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Socioeconomic determinants of regional differences in outpatient antibiotic consumption : evidence from Switzerland

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Socioeconomic determinants of regional differences in outpatient antibiotic consumption: evidence from Switzerland.

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Updated version[§]

Abstract

This paper investigates the determinants of regional variations in outpatient antibiotic consumption using Swiss data. The analysis contributes to the debate on appropriate antibiotic use by improving the understanding of its determinants, and may help to define more effective health care policies to reduce the resistance phenomenon. Findings suggest that Switzerland exhibits relatively low levels of consumption among European countries. There are significant differences between cantons both in the per capita antibiotic sales and Defined Daily Doses per 1000 inhabitants per day (DID). Econometric estimations suggest that per capita income, demographic factors, and the density of medical practices, are significantly related to antibiotic consumption. The incidence of bacterial infections is ambigouous. Appropriate policies affecting antibiotic consumption in the community can be designed by looking at crucial determinants in the model and their relative impact.

Keywords: Antibiotic consumption. Regional differences.

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[§]This work constitutes a revised version of the working paper No 04.09 based on an updated dataset delivered by IHA-IMS. It includes slightly changes in Swiss antibiotic consumption and adds data for 2004. We obtain slighly different results although the main conclusions are the same.

1 Introduction

The consumption of antibiotics has rapidly increased during the past 50 years. Antibiotics have significantly contributed to the reduction in the likelihood of dying from infectious diseases worldwide (WHO, 2000; 2001). However, researchers suggest that almost one third of drug prescriptions are questionable (Wise et al., 1998; Homer et al., 2000).

During the 90s, the USA experienced an increase in the use of broad spectrum antibiotics and prescriptions of antibiotics for common viral diseases such as upper respiratory tract infections (Steinman et al., 2003). McCaig et al. (2003) reports that total antibiotic prescriptions in ambulatory care fell to 126 millions in 2000 from 151 millions in 1992. This means that 45% of the population received antibiotics in 2000. According to Cantrell et al. (2002) antibiotic prescription rates for people with colds, URIs, and acute bronchitis was 46%, 47%, and 60% in 1996. Their analysis shows that around 11 millions of prescriptions in the USA are inappropriate and estimate a waste of health care resources up to \$ 281 millions.

Antibiotic consumption may not be optimal because of multiple market imperfections. First, patients may not face the marginal cost of drugs when making their consumption choices. Consumers have an incentive to purchase more drugs than they would if insurance was not available (Newhouse, 1993). Second, the individual production function of health is characterized by uncertainty. Although antibiotics are not effective in treatments of viral

diseases, patients' lack of knowledge and experience may increase inappropriate consumption. Indeed, studies have shown that doctors decisions to prescribe antimicrobials are related to patients' expectations. Under time pressure, doctors tend to satisfy their patients and to avoid follow up visits (Butler et al., 1998). Third, marginal social benefits from consumption may not reflect marginal private benefits. Marginal private benefits from consumption may not internalize external benefits derived from one's treatment with antibiotics which reduces the probability of infection spreading to other individuals (Elbasha, 2003). Finally, over consumption of antibiotics may contribute to the selection of resistant bacteria, and hence, reduce their effectiveness (McGowan, 2001). Marginal social costs of antibiotic usage may then not reflect marginal private costs since the latter do not consider the costs of reduced antibiotic effectiveness due to bacterial resistance (Levy, 1998 ; Coast et al., 1998). Because of resistance, antibiotics become a scarce resource and it is in the interest of the society as a whole to preserve their effectiveness (Laxminarayan and Weitzman, 2002; Rowthorn and Brown, 2003; Rudholm, 2002).

The investigation of regional variations in antibiotic consumption may contribute to the debate on appropriate antibiotic use by improving the understanding of its determinants. Moreover, the analysis may help to define more effective health care policies to reduce the resistance phenomenon.

