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Abstract

Appropriate use of antibiotics is an important strategy to combat the problem of growing antibiotic resistance rates. In order to follow this strategy, it is important to understand the determinants of antibiotic use. We analyse the potential link between competition among general practitioners (GPs) measured with the Herfindahl-Hirshman index (HHI) and regional antibiotic consumption in Norway in 2015 and 2016. We use the data about antibiotic consumption expressed by the number of prescriptions of antibiotics for systemic use (J01) and by the number of antibiotics for respiratory tract infections (phenoxymethylpenicillin (J01CE02), doxycycline (J01AA02), amoxicillin (J01CA04) and macrolides (J01FA)) per 1000 inhabitants. We apply multiple regression analysis to the data mentioned above and control for socioeconomic characteristics of the municipalities. Our findings suggest that competition may contribute to about 37-80 additional antibiotic prescriptions per 1000 inhabitants per year and 23-46 additional prescriptions per 1000 inhabitants of antibiotics for respiratory tract infections. Moreover, our estimations suggest that antibiotic prescription is significantly related to the average number of consultations per patient, the average length of the patient list, travel time to a pharmacy, income, and the share of women.

Keywords

Antibiotic resistance, economic incentives, salary, fee-for-service, capitation, Herfindahl-Hirschman Index (HHI)

1. Introduction

Antibiotic resistance (AR) rates have increased significantly during the last 50 years, making antibiotics less and less effective in treating infectious diseases. Widespread use of antibiotics is the main reason for such growth. Antibiotics constitute an important cure for a range of, sometimes life-threatening, diseases. However, in many cases, antibiotics are prescribed when the treatment has very little or even no effect. This is especially common in primary care in the case of Respiratory Tract Infections (RTIs). According to Fleming-Dutra *et al.* [1], almost half of antibiotics prescriptions for RTIs in the US are inappropriate. A decrease in antibiotic misuse may slow down the growing rates of AR. To accomplish a decrease in inappropriate prescription of antibiotics, it is important to analyse drivers of antibiotics use.

This paper tests if competition between primary care providers, more specifically, general practitioners (GPs), affects antibiotic prescription. According to economic theory, 'perfect' market competition leads to the most efficient outcomes for both buyers and sellers. However, the health market is associated with asymmetric information and could hardly be called 'perfect'. Patients usually have limited knowledge about their health condition and the potential effect of treatment. Therefore, the role of competition versus regulation for the efficiency of the health care market has always been a subject of debate. Previous research shows that competition may affect physicians' medical decision-making and their gatekeeping function [2-4]. In the case of antibiotics, competition may affect doctor's prescription behaviour in the following ways. Patients may have limited knowledge about the problem of AR or about the effectiveness of antibiotics, and do not carry the full cost of their antibiotic use. Therefore, they may consider the doctor's decision to prescribe an antibiotic as a quality of care mark [5, 6]. At the same time, if doctors' reimbursements depend on the number of patients, and if the environment is competitive, willingness to attract patients may cause over-prescription of antibiotics [7-9].

To the best of our knowledge, there are only a few studies about competition and antibiotic use. Fogelberg [10] studied the effect of a competition-inducing reform implemented in Sweden, in a period between 2007 and 2010, on the prescription of antibiotics. The reform allowed patients to choose their primary care providers, increased the number of primary clinics by attracting new private providers to the market, and changed the compensation rules. Because the reform took place in different municipalities at different dates, Fogelberg conducted the difference-in-difference analysis using municipality level data. According to the study results, the competition-inducing reform increased prescriptions of antibiotics in the areas where providers did not have to pay for the prescribed pharmaceuticals. The Fogelberg's study provides important insights, and the difference-in-difference approach makes it possible to identify the causal effect of the reform on antibiotics prescriptions. However, this approach does not allow measuring the relationship between the level of market concentration and antibiotics use. In another paper, Kwon and Jun [11] studied the effect of the information disclosure policy on antibiotic prescription rates in Korea. The policy forced clinics and hospitals, which had more than one-hundred antibiotic prescriptions for the common cold per quarter, to disclose their antibiotic prescription rates. Kwon and Jun found that competition between clinics affected the policy effect size: the average prescription rates declined less in the markets with stronger competition. Kwon and Jun measured competition by the number of clinics per 1000 inhabitants. However, the number of clinics may grow proportionally with population size, i.e., areas with few clinics can have the same or even higher number of clinics per person than areas with many clinics. Therefore, it is important to account for how great is the selection of providers for the patients and, hence, how easy is it to switch from one provider to another. Bennett *et al.* [12] used the Herfindahl-Hirschman index (HHI) to study the link between competition and antibiotic use in Taiwan from 1997 to 2005 using a sample of 200,000 patients. The HHI is a more reliable measure of competition because it takes into account the market share of each specific provider and shows how concentrated the market is, rather than the number of providers per consumer. The results of the study by Bennett *et al.* suggest that antibiotic use is positively correlated with the level of competition in the market. However, the study treated clinics and hospitals with the median size of 25 physicians, rather than GPs, as competitors, which, again, does not allow taking into consideration the full number of options for the patient when choosing the health care provider.

In this paper, we test if competition between primary care providers using HHI affect prescriptions of antibiotics in Norway. In contrast to Bennett *et al.* [12], we measure competitions not between clinics but between GPs. This allows us to take into account both how great the selection of providers for the patients is and how homogeneous the providers are in terms of market share. One more reason for calculating HHI based on the GPs' lists is that we suppose that GPs receiving a mixture of capitation payment for registered patients and fee-for-service (compared to GPs compensated from the clinics) may have more incentives to please patient by overprescribing antibiotics.

We use data on antibiotic prescriptions in primary care for Norwegian municipalities in 2015 and 2016, along with data on HHI and other socioeconomic characteristics. In contrast to Bennett *et al.* [12], we use aggregated information about all antibiotic prescriptions dispensed by the pharmacies in Norway (which reflects the residential location of the patients) and account for the availability of the health services in different municipalities. Another advantage of or approach is that nearly all antibiotics prescribed by GPs and all antibiotics dispensed by pharmacies in Norway are registered electronically, as well as over-the-counter sales of antibiotics are restricted. Moreover, Norway has a strict attitude towards antibiotic consumption, high public awareness about the AR problem, and a relatively low prevalence of AR [13, 14]. This can diminish the effect of the associated confounders in the analysis.

2. Primary health care in Norway

Municipalities are responsible for the organisation of primary care in Norway. All Norwegian residents are covered by the National Insurance Scheme (Folketrygden). GPs play a very important role in Norwegian health care system due to their gatekeeping function. They may work individually or in a primary health care centre and do nearly all initial assessments, treatment, and referrals to secondary care [4]. According to the data from Norwegian Health Economics Administration (HELFO), in July 2017, there were 4787 GPs in Norway.

In 2001, Norway implemented a reform called The Regular General Practitioners Scheme (also called the 'list-patient' system). The reform made it possible for patients to choose a personal GP and change GP twice per year. Almost all registered users (99%) actively choose a GP. The reform also allowed GPs to set the maximum length of their patient list. On average, each GP has about 1200 patients on the list [15].

The implementation of the 'list-patient' system in 2001 also changed the way GPs are reimbursed [16]. Although primary health care is still primarily funded and regulated by the central government, the 2001 reform has made the market substantially more competitive [4]. Besides the free choice of GP, another reason for the increase in competition is that most of GPs in Norway are self-employed and get a mixture of fee-for-service, capitation (both visits and list length-based), and co-payments from patients. Only about 5% of GPs are salaried physicians.

The patient co-payment rate is about 15%. In 2014 the average consultation fee was 172 NOK. After reaching a certain ceiling (2185NOK (230 euro) in 2015), the patient is exempted from co-payments for the rest of the year. In 2014 the average consultation fee was 172NOK. Some groups of patients are exempted from this fee, e.g., children under 16, visits related to prenatal care, visits related to transmittable diseases that are a threat to public health [17].

3. Empirical approach

Data and variables

To identify the effect of competition on antibiotic consumption, we use yearly data on antibiotics prescriptions processed at Norwegian pharmacies. The data covers the years 2015 and 2016 and includes patients up to the age of 79 years. Our data is on the municipality level, and we have retrieved it from the Norwegian Public Health Institute webpage [18]. During the study period, there were 428 municipalities in Norway. The data for 3 of them is missing. With 425 municipalities and two years, we have access to 850 unique observations. Prescriptions of antibiotics for patients in hospitals or nursing homes are not included in the data. The data includes information about the type of antibiotics, dividing them into the following groups according to the Anatomical Therapeutic Classification (ATC) code: Antibiotics for systemic use (J01) and Antibiotics used for RTIs (phenoxymethylpenicillin (J01CE02), doxycycline (J01AA02), amoxicillin (J01CA04) and macrolides (J01FA)). We include both groups in the analysis.

To measure competition among GPs in each municipality, we use the data from HELFO register provided by the Norwegian Directorate of Health (Helsedirektoratet). The register contains monthly data on patient lists (number of patients on the list, maximal expected length of the list), and GP characteristics (name, gender, municipality, reimbursement type, if the doctor is a specialist in general practice or not). This data allows us to calculate HHI using formula (1)

$$HHI = \sum_{i=1}^{N} s_i^2, \qquad (1)$$

where s_i is the market share of GP i in a market of N GPs. In our case, the market share is calculated as the number of patients on the list divided by the total number of listed patients in each municipality. HHI varies in the interval between $\frac{1}{N}$ (when there are N equal-sized providers in the market) and one. The higher the value of HHI is, the lower is the level of competition between GPs in a municipality. In a very competitive environment, HHI is close to zero.

Identifying the link between competition and antibiotic prescriptions is challenging for a number of reasons. One such reason is that a range of socioeconomic, cultural, and regulatory factors may also affect antibiotic prescription rates. Norway has a homogenous regulatory system for prescriptions of antibiotics. However, the patient population differs between municipalities. To control for such differences, we have collected data on the relevant according to the literature [19-21] socio-demographic and socioeconomic characteristics of the patient population in each municipality from Statistics Norway[1]. To control for morbidity, we use the total number of visits to GPs in each municipality divided by its population. We use the number of GPs' consultations per inhabitant in each municipality as a proxy for GPs' workload and availability.

[1] One observation is missing and therefore we had to exclude it from the analysis.

Table 1 Description of the variables and descriptive statistics

Variable	Description	mean	SD	min	max
Antibiotics					
Antibiotics per 1000 inhabitants	number of prescriptions of antibiotics for systemic use (J01) per 1000 inhabitants	345.768	86.147	98.973	616.178
RTI antibiotics per 1000 inhabitants	number of prescriptions of antibiotics used for RTIs (phenoxymethylpenicillin (J01CE02), doxycycline (J01AA02), amoxicillin (J01CA04) and macrolides (J01FA)) per 1000 inhabitants	178.668	53.014	40.203	378.267
HHI	Herfindahl-Hirschman Index	0.286	0.240	0.002	1.000
Consultations	the number of GPs' consultations per inhabitant	2.719	0.367	1.600	4.000
List length	average GP's list length	930.485	265.814	154.000	1542.000
Women	percent of women	48.417	1.087	42.960	50.846
Age 0_15	percent of people of age from 0 to 4	19.590	2.390	12.173	25.786
Age16_34	percent of people of age from 16 to 34	23.704	2.356	18.026	33.111
Age35_54	percent of people of age from 35 to 54	27.793	1.741	22.459	33.612
Low_income	percent of people in households with income below 60% of national median income, calculated by EU scale	9.175	2.093	3.700	19.700
Immigrants	percent of immigrants	9.589	3.615	1.717	25.461
Education	percent of people over 16 with higher education	18.981	3.654	9.900	31.500
Time to pharmacy	estimated median travel time to pharmacy	21.228	30.326	0.000	216.000

Another challenge is that the number of antibiotic prescriptions in the data may be underestimated for municipalities with low pharmacy density [18]. In such areas, the percentage of drug delivery (including antibiotics) for acute treatment directly from a doctor's office or emergency service may be higher than in other areas (these types of deliveries are not a part of the statistics on antibiotic prescriptions). To control for this, we use data from the Norwegian Directorate of Health webpage [22] on the estimated travel time to the nearest pharmacy in different municipalities. Unfortunately, the data on time to a pharmacy is missing in 16 municipalities. Therefore, we will present the analysis both with and without correction for the availability of pharmacies. We present the description of the variables (yearly municipality characteristics) included in the analysis and the descriptive statistics in Table 1.

Empirical specification

To estimate the influence of competition and other previously discussed factors on antibiotic use, we use equation (2) and apply linear regression analysis.

$$\begin{aligned} Antibiotics_i = {} & \alpha + \beta_1 HHI_i + \beta_2 Consultations_i + \beta_3 List\_length_i + \beta_4 Women_i \\ & + \beta_5 Age0\_15_i + \beta_6 Age16\_34_i + \beta_7 Age35\_54_i + \beta_8 Year\_2016_i \\ & + \beta_9 Low\_income_i + \beta_{10} Immigrants_i + \beta_{11} Education_i \\ & + \beta_{12} Time\_to\_pharmacy_i + \sum_{a=2}^{5} \gamma_a Region_{ai} + \varepsilon_i, \end{aligned} \tag{2}$$

where $Year\_2016$ is a dummy variable for the year 2016, and $Region$ identifies the geographical area to which each municipality belongs. There are five geographical regions in Norway: Nord-Norge, Sørlandet, Trøndelag, Vestlandet, Østlandet. We use these two variables to control for potential cultural and regulatory differences across geographic regions and time.

We use four different specifications of equation (2). One reason for using different specifications is that the dependant variable of the equation (2) is represented by two different measures: Antibiotics for systemic use and Antibiotics used for RTIs. Another reason is that we want to estimate equation (2) both with and without $Time\_to\_pharmacy$.

Results

We present estimation results for all four specifications of the model (2) in Table 2. Our results suggest that the number of antibiotic prescriptions increases with higher competition (a decrease in HHI). More specifically, our empirical analysis suggests that there are about 37-80 fewer yearly prescriptions per 1000 inhabitants in municipalities with a monopoly for primary care (HHI = 1) than in municipalities with the highest level of competition (HHI $\approx$ 0). The average number of antibiotic prescriptions in municipalities with just one GP is 289 prescriptions per 1000 inhabitants per year. According to our model, moving to the almost pure competition will increase this number by about 13-28 percent.

We find a similar relationship if we focus on the analysis of antibiotics for RTIs. The difference, in this case, is about 23-46 prescriptions per 1000 inhabitants per year. The predicted average number of antibiotics is 16-33 percent higher for municipalities with almost pure competition than in municipalities with a monopoly. Moreover, antibiotic prescription increases with the length of the GPs' lists. This indicates that a higher workload among GPs may cause over-prescription. At the same time, the decision about having longer lists may also be based on the willingness to increase profit, which may be correlated with the willingness to attract patients by prescribing antibiotics. The average number of consultations per person was used as a proxy for morbidity. A one-unit increase in this number is associated with the increased antibiotic use by 40-44 yearly prescriptions per 1000 inhabitants and approximately 23 yearly prescriptions per 1000 inhabitants for RTI antibiotics.

Our results also suggest a significant effect of regional and other socioeconomic characteristics. A higher share of women in the region is associated with higher consumption of antibiotics. This finding is consistent with the fact that women have a higher frequency of urinary tract infections. We do not find any significant relationship between the share of children and antibiotic prescription. However, all four specifications predict the use of more antibiotics by people of age 35 to 54 compared to the age group of 55 to 79. Previous research suggests that a higher education level is associated with more responsible use of antibiotics [23, 24]. In accordance with this, we find that the total use of antibiotics decreases with a higher percentage of educated people in a municipality. However, this difference is only significant when we control for accessibility of pharmacies. The level of income may also serve as an indicator of the patient knowledge adequacy [25]. Our results are consistent with this: we find a significant and positive relationship between the share of low-income households and antibiotic consumption in specifications (2.1) - (2.3). Immigration is another important factor to consider due to various attitudes towards antibiotics among different cultures. Our results suggest that a higher share of immigrants is associated with a decrease in the use of antibiotics, but only in specifications (2.1) and (2.3).

Correction for the availability of pharmacy improves model characteristics and decreases the effect of competition in the model. According to our results, the longer it takes to travel to the pharmacy, the lower is the antibiotic prescription rate in the municipality. This result is consistent with the presumption about a higher percentage of drug delivery for acute treatment directly from a doctor's office or emergency service in municipalities with low drugstore density. However, it is also possible that patients who got an antibiotic prescription for self-limiting infections (which do not require antibiotic therapy) choose not to utilize the drug if the travel time to the pharmacy is too long. In the online appendix, we present the robustness analysis of our modelling where we address potential collinearity problems. The analysis suggests that the corrections for collinearity are not required.

Table 2 Estimation results of model 1

	Dependent variable			
	Antibiotics per 1000 inhabitants		RTI antibiotics per 1000 inhabitants	
	(2.1)	(2.2)	(2.3)	(2.4)
HHI	-79.986***	-36.644***	-46.457***	-22.974***
	(13.493)	(13.364)	(8.063)	(8.373)
Consultations	44.445***	40.415***	22.927***	22.923***
	(6.985)	(6.655)	(4.174)	(4.170)
List length	0.055***	0.033***	0.031***	0.019***
	(0.012)	(0.011)	(0.007)	(0.007)
Women	8.018***	8.685***	4.564***	5.177***
	(2.931)	(2.719)	(1.751)	(1.703)
Age 0_15	-0.100	-1.705	0.789	0.061
	(1.358)	(1.229)	(0.811)	(0.770)
Age16_34	1.129	-0.775	0.776	-0.167
	(1.471)	(1.333)	(0.879)	(0.835)
Age35_54	7.120***	6.300***	3.827***	3.530***
	(2.014)	(1.847)	(1.204)	(1.157)
Year_2016	-13.544***	-14.842***	-9.307***	-10.327***
	(4.868)	(4.343)	(2.909)	(2.721)
Low_income	5.450***	3.464***	2.572***	1.414*
	(1.422)	(1.291)	(0.850)	(0.809)
Immigrants	-5.084***	-1.713*	-2.334***	-0.596
	(0.964)	(0.895)	(0.576)	(0.561)
Education	-0.292	-3.003***	-0.395	-1.692***
	(0.855)	(0.784)	(0.511)	(0.491)
Time to pharmacy		-1.146***		-0.549***
		(0.098)		(0.061)
Sørlandet	61.363***	45.090***	54.343***	46.841***
	(11.505)	(10.332)	(6.875)	(6.474)
Trøndelag	48.037***	31.711***	23.678***	15.962***
	(9.765)	(8.733)	(5.836)	(5.472)
Vestlandet	47.333***	29.118***	36.426***	26.793***
	(8.339)	(7.617)	(4.984)	(5.230)
Østlandet	32.020***	5.784	32.541***	20.061***
	(8.623)	(7.904)	(5.153)	(4.952)
Constant	-437.218***	-268.621*	-277.151***	-217.751**
	(156.427)	(149.840)	(93.479)	(93.882)
Observations	849	817	849	817
R^2	0.349	0.457	0.387	0.450
Adjusted R^2	0.337	0.447	0.376	0.439
Residual Std. Error	70.059	63.310	41.866	38.414
	(df = 833)	(df = 800)	(df = 833)	(df = 800)
F Statistic	29.748***	42.162***	32.431***	40.963***
	(df = 15; 833)	(df = 16; 800)	(df = 15; 833)	(df = 16; 800)

Note: *p<0.1; **p<0.05; ***p<0.01. Standard errors are shown in parentheses.

4. Conclusions

Growing rates of AR are one of the major public health problems worldwide. Reduction in inappropriate use of antibiotics is an important strategy to tackle this problem. Therefore, the analysis of the driving forces of antibiotic misuse is extremely important. However, there is a lack of empirical evidence about the possible determinants of antibiotic consumption.

In this paper, we considered an important factor from an economic perspective – competition between health care providers. It is essential to know in what way it can be beneficial or harmful for health care. Competition in a 'perfect' market should make producers more sensitive to the needs and preferences of consumers. However, the health care market is characterized by asymmetric information and knowledge. As a consequence, increased competition may make GPs more inclined to please patients via frivolous prescription of antibiotics, as this can increase the chance to keep existing and attract new patients. This may result in inappropriate antibiotic prescriptions. Our findings support this statement and are consistent with the previous literature on this topic [10-12]. We used Norwegian municipality-level data on antibiotic consumption and the level of competition among GPs, measured with HHI, and found that antibiotic prescription rates are significantly higher in municipalities with stronger competition. Our results suggest that competition in primary care may indeed be one of the factors contributing to the problem of growing AR rates and antibiotic misuse. According to our estimations, competition between GPs may contribute up to about 80 yearly additional prescriptions per 1000 inhabitants, which is about 22 percent of the average prescription rate in Norway.

Moreover, we controlled for socioeconomic characteristics, such as age and gender balance, income, education, the share of immigrants, morbidity (in terms of the number of consultations), regional effects, GPs workload, or availability of primary care (in terms of number of GPs per patient). Our results suggest that education and income used as a proxy for patients' knowledge are significantly related to the use of antibiotics, and that lack of knowledge and education may contribute to the more frequent use of these drugs. We also found that antibiotic consumption is higher in the municipalities with longer lists. This can, to some extent, also serve as an argument in favour of the statement about profit-maximising behaviour of GPs, because most of the GPs set the length of their list themselves. Our result is consistent with Gjelstad *et.al* [26], who argued that GPs may prescribe an antibiotic in order to save time and found that GPs with most consultations prescribe more antibiotics. Therefore, it is also important to consider that high workload and hence the shortage of time for each consultation may cause less responsible prescription of antibiotics.

An important limitation of our study is the use of aggregated data. The attitude towards antibiotic use may be explained by variation in individual characteristics of the patient as well as the prescriber (e.g., experience, level of altruism or reimbursement type). Moreover, the antibiotic prescription rate may depend on patient age or health condition. The kind of patient on the list of each individual GP may both depend on the patients' and GP's characteristics, e.g., age, gender, location. Therefore, the use of individual prescription data along with the diagnostic information, would be beneficial. However, we believe that a considerable difference in antibiotic consumption between the municipalities found using aggregated data along with a relatively low level of antibiotic consumption (including misuse) in Norway may still serve as an argument in favour of competition being an important factor contributing to the AR problem.

There is a need for effective policies aimed to improve antibiotic prescription in primary care. The design of such policies may be, to some extent, based on our findings. It could be important to consider increasing the share of contracts with fixed salaries and putting a limitation on the maximum list length. Another way of approaching the problem is by implementing antibiotic-related pay-for-performance indicators in general practice. If the workload is indeed an important factor contributing to antibiotic over-prescription, it may be beneficial to reduce the gatekeeping function of GPs and increasingly involve specialist care for certain types of non-infectious diseases (e.g., mental disorders, prenatal care, etc.). Moreover, policies should target not only GPs, but patients as well. There is a need for educational campaigns among patients about the indications for antibiotic treatment and both individual and societal effects of antibiotic use. Another thing that may be important to consider is reducing the co-payment rates for the follow-up appointment for infectious diseases, especially RTIs. In this case, patients would not feel left without attention if an antibiotic is not prescribed immediately, and GPs would have more room for control over the patient's condition.

Thus, more studies are needed both in order to address the relationship between competition and antibiotic use and to find the best policy solutions in case competition is a factor contributing to the problem of AR. Because competition may be beneficial for primary care in terms of other aspects, which are not related to antibiotics, it is important to know how far we can go in limiting it and to what extent these policies should be implemented.

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Appendix

Robustness analysis

We present correlation matrix for specifications 1 and 3 in Table A1; and correlation matrix for specifications 2 and 4 in Table A2.

Table A1 Correlation matrix for specifications 1 and 3

	HHI	Consultations	List length	Women	Age 0_15	Age16_34	Age35_54	Low_income	Immigrants	Education
HHI	1									
Consultations	-0.02	1								
List length	-0.47	0.12	1							
Women	-0.43	0.05	0.45	1						
Age 0_15	-0.27	-0.07	0.34	0.26	1					
Age16_34	-0.42	-0.2	0.28	0.1	0.35	1				
Age35_54	-0.33	0.05	0.35	0.2	0.19	0.05	1			
Low_income	0.03	0	-0.11	-0.04	-0.21	0.07	-0.05	1		
Immigrants	-0.21	-0.09	0.18	-0.06	0.07	0.42	0.43	0.29	1	
Education	-0.4	-0.2	0.33	0.39	0.34	0.43	0.24	-0.04	0.32	1

