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Abstract

The regulation on prescribing and dispensing of antibiotics has a double purpose: to enhance access to antibiotic treatment and to reduce the inappropriate use of drugs. Nevertheless, incentives to dispensing physicians may lead to inefficiencies. We sketch a theoretical model of the market for antibiotic treatment and empirically investigate the impact of self-dispensing on the per capita outpatient antibiotic consumption using data from small geographic areas in Switzerland. We find evidence that a greater proportion of dispensing practices is associated with higher levels of antibiotic use. This suggests that health authorities have a margin to adjust economic incentives on dispensing practices in order to reduce antibiotic misuse.

JEL classification: I11; I18; D12; D21; D43; D81; D82

Keywords: Physician dispensing, Antibiotic use.

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1 Introduction

Prescribing and dispensing of drugs are main aspects of access to primary health care. Dispensing has been physicians' responsibility for long time. Nowadays, in developed countries physicians' main role is to prescribe drugs without direct dispensing. For instance, doctors are not allowed to sell drugs directly to their patients in Germany and the Scandinavian region. The reason is two-fold. First, the need to avoid a conflict of interest for the prescriber, and second, to optimise rationality of treatment by ensuring good practice in dispensing (Trap and Hansen, 2003). The latter explanation recalls the fact that pharmacists can often review doctors' prescriptions and check contraindications and drug interactions.

However, direct dispensing of drugs is generally possible in some countries, likely for the purpose of improving access to pharmaceuticals. For instance, one Scottish region (Highland) included almost 20% of the total number of dispensing doctors in Scotland in 2005 (Information Services Division of the National Health System in Scotland, 2006). In Switzerland, physicians are allowed to sell drugs directly to their patients in several cantons, with few exceptions.[1] The reason may not lie straightforwardly in the regulator's objective to compensate for the lack of access to drug treatment. Historical and cultural aspects may have contributed to shape different rules across the country. Consequently, the low density of pharmacies in one area may either be the reason that led the regulator to allow for self-dispensing or the consequence of the advantage of dispensing practices in comparison to pharmacies. Indeed, the proportion of dispensing practices among all practices is highly heterogeneous across the country and is only slightly correlated with the degree of urbanization.

The purpose of this article is to explore the role of practice regulation in enhancing access to antibiotic treatment and reducing inappropriate use of antibiotics. It has been suggested that the regulatory policy that allows physicians to sell drugs directly to the patient may promote the overuse of drugs (Holloway, 2005; Nelson, 1987) and, consequently, exacerbates the physican agency problem (McGuire, 2000). Physicians may have an incentive to induce antibiotic consumption in order to increase their

[1] Switzerland is a federal state made of 26 cantons with remarkable differences in terms of organization of the health care system and health care policy. Self-dispensing is not allowed in Geneva, Vaud, Balle ville, Ticino and Argau. In some regions of the other cantons self-dispensing is permitted.

revenues. Filippini at al. (2009b) have recently found a positive correlation between physicians density and the proportion of more expensive antibiotics consumed across small areas in Switzerland. A question arises as to whether the regulator underestimates the potential inefficiencies induced by incentives on dispensing practices.

The literature lacks theoretical analysis of physician dispensing and empirical investigations generally use a correlation coefficient approach rather than applying econometric models. There is evidence that prescribing costs per patient in dispensing practices are higher than costs in non dispensing practices. This may be explained by reluctancy to prescribe generics (Morton-Jones and Pringle, 1993). Moreover, dispensing doctors charge higher retail prices (Abood, 1989) and have higher probability of prescribing drugs with high margin compared to non-dispensing physicians (Rischatsch and Trottmann, 2009). Finally, they have a tendency to prescribe more drugs per capita in comparison with non dispensing practices (Chou et al., 2003). This seems to be particularly evident for antibacterials. Focusing on one antibiotic substance (cotrimoxazole), Trap and Hansen (2002) examine differences in the rationality of the prescription in relation to diagnosis and symptoms between dispensing and non dispensing doctors. Dispensing doctors are found to prescribe an antibiotic 2.5 times more frequently than other doctors. As a consequence, dispensing practices may lead to increasing health hazards and bacterial resistance.

In this article we first propose a theoretical model of the market for community antibiotic treatment. Under a fee-for-service remuneration scheme as in Switzerland, doctors receive a consultation fee which varies with time allocated to the patient and the diagnostic tests performed. Dispensing doctors may incur additional costs for drugs in stock and gain a margin on antibiotics sold to the patient. We argue that the interaction between imperfect information on the nature of patient's infection and economic incentives to dispensing practices may increase the likelihood of antibiotic prescriptions, *ceteris paribus*. Under uncertainty on the nature of patient's infection self-dispensing physicians may increase their revenue by selling more antibiotics. To some extent, this effect may overcome the opposite effect of restrictions on antibiotic use due to difficulties in access to health care treatment in areas where the density of providers is relatively poor.

Using an ad-hoc demand model we then investigate the impact of dispensing practices on the individual outpatient antibiotic consumption empirically. Data are drawn from small geographical areas in Switzerland. The effect of dispensing practices is disentangled by means of econometric estimations which take into account the main demand-side determinants of antibiotic use.

The article is organized as follows. In Section 2 we sketch the model and derive the equilibrium levels of antibiotic use for dispensing and non dispensing practices. Section 3 empirically investigates the impact of dispensing practices on antibiotic use and discusses the results. Section 4 concludes.

2 A model of markets for antibiotic treatment

We develop a theoretical framework of the market for antibiotic treatment provided by primary care physicians (GPs). We model the interaction between patients and general practitioners when antiinfective treatment is needed as a sequential choice in three stages. At the beginning of stage 1, nature assigns a health problem (mild respiratory or gastro-intestinal infection), $i \in \{b, v\}$, to each of the N individuals uniformly distributed along a circle line, where b is a *bacterial* infection and v represents a *viral* infection. Consumers initially observe a symptom but cannot infer the type of infection they suffer from. We assume that both types of infections are equally likely. Hence, the probability of having a bacterial infection is $p = p[i = b] = p[i = v] \equiv 1/2$.[2]

Individuals maximise their expected utility from choosing a practice. In the market there are M general practice firms (GP_j, with $j \in [1, .., M]$), with $M \geq 2$. General practitioners can either be allowed to sell drugs directly to their patients or not according to the legislative frame set by the health authority. Practices are located at equal distance around the circle. All practices have equal size. Finally, whatever the type of practices, we assume that M pharmacies are also in the market and located nearby each practice[3]

Patient's choice of practice depends on the perceived level of diagnosis accuracy. Patients differ with respect to their location from general practitioners and to the type of infection they suffer from. We normalise the total market distance to 1. Hence, a patient is located at distance $d_l \in [0, 1/M]$ from the nearest practice at his left and at distance $d_r = 1/M - d_l$ from the practice at his right. The differentiation parameter

[2] The assumption of dichotomous health problems is quite common in the health economics literature. For instance, Jelovac (2001) assumes that patients have the same probability of suffering from a "mild" illness as well as from a "severe" one.

[3] This implies that patients do not incur additional costs of transportation to buy drugs after a consultation with a GP. Clearly, we also hypothesize that pharmacies are not allowed to change a doctor's prescription.

d can either be interpreted as a geographical distance between the individual and the provider location or the distance between the individual's preferences and the characteristics of the provider that maximises his utility.

In stage 2 the doctor makes a prescription based on a diagnosis signal. The patient recovers naturally from viral infections after some time, by the end of stage 2 (see Figure 1). Our depicted scenario applies for instance to mild respiratory tract infections in the community, such as colds, rhynofaringites, mild pneumonia and otitis. We assume that some treatment with healing drugs suitable, for instance, to reduce body temperature (antipyretic or anti-inflammatory), cough (syrup) or nose constipation (spray), decreases the cost of illness because of quicker recovery and/or less discomfort and is always prescribed, independently of antibiotic treatment. On the other hand, treatment with antibiotics (A) is necessary to recover from a bacterial infection. Antibiotics do not provide any additional benefit against viral infections. Since doctor's diagnosis is not always correct, a second consultation may be required later on (stage 3) if the patient suffers from a bacterial infection and an antibiotic treatment was not initially prescribed.

[Figure 1]

2.1 Information structure

The accuracy of a GP's prescription is related to the level of diagnostic services provided. We define $p_j^c \in [0,1]$ as the probability of a correct diagnosis by GP j. More diagnostic services increase the probability of a correct diagnosis through the following simple relationship $p_j^c(e_j) = \beta e_j$, where e_j represents the level of diagnostic services provided by the practice and $\beta \in [0,1]$ is a parameter. Consequently, the probability that the diagnosis is a bacterial infection and an antibiotic is correctly prescribed is $pp_j^c = \frac{1}{2}\beta e_j$. The probability of mistaken diagnosis will then be $\frac{1}{2}(1-\beta e_j)$. We assume that doctors rely on diagnostic tests to decide upon the type of treatment to be prescribed. Alternatively, we could assume that doctors share the results of diagnostic tests with patients and cannot cheat on this information.

Before a consultation patients are imperfectly informed about the level of diagnostic services (e_j) provided by the practice. They roughly assume that each value in the range $e_j \in \left[e^{\min}, e^{\max}\right]$ is equally likely. Consequently, patients expect an average level of services $\hat{e}_j = \frac{1}{2}e^{\min} + \frac{1}{2}e^{\max} \equiv \bar{e}$. We normalise e_j to $1/\beta$ and set $e^{\min} = 0$ and $e^{\max} = 1/\beta$.

Patients are aware that higher intensity of diagnostic services increases the probability of a correct prescription but don't know the true level of e_j. They expect a second consultation if they do not recover by the end of stage 2.

2.2 Expected net benefits of care

Switzerland is a federal state made of 26 cantons with remarkable differences in terms of organization of the health care system and health care policy. General practitioners are paid under a pure fee-for-service scheme. This implies that total reimbursement for a consultation depends upon the level of diagnostic services provided.[4] Since primary health care services are covered by compulsory health insurance contracts, patients pay only a small fraction (α) of the total cost of care. In Switzerland this depends upon the type of insurance plan chosen since different deductible schemes are available.

We assume that a consultation with a doctor has a cost $f(1 + e_j)$ and does not depend on the kind of prescription which follows. Treatment with antipyretic/anti-inflammatory drugs does not vary with the type of infection; the cost of this treatment is set to zero. On the other hand, a course of treatment with antibiotics has a fixed cost of z $(z < f)$.

Patients incur distance costs td_j to purchase services from provider j, where t is the unit cost of distance. The discomfort or the cost of time for recovering, when patients are not given an effective treatment is θ. We summarise the costs implied by alternative treatments conditional upon the type of infection in Table 1. To simplify notation we define $w_j = f(1 + e_j)$.

For instance, consider a patient with a viral infection consulting doctor j. If the GP decides to prescribe an antipyretic/anti-inflammatory without an antibiotic, the total cost of treatment includes the partial cost of a consultation (αw_j), plus the cost of distance (td_j). This gives $\alpha w_j + td_j$ in Table 1. However, if the GP makes a wrong diagnosis, the cost of treatment will increase by αz since and antibiotic will be later prescribed. The total cost will then be $\alpha(w_j + z) + td_j$.

[4] For instance, a consultation has a fixed fee for the first five minutes allocated to the patient. A diagnostic test to assess the type of infection implies an additional fee. Hence, the total fee increases with the intensity of care provided.

[Table 1]

2.3 Demand for GP consultations

A fully recovered patient has utility $u^h > 0$ defined in monetary terms. Using Table 1 we can write the expected net benefits from choosing practice j as

$$\begin{aligned}\hat{u}_j &= u^h - \frac{1}{2}\beta\hat{e}_j\left(\alpha\hat{w}_j + td_j\right) - \frac{1}{2}\beta\hat{e}_j\left(\alpha\hat{w}_j + \alpha z + td_j\right) \\ &\quad -\frac{1}{2}\left(1-\beta\hat{e}_j\right)\left(\alpha\hat{w}_j + \alpha z + td_j\right) - \frac{1}{2}\left(1-\beta\hat{e}_j\right)\left(2\alpha\hat{w}_j + \alpha z + 2td_j + \theta\right) \\ &= u^h - \frac{1}{2}\left[\left(3-\beta\bar{e}\right)\left(\alpha\bar{w} + td_j\right) + \left(2-\beta\bar{e}\right)\alpha z + \left(1-\beta\bar{e}\right)\theta\right]. \qquad (1)\end{aligned}$$

The terms inside the brackets of equation (1) indicate the costs of treatment when a viral infection is correctly diagnosed (first term), a bacterial infection is correctly diagnosed (second term), a viral infection is wrongly diagnosed and an antibiotic is prescribed (third term), and a bacterial infection is wrongly diagnosed so that patients need a second consultation (fourth term).

The assumption on patients' information implies that patient's choice of practice is based upon costly distance.[5] Patients at distance $d_j \leq 1/(2M)$ from GP_l will then prefer to consult GP_l instead of GP_r. Similarly, patients with distance $d_j > 1/(2M)$ will choose GP_r. By summing up the two market segments to the left-hand side and to the right-hand side of $GP\ j$, we derive doctor's initial demand for consultations as

$$D_j = \frac{N}{M}. \qquad (2)$$

The demand for consultations for $GP\ j$ decreases with the number of firms in the market. Since doctor's initial demand is the same for all GPs, we drop the indexed notation and use D instead of D_j in the following section.

2.3.1 Antibiotic treatment delay

Patients with a bacterial infection who receive a wrong diagnosis need an additional consultation to switch to antibiotic treatment. We assume that patients disappointed

[5] Brekke, Nuscheler and Straume (2006, 2007) assume that a proportion of patients is uninformed and chooses a doctor according to distance. Gravelle and Masiero (2000) assume that patients observe practice quality with an error and then learn by experience. These models focus on capitated systems rather than fee-for service. Our assumption is useful to simplify the model and to focus on patient's alternative strategies rather than the effects of competition among providers. We then ignore the impact of patient's information structure on the choice of practice.

with the practice because of health complications or loss of revenue due to antibiotic treatment delay will not leave the current practice, at least before the infection has been cured. This hypothesis simplifies the model and is perhaps quite realistic since the nature of the infection is now fully revealed and an antibiotic will be prescribed by the current practice.

The total demand for consultations can then be derived as

$$D^c = D + \frac{1}{2}(1 - \beta e_j)D. \tag{3}$$

Patients with a bacterial infection who need a second consultation because of wrong diagnosis are $\frac{1}{2}(1 - \beta e_j) D$.

2.4 Physician's objective

The general practitioner has an objective function (π_j) which depends upon the benefits and costs of diagnostic services provided. Using (3) we can write

$$\pi_j = [f (1 + e_j) - c] D^c - \gamma e_j^2, \tag{4}$$

where c is the fixed marginal cost of a consultation ($c < f$) and γ is the marginal cost of diagnostic services.[6]

The level of diagnostic services is assumed to be a local public good, i.e. it does not depend upon the number of patients diagnosed. The hypothesis suggests that improvements in diagnosis accuracy are related to the availability of a diagnostic technology rather than time spent with a patient.

2.4.1 Dispensing physicians

Dispensing physicians may differ from other practitioners for at least two reasons. Doctors may incur some costs for keeping drugs on stock. In this sense they are more similar to a pharmacy, than to non-dispensing practices. A shortage in the stock implies some risks if patients cannot receive the treatment when it is needed. On the other hand, big stocks of drugs increase the risk of getting closer to the expiry date. Unsold drugs may imply some costs for the practice.

[6] Although there is a time span between different stages of the game and patients realise the success or the failure of the initial consultation, this is a short period of time (few days) and discounting for future profits is not applied. For similar reasons, overlapping generations of patients are not considered, nor is the possibility of multiple infections in the cohort of patients. Our model is maybe suitable to capture doctor's behaviour under seasonal epidemic threat with annual recurrence.

In Switzerland, dispensing physicians get a mark-up on drugs prescribed. Plausibly, dispensing doctors are subject to pressure from pharmaceutical companies to increase prescriptions to the same extent as other doctors.

We modify the objective function of the general practitioner defined by (4) to include the expected costs and benefits of self-dispensing as

$$\pi_j^d = \left[f\left(1+e_j\right)-c\right]D^c + \left(D^c - \frac{D}{2}\right)(z-\eta) - \gamma e_j^2, \tag{5}$$

where z is the unit price of drugs dispensed to the patient and $\eta \leq z$ represents the unit cost of drugs on stock. The number of antibiotic treatments sold is obtained by summing up the number of patients with a bacterial infection correctly diagnosed plus the number of viral infections with a wrong diagnosis, and the number of patients who requires a second consultation because a bacterial infection was not initially diagnosed. The total amount of treatments can be summarised by $D^c - D/2$.

2.5 Market equilibrium

Practice firms maximise their profits in a Nash-Cournot game where the levels of diagnostic services of the neighbouring competitors are given. Consequently, we simultaneously consider the set of M objective functions π_j. Using (4) we derive profit with respect to the level of diagnostic services

$$\frac{\partial \pi_j}{\partial e_j} = -2\gamma e_j - \left[f\left(1+e_j\right)-c\right]\frac{1}{2}\beta D + f\left[D + \frac{1}{2}(1-\beta e_j)D\right]. \tag{6}$$

Since practice j's profit depends upon the level of diagnostic services of the two neighbouring practices, j^+ and j^-, we solve the set of first-order conditions $\partial\pi_j/\partial e_j = \partial\pi_j/\partial e_{j^+} = \partial\pi_j/\partial e_{j^-} = 0$. Substituting for D in (6) and solving for the level of diagnostic services we then get

Proposition 1 *A Cournot-Nash equilibrium in the level of diagnostic services is defined by*

$$e^* = \frac{3f - (f-c)\beta}{2\left(2\frac{M}{N}\gamma + f\beta\right)}. \tag{7}$$

The level of diagnostic services increases with the number of infected patients (N) and decreases with the marginal cost of effort γ and the efficiency of services β. The number of providers, M, decreases diagnostic services since the marginal benefit from higher treatment accuracy is reduced. This suggests that the density of general practices may have relevant implications on the use of antibiotics. The result will be further discussed in the following section.

2.5.1 Equilibrium with self-dispensing

Using the objective function for dispensing doctors defined by (5) and following the procedure for profit maximisation above, we obtain

Proposition 2 *A Cournot-Nash equilibrium in the level of diagnostic services with self-dispensing is defined by*

$$e^{*d} = \frac{3f - [f - c + (z - \eta)]\,\beta}{2\left(2\frac{M}{N}\gamma + f\beta\right)}. \tag{8}$$

Note that $(z - \eta)$ increases or reduces the equilibrium level of services depending on the relative magnitude of z and η. Clearly, if antibiotic price is high enough, then $e^{*d} < e^*$, *ceteris paribus*. Diagnosis accuracy is lower for dispensing practices. However, this result may be partially offset by the relatively low density of practices in areas where direct dispensing is allowed. If the cost of access to health care providers in one area is higher because of the reduced number of practices, i.e. M is low, the equilibrium level of services in (8) is also higher. Consequently, the negative impact of a markup on sales $(z - \eta > 0)$ on the level of diagnostic services provided may be compensated by the positive effect of higher costs of access in markets with dispensing practices. This aspect will have important implications on the per capita levels of antibiotic use since it represents the crucial point for the comparison of prescribing practices in different areas.

2.6 Antibiotic prescriptions

Using the equilibrium level of diagnostic services in (7) and (8), we can summarise antibiotic prescriptions per capita. A number of patients $\frac{1}{2}(\beta e^*)\,D$ receive a correct diagnosis of bacterial infection and are treated with antibiotics at the first consultation. Misdiagnosed patients with a viral infection also receive an antibiotic at the first consultation. These are $\frac{1}{2}(1 - \beta e^*)D$ patients. Some patients suffering from a bacterial infection with a wrong diagnosis at the first consultation will be prescribed an antibiotic at the second visit. The number of these patients is $\frac{1}{2}(1 - \beta e^*)D$. Summing up all the patients receiving antibiotics and dividing by practice market share

(N/M) we derive the per capita antibiotic use without and with self-dispensing as

$$a^* = \left(1 - \frac{\beta}{2}e^*\right), \tag{9}$$

$$a^{*d} = \left(1 - \frac{\beta}{2}e^{*d}\right). \tag{10}$$

Some interesting features can be straightforwardly derived from both (9) and (10) through the level of diagnostic services. The marginal cost of diagnostic services (γ in e) increases antibiotic use per capita, whereas the efficiency of the diagnosis (β in e) improves the diagnosis accuracy and reduces per capita antibiotic consumption. This is because diagnostic services reduce the number of false prescriptions. For $e^* = e^{\max} = 1/\beta$, GPs would prescribe $a^* = 1/2$. All patients with a bacterial infection would receive an antibiotic at the first consultation. Conversely, none of the patients with a viral infection would receive an antibiotic. Because of uncertainty $\beta < 1$, which implies $e^* < e^{\max}$. Consequently, at least in some cases antibiotics will not be correctly prescribed.

The number of practices (M in e) increases antibiotic consumption because the level of diagnosis accuracy is reduced. Doctors have lower marginal benefits from improving diagnostic services, which in turn increases inappropriate prescriptions.

The number of infected patients, N, decreases the per capita antibiotic use. Although the total number of prescription increases, the per capita antibiotic use may decrease. We assumed that patients incur just one infection per period and that the external benefits from antibiotic use are not taken into account by doctor's decisions. The incidence of infections increases doctor's demand, hence the expected benefits from increases in diagnosis accuracy (N raises e). This leads doctors to reduce inappropriate prescriptions per patient.

From comparison between (9) and (10) note that $a^* < a^{*d}$ for $e^* > e^{*d}$, *ceteris paribus.* We then postulate the following proposition

Proposition 3 *Dispensing practices are likely to prescribe more antibiotics per capita compared to other practices as far as there is a positive mark-up from selling antibiotics directly to the patient.*

The result of Proposition 3 holds provided that the density of practices is the same in markets where dispensing is permitted or not. As mentioned above, the rationale behind direct dispensing of drugs is to reduce the costs of access to health care treatment. The regulator's main objective is to allows for direct dispensing of drugs in areas where the density of practices is relatively low compared to other areas. This implies that the positive effect of the mark-up on antibiotic sales may not completely offset the impact of the higher cost of access (low density of practices) as compared to markets where direct dispensing is not allowed. The magnitude of these opposite effects is critical aspect that we will try to disentagle by means of an empirical approach in the following session. The hypothesis we want to test can be summarised by the following proposition

Proposition 4 *In areas where dispensing practices are allowed the individual consumption of antibiotics is higher compared to other areas if the positive impact of mark-up on antibiotic sales is not completely offset by the higher costs of access to health care services.*

Whether or not dispensing practices lead to higher levels of antibiotic use compared to non dispensing practices clearly depends upon the strength of the incentive related to the mark-up on antibiotic sales.

3 Empirical analysis

3.1 Econometric specification

The theoretical framework presented in section 2 (equations 7, 8, 9 and 10) suggests that in a region defined by a circle the demand for antibiotics is influenced by the following factors: physician density, the price of antibiotics, the price of a consultation, the probability of a correct diagnosis and the incentives attached to direct dispensing of drugs. Moreover, it is important to underline that the demand equations (9) and (10) have been derived for a region characterised by individuals with homogeneous socioeconomic variables such as income, age, and cultural factors.

For the empirical part of this paper we use aggregate data on the consumption of antibiotics for 240 Swiss regions and we will adopt a representative consumer approach, i.e. for each region we define the dependent variable as the per capita antibiotic consumption. Therefore, we hold the assumption that individuals are homogeneous within the region. However, the econometric specification of the demand for antibiotics hypothesises that some socioeconomic variables vary across the regions.[7]

Moreover, in order to estimate one demand function rather than the two represented by (9) and (10), the empirical model includes a dummy variable representing the difference of practice styles and incentives attached to the possibility of direct dispensing of drugs.

Building on the theoretical framework and a previous empirical study on the determinants of small area variations in the use of outpatient antibiotics (Filippini et al., 2009a), we specify the following model:

$$\begin{aligned} DID_k &= f(DPHY_k, DPHA_k, PA_k, PC_k, INF_k, POP_{lk}, Y_k, \\ &\quad DBOR_k, DLAT_k, DHOS_k, NOSELF_k, SELF_k, DT_t), \end{aligned} \tag{11}$$

where DID_k is the per capita outpatient antibiotic use in the k^{th} market area measured in defined daily doses per 1000 inhabitants. $DPHY_k$ and $DPHA_k$ are respectively the density of physicians in the area and the density of pharmacies; and PA_k and PC_k are the prices of a defined daily dose of antibiotic and of a consultation, respectively. POP_{lk} is the percentage of the population in the l age range and INF_k is the incidence of bacterial infections (campylobacter and salmonella).[8] These two variables are proxies for the probability of a correct diagnosis. Further, the model (11) considers some explanatory variables not explicitely defined in the theoretical models (9) and (10). Y_k is the average income in the area; $DBOR_k$, $DLAT_k$, and $DHOS_k$ are dummy variables. The first one captures any borderland effect with neighbouring countries. The second considers whether an area is mainly characterised by Latin culture (French- and Italian-speaking), or German culture. The third dummy accounts for at least one hospital in the area.

Finally, since we cannot directly measure the magnitude of the mark-up on antibiotic sales we use the status of practices, i.e. whether a practice can sell drugs directly to their patients or not, as an indicator for a positive mark-up on antibiotic

[7] The literature on determinants of the demand for physician's services emphasises the role of socioeconomic characteristics of the population and practice styles (Hunt-McCool et al., 1994; Carlsen and Grytten 1998; Grytten and Sorensen, 2003). More closely to antibiotics, the literature suggests that cultural aspects may influence the use of antibiotics. For instance, Italian children receive more courses of antibiotics than Danish children (Resi et al. 2003; Thrane et al., 2003).

[8] These are the leading causes of gastrointestinal infections. Since data are not available at local level, we use information at cantonal level.

prescriptions. Therefore, two dummy variables, $NOSELF_k$ and $SELF_k$, are introduced in the model in order to capture the impact of direct dispensing of antibiotic use. $NOSELF_k$ takes value equal to 1 if there are no dispensing practices in the area, 0 otherwise; $SELF_k$ takes value equal to 1 if the proportion of dispensing practices in the area is greater than 50%. The intermediate case where the proportion of dispensing practices is greater than 0 and lower than 50% represents our benchmark.

DT_t are time dummies ($t = 2, 3, 4$ since the first quarter is excluded to allow for price lags) identifying the 2002 quarters. DT_4 (October, November, December) is the baseline quarter.

From the empirical point of view, the inclusion of practice styles and incentives attached to direct dispensing of drugs ($NOSELF_k$ and $SELF_k$) represents the novelty of the current approach compared to our previous study (Filippini et al., 2009a) since practice regulation has not been considered before. Moreover, we use a log-log functional form whereas a linear specification has been previously applied for the purpose of measuring the welfare loss from heterogeneous attitudes towards antibiotic use.[9]

We use data on the per capita antibiotic use and possible determinants in 240 small market areas in Switzerland during the four quarters of 2002. A summary of the statistics of the variables used in this empirical analysis is provided in Table 2.

[Table 2]

The log-log specification offers an appropriate functional form for investigating the responsiveness of local per capita antibiotic sales to changes in the explanatory variables. Estimated coefficients can be interpreted as elasticities. We apply the log-log form to equation (11) assuming independently and identically normally distributed errors (*Model 1*).

To deal with the potential endogeneity problems related to prices and the incidence of infections, we consider the inclusion of lagged values. PA_k is the one-period lag for price of a defined daily dose. PC_k represents the price of a standard consultation with a general practitioner defined at cantonal level and captured by the

[9]Clearly, the model does not allow to disentagle the possible mismatch between antibiotic prescriptions, antibiotic sales and antibiotic use since detailed data on these figures are not available. We focus on determinants of antibiotic use and assume patient's non-compliance to be a negligible factor.

point values (weights) calculated for the reimbursement of services provided by general practitioners in 2001.[10] As for the incidence of infections, we use the average incidence of bacterial infections calculated over the years 1999-2001.

An econometric problem that could arise when estimating the demand model in (11) is the spatial correlation due to spatial dependency in antibiotics consumption. For this reason, we consider a second specification (*Model 2*). We estimate a spatial two-stage least-square model (S-2SLS) which assumes that the spatially weighted average of consumption in adjacent regions (DID_{-k}) affects the consumption in each region in addition to the standard explanatory variables. Spatial lags of exogenous variables and cantonal dummies are used as a set of instruments to estimate the mean antibiotic consumption in regions which are contiguous with region k.[11]

Our data set contains a relatively small number of time periods ($t = 3$), a relatively large number of cross-sectional units ($N = 240$) and a zero within variation for most of the explanatory variables. When price endogeneity is taken into account observations for the first quarter ($t = 1$) are not used. The only two variables that are changing over time (3 quarters) are the outpatient per capita consumption and the price of a daily dose. Consequently, the typical model for panel data, e.g. the least squares dummy variable model and the error components model are not appropriate.[12]

The estimation of *Model 1* is then carried out with 720 observations and by using Ordinary Least Squares (OLS) with robust standard errors.[13] In the standard OLS specification the error term is supposed to be independently and identically distributed. When the assumption is partially relaxed, the linearization/Huber/White/sandwich (robust) procedure allows to get estimates of the variance of the coefficients that are robust to the distribution assumptions. Instead, we use a two-stage least-square procedure when spatial dependency is taken into account (*Model 2*). Estimations are

[10] In Switzerland, a detailed fee-for-service system with more than 4600 items is applied for the reimbursement of health care providers. A given number of points is assigned to each type of service according to time, complexity and facilities. The cantons apply different values to the basic point, which reflects the heterogeneity in the costs of services across the country. Therefore, the point value can be interpreted as a proxy for the price of a consultation.

[11] For more detailed explanation see Anselin (2001) and Kelejian and Prucha (1998).

[12] The reliability of these estimators depends on the extent of within-regional as well as between-regional variations of the dependent and the independent variables. As Cameron and Trivedi (2005) point out, the fixed-effects approach has an important weakness in that the coefficients of the explanatory variables are "very imprecise" if the variable's variation over time is dominated by variation across regions (between variation).

[13] We also run regressions with a between estimator and with and without spatial dependency. The results are generally confirmed.

performed using the econometric software STATA.

3.2 Estimation results

Before focusing on the effect of self-dispensing, we briefly summarize the main results from the estimation of the two models (Table 3). The adjusted R^2 indicates that the models explain approximately 75% of variations in the use of antibiotics.

The estimated spatial autoregressive parameter associated with the lag term DID_{-k} in *Model 2* is significant and negative. This may suggest the evidence of positive consumption externalities across the areas.[14]

Income elasticity varies between 0.16 and 0.22, which supports the hypothesis that antibiotics are normal goods.[15] Our result is in accordance with other findings in the literature (Nilson and Laurell, 2005; Henricson et al.,1998; Thrane et al., 2003).

A higher proportion of children between 0 and 14 years of age increases antibiotic consumption in the area; conversely antibiotics are less likely to be prescribed in the areas with a larger proportion of individuals over 74 years of age compared to the baseline class. A negative impact is also observed for the proportion of individuals between 60 and over 74, although the coefficient is not significant.[16]

[Table 3]

In both model specifications the coefficient of the incidence of infections exhibits the expected positive sign but is poorly significant. However, the estimated coefficients of the second and the third quarters (DT_2 and DT_3) are both negative and highly significant. This is in accordance with seasonal fluctuations observed by Elseviers et al. (2007) across Europe.

[14] A plausible explanation for this result is related to the double role of antibiotics. Antibiotics are used to cure bacterial infections and to prevent the spread of infections and bacterial resistance to other individuals. Consequently, the use of antibiotics in one area minimises the spread of infections in neighbouring areas. This implies that a smaller amount of antibiotics is required to obtain the same level of health benefits. Although patients' imperfect information may suggest that this effect is not internalised by the individual, antibiotic prescribers such as general practitioners are quite likely to be aware of this effect.

[15] Baye et al. (1997) find higher income elasticity (1.33) that may be related to differences in the population under study and the type of antibiotics considered (only penicillins and tetracyclines).

[16] Similar results are obtained, for instance, by Mousquès et al. (2003), who investigate a panel of general practitioners prescribing antibiotics for rhynopharingeal infections.

Antibiotic price has a negative and significant impact on antibiotic use in the area. Price elasticities in *Model 1* and *Model 2* (-0.71) are close to the estimates of Baye et al. (1997), who found negative compensated (-0.785) and uncompensated (-0.916) own-price effects for anti-infectives. Ellison et al. (1997) calculate price elasticities unconditional on drug (cephalosporins) expenditure using US wholesales data from 1985 to 1991. Their estimates range between -0.38 and -4.34. The coesfficient on the price of a doctor consultation is not significant. Although expensive consultations imply higher diagnosis effort, which may reduce inappropriate prescriptions of antibiotics, this hypothesis cannot be confirmed by our results.

The physicians' density is positively and significantly associated with the local per capita antibiotic use. Estimated elasticities are around 0.11 in both specifications. Similarly, an increase in the density of pharmacies leads to higher levels of per capita outpatient antibiotic use in the area. The estimated coefficient ranges between 0.61 and 0.63.

As for the impact of self-dispensing, we find that the proportion of practices without direct dispensing of drugs (NOSELF) has a negative effect on antibiotic use, although the coefficient is not significant. Consequently, we cannot reject the hypothesis that areas without dispensing practices and areas with a relatively small proportion of self-dispensing practices (below 50%) exhibit similar levels of antibiotic use per capita. However, when the proportion of dispensing practices is relatively high (more than 50%), the effect on consumption is positive and significant. The estimated coefficients suggest that a one percent increase in the proportion of dispensing practices beyond 50% will increase per capita antibiotic sales by 0.32% (0.29% when spatial dependency is taken into account).

It is worth noticing that the correlation between the rate of dispensing practices and the density of pharmacies in the area is remarkable. This may suggest that self-dispensing improve access to medical services. Note, however, that our estimated coefficient for dispensing practices is adjusted for the density of pharmacies and the density of all practices. This implies that direct dispensing of drugs may increase antibiotic consumption beyond the levels usually attained by satisfactory access to medical services.

It can also be argued that the density of pharmacies is not a good indicator for access to antibiotic treatment in the area. Indeed, travelling costs for the patient may vary consistently. Consider, for instance, two small areas of the same size but different number of pharmacies and inhabitants. The two areas may have the same number of providers per inhabitant but the average patient's distance from the pharmacy may be different. To address this point we run separate estimations with the density of the population as an additional regressor. This captures the level of urbanization of the areas and can be used as a proxy for travelling distances. The variable is never significant, nor it changes the results of the other covariates significantly.

4 Conclusions

In developed countries, prescribing and dispensing of antibiotics are generally kept separate. Switzerland, however, represents and exception. The rationale for direct dispensing is that prescribers improve access to pharmaceuticals in areas with low density of pharmacies. However, the regulation of self-dispensing may not be efficient in preventing antibiotic misuse. It has been suggested that prescribing costs per patient in dispensing practices are higher than costs in non dispensing practices (Morton-Jones and Pringle, 1993). The separation of drug prescribing and dispensing has recently proved to be effective in reducing drug expenditure, for instance in Taiwan (Chou et al., 2003).

We investigated the impact of dispensing practices on the per capita outpatient antibiotic consumption by combining a theoretical and an empirical approach. Our model hypothesises that the regulator who allows for direct dispensing of drugs, presumably to reduce the high costs of access to health care services, does not take economic incentives on dispensing practices into account correctly. Dispensing practices may reduce diagnosis accuracy of bacterial infections compared to non-dispensing practices, thus leading to higher rates of antibiotic use per capita. The rationale behind this may be three-fold: the additional costs for stocking drugs and the risk of drugs expiring, the exposure to advertising pressure by pharmaceutical firms, and the tendency to meet patients' preferences for antibiotic treatment. Indeed, Rischatsch and Trottmann (2009) recently suggested that dispensing physicians have higher probability of prescribing drugs with high margin compared to non-dispensing physicians.

Using an ad-hoc econometric model we estimated the impact of self-dispensing on the demand for outpatient antibiotics across small areas in Switzerland after controlling for access to primary care services. Our findings support the prediction of the theoretical frame that dispensing practices induce higher rates of antibiotic use, *ceteris paribus*. The adjustment of economic incentives attached to dispensing practices may then contribute to reduce the inappropriate use of antibiotics to contain the threat of bacterial resistance.

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Infection	Prescription	Cost of different treatment's strategies
v	NA	$\alpha w_j + td_j$
v	A	$\alpha w_j + z + td_j$
b	A	$\alpha w_j + z + td_j$
b	$NA{+}A$	$2\,(\alpha w_j + td_j) + z$

Table 1: The total cost of treatment depends upon doctor's prescription strategy (A=antibiotics, NA=antipyretic/anti-inflammatory only) and the type of patient's infection (b=bacterial, v=viral).

Variable	Description	Mean	Std dev.
DID	Defined daily doses per 1000 inhabitants	11.714	13.061
Y	Income per capita defined in CHF	23465	6849.4
POP_1	Proportion of 0-14 in total population	0.1658	0.0243
POP_2	Proportion of 15-25 in total population	0.1247	0.0173
POP_3	Proportion of 26-59 in total population	0.4956	0.0314
POP_4	Proportion of 60-74 in total population	0.1363	0.0213
POP_5	Proportion of over 74 in total population	0.0776	0.0190
INF	Incidence of common gastrointestinal infections (salmonella and campylobacter) in 100000 inhabitants	114.69	22.580
$DPHY$	Density of physicians for 100000 inhabitants	565.21	1052.5
$DPHA$	Density of pharmacies for 100000 inhabitants	35.098	39.112
PA	Price of a defined daily dose	3.7112	0.3113
PC	Price of GP consultations	0.9074	0.0526
$DBOR$	Whether or not the area borders other countries	-	-
$DLAT$	Whether an area has a Latin (French and Italian) or a German culture	-	-
$DHOS$	Whether or not there is at least one hospital in the area	-	-
$NOSELF$	Whether or not there are no self-dispensing practices in the area	-	-
$SELF$	Whether or not there is a majority of self-dispensing practices in the area	-	-

Table 2: Variables notation and summary statistics.

	Model 1				Model 2			
Equation	Obs.	Param.	Adj. R^2	F Stat.	Obs.	Param.	Adj. R^2	F Stat.
DID_k	720	17	74.79	67.77	720	18	75.06	117.39
DID_{-k}	-	-	-	-	720	51	0.8906	106.61
Covariates	Coefficients	St. Err.	p-value		Coefficients	St. Err.	p-value	
Constant	-1.251277	0.748058	0.095		-1.924927	0.692655	0.006	
Y	0.160487	0.063923	0.012		0.218532	0.061701	0.000	
POP_1	0.706238	0.150325	0.000		0.663000	0.158446	0.000	
POP_2	-0.316837	0.124396	0.011		-0.441092	0.144956	0.002	
POP_4	-0.007090	0.112109	0.950		-0.125122	0.114807	0.276	
POP_5	-0.246217	0.066816	0.000		-0.217611	0.058438	0.000	
INF	0.018684	0.020539	0.363		0.024631	0.023431	0.293	
DPHY	0.115837	0.026087	0.000		0.113938	0.018334	0.000	
DPHA	0.629443	0.042219	0.000		0.606146	0.028297	0.000	
PA	-0.715534	0.141442	0.000		-0.708980	0.136962	0.000	
PC	0.023307	0.212043	0.913		-0.016681	0.210218	0.937	
DBOR	0.006267	0.029780	0.833		0.016469	0.032790	0.616	
DLAT	-0.006311	0.042069	0.881		0.038515	0.046222	0.405	
DHOSP	0.022475	0.034107	0.510		0.014798	0.029501	0.616	
NOSELF	-0.033033	0.032570	0.311		-0.029458	0.034179	0.389	
SELF	0.316936	0.036274	0.000		0.294635	0.034244	0.000	
DT_2	-0.171542	0.024674	0.000		-0.204803	0.026352	0.000	
DT_3	-0.184313	0.023775	0.000		-0.214289	0.025391	0.000	
DID_{-k}	-	-	-		-0.165151	0.049700	0.001	

Table 3: Parameter estimates

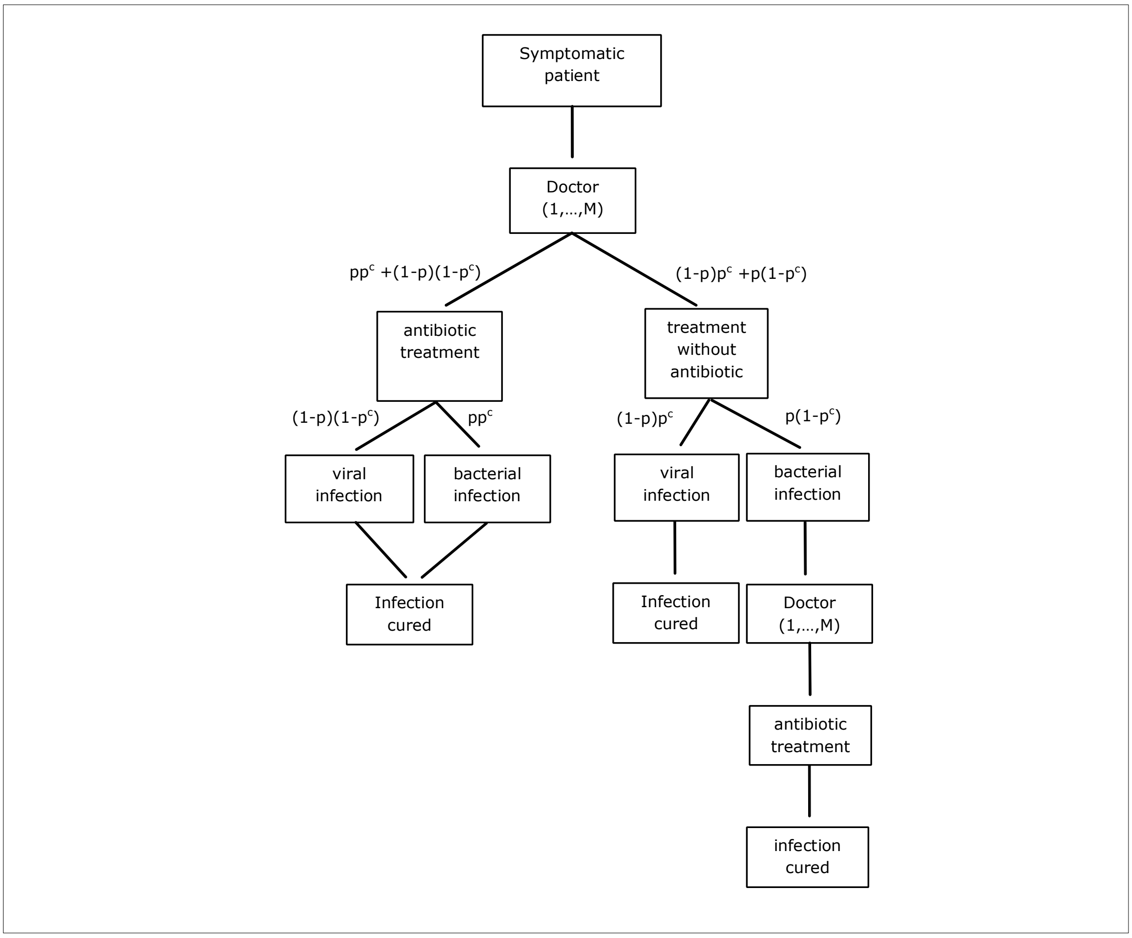

Figure 1: Doctor's strategies to tackle a mild respiratory/gastro-intestinal infection.

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