outcome variable		1.29		8.45		

Cluster-robust standard errors in brackets, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Controls: settlement and monthly date fixed effects, settlement level controls (see text)

Settlement-month level NHSC data, weighted by the population of settlements,
years: 2010-2015

Respiratory tract infections: acute otitis media, acute upper respiratory infections,
sinusitis, tonsillitis, bronchitis.

Table 6: Effect of the ratio of unfilled general practices on the use of selected antibiotic categories, fixed effects models

5.3 GP care use and antibiotics: understanding the mechanism

We turn to the analysis of how the effect of unfilled practices on the number of GP visits interferes with the effect on antibiotic use. Living in a village where the single general practice is unfilled throughout the entire year implies on average 9.8% fewer GP visits, holding settlement-level controls and time invariant characteristics fixed, and netting out time effects (Table 7, first column). Due to the measurement error in the GP care use indicator (measured at the centre of a catchment area, as explained in section 3.3), the true effect could be even higher. Nevertheless, the results indicate a substantial negative effect of unfilled practices on GP care use.

It is also known from our previous results that per capita antibiotic DOT decreases on average only by 3.2% (Table 3). The smaller decrease in antibiotic use than in GP visits suggests that the limited availability of GP care is partly compensated by a higher likelihood (or higher number) of antibiotic prescription per GP visit. Indeed, as shown in the second column of Table 7, a single practice becoming unfilled is estimated to increase antibiotic prescriptions per GP visits by 7.2%. Hence the overall negative effect of unfilled practices on antibiotic use stems from the limited access to GP care, and not from the deputy GPs prescribing fewer antibiotics per visit.

6 Conclusions

Using administrative data from Hungary, we estimated the effect of primary care availability on antibiotic use. We exploited the geographical and time variations in unfilled general practices as a source of exogenous variation in primary care supply. We estimated a negative

	log of annual GP visits per capita	log of antibiotic DOT per GP visit
ratio of unfilled practices	-0.0975*** [0.0215]	0.0722*** [0.0233]
number of observations	8,510	8,509
number of settlements	1,438	1,438

Cluster-robust standard errors in brackets, *** p<0.01, ** p<0.05, * p<0.1
Controls: settlement and year fixed effects, settlement level controls (see text)
Settlement-year level T-STAR data, weighted by the population of settlements,
years: 2010-2015

Table 7: Effect of the ratio of unfilled practices on annual GP visits and antibiotics prescription per GP visit, fixed effects models

3.2% effect on per capita antibiotic use if a general practice becomes unfilled in a settlement that is otherwise covered with a single general practice. Larger effects are estimated for smaller settlements and for settlements where there is a limited availability of specialist care and pharmacies. While the use of antibiotics decreases as a consequence of the supply-side effects, we also find evidence that the quality of antibiotic prescriptions deteriorates.

Overall, our results suggest that given the socio-economic status of a settlement, and given the supply of secondary care, the availability of primary care has a non-negligible effect on the quantity and quality of antibiotic consumption. The main message of our findings is that antibiotic use can be influenced by supply-side factors, the usage is sensitive to the access to primary care. The overuse of antibiotics might be limited if the number of avoidable visits to primary care physicians is decreased. However, it is important to keep in mind that for avoiding antibiotic resistance, it is desirable not only to reduce the overall use of antibiotics, but also to shift consumption towards narrow-spectrum antibiotics. According to our results, such a quality improvement cannot be achieved with limiting the availability of primary care.

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