Table A2 Correlation matrix for specifications 2 and 4

	HHI	Consultations	List length	Women	Age 0_15	Age16_34	Age35_54	Low_income	Immigrants	Education	Time to pharmacy
HHI	1										
Consultations	-0.07	1									
List length	-0.43	0.15	1								
Women	-0.42	0.04	0.44	1							
Age 0_15	-0.29	-0.09	0.35	0.27	1						
Age16_34	-0.39	-0.2	0.26	0.1	0.36	1					
Age35_54	-0.38	0.03	0.38	0.22	0.2	0.04	1				
Low_income	0.03	0.03	-0.09	-0.02	-0.2	0.06	-0.06	1			
Immigrants	-0.26	-0.09	0.21	-0.02	0.08	0.43	0.43	0.28	1		
Education	-0.4	-0.2	0.33	0.4	0.33	0.45	0.26	-0.04	0.36	1	
Time to pharmacy	0.5	-0.15	-0.51	-0.48	-0.36	-0.25	-0.26	0.08	-0.01	-0.34	1

From Table A2, we may notice a moderate correlation between *HHI* and *Time to pharmacy*. Therefore, in Table A3 we present variance inflation factors measures, which do not exceed five. These measures may serve as the evidence of absence of serious collinearity problem requiring correction.

Table A3 Estimation of variance inflation factors

Variables	Tolerance	VIF
HHI	0.521	1.92
Consultations	0.832	1.20
Average list length	0.539	1.86
Women	0.561	1.78
Age 0_15	0.536	1.87
Age16_34	0.472	2.12
Age35_54	0.442	2.26
Year_2016	0.976	1.02
Low_income	0.653	1.53
Immigrants	0.448	2.23
Education	0.569	1.76
Time to pharmacy	0.521	1.92
Sørlandet	0.633	1.58
Trøndelag	0.582	1.72
Vestlandet	0.396	2.52
Østlandet	0.328	3.05

In addition, we present the analysis with the interaction of *HHI* and *Time to pharmacy* in the regression model. The results of these estimations are presented in Table A4. The results suggest that effect of interaction term is not significant, while the effect of both variables on itself remains significant and is stronger than for the models without interaction term.

Table A4 Estimation results of model 1 with interaction of *HHI* and *Time to pharmacy*

	Dependent variable:	
	Antibiotics per 1000 inhabitants	RTIs antibiotics per 1000 inhabitants
	(1)	(2)
HHI	-52.835***	-32.044***
	(19.314)	(12.103)
Consultations	39.629***	22.482***
	(6.688)	(4.191)
Average list length	0.032***	0.019***
	(0.011)	(0.007)
Women	8.388***	5.010***
	(2.730)	(1.711)
Age 0_15	-1.637	0.100
	(1.230)	(0.771)
Age16_34	-0.968	-0.275
	(1.343)	(0.842)
Age35_54	6.118***	3.428***
	(1.854)	(1.162)
Year_2016	-14.793***	-10.300***
	(4.342)	(2.721)
Income	3.670***	1.530*
	(1.303)	(0.816)
Immigrants	-1.761**	-0.622
	(0.896)	(0.561)
Education	-3.201***	-1.803***
	(0.802)	(0.503)
Time to pharmacy	-1.341***	-0.658***
	(0.185)	(0.133)
Sørlandet	45.126 ***	46.861 ***
	(10.330)	(6.473)
Trøndelag	30.669 ***	15.378 ***
	(8.777)	(5.500)
Vestlandet	29.790 ***	28.835 ***
	(7.637)	(4.786)
Østlandet	5.837	20.091 ***
	(7.902)	(4.952)
HHI:Time to pharmacy	0.494	0.277
	(0.426)	(0.267)
Constant	-236.588	-199.806 **
	(152.327)	(95.456)
Observations	817	817
R^2	0.458	0.451
Adjusted R^2	0.447	0.439
Residual Std. Error (df = 799)	61.297	38.412
F Statistic (df = 17; 799)	39.778***	38.620***

Note: *p<0.1; **p<0.05; ***p<0.01. Standard errors are shown in parentheses.