Differences between geographical areas may be explained by demographic, cultural, and socioeconomic factors. However, it is hard to believe that physi-

cians and/or patients in different areas will not vary in their preferred treatment practices for health conditions where alternative treatments are available and where the nature of the infection exhibits substantial uncertainty. Researchers suggest that the investigation of small geographical areas may bring out the role of health care supply organizational factors compared to demand variables (Wennberg and Gittelsohn, 1982).

The literature lacks empirical investigation of within country variations in antibiotic consumption. Moreover, studies focusing on international comparisons between countries use a descriptive statistics approach rather than applying econometric techniques to explain the determinants of cross-country variations (Bremon et al. 2000).

The paper intends to investigate regional variations in outpatient antibiotic use in Switzerland, to estimate the cantonal demand for antibiotics and study the impact of critical factors. In section 2 we compare outpatient antibiotic consumption in Switzerland with other European countries and investigate cantonal differences within the country. In section 3 we estimate the cantonal demand for outpatient antibiotics and discuss its determinants. Section 4 concludes.

2 Variations in antibiotic consumption

2.1 Outpatient antibiotic consumption in Switzerland

In this section, we investigate outpatient antibiotic consumption in Switzerland and compare it with consumption in other European countries. We

consider both total consumption in terms of defined daily doses per 1000 inhabitants per day (DID)[1] and sales per capita. Swiss sales data were provided by IHA-IMS Health Market Research. Defined daily doses per 1000 inhabitants daily and sales per capita were calculated using additional demographic information and WHO standard doses (we refer the reader to section 3.2 for further details on data).

Figure 1 is constructed by using data from the European Surveillance of Antimicrobial Consumption (ESAC I) project and including new data from Switzerland.

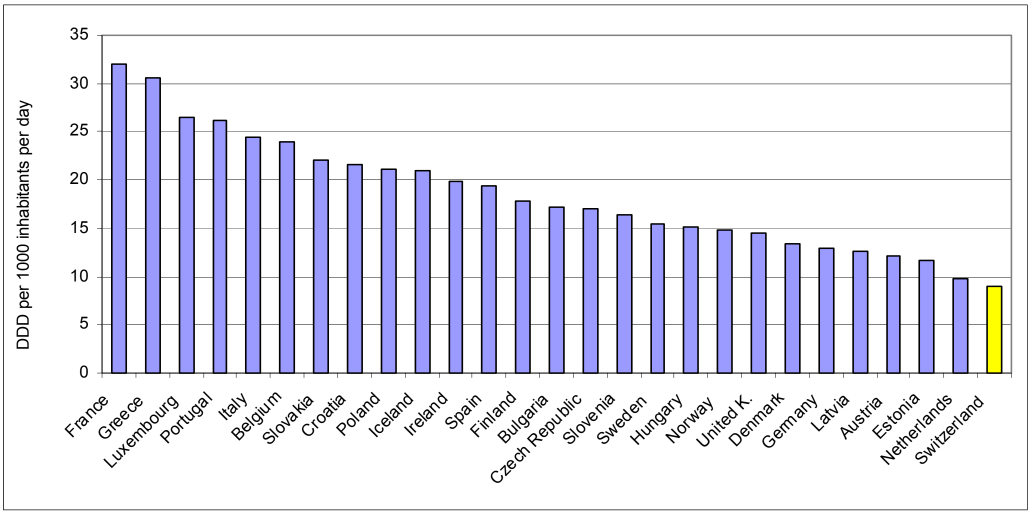

Figure 1: Outpatient antibiotic use per country including Switzerland (2002). Sources: ESAC and IHA-IMS.

Large differences in outpatient antibiotic consumption are observed across European countries (Cars et al. 2001 ; Goossens et al., 2005). Relatively high

[1] The defined daily dose (DDD) measurement unit is based upon the WHO version 2003.

consumption defined in daily doses per 1000 inhabitants per day (DID) are observed in France, Greece, Luxembourg, Portugal, and Italy, among others. On the contrary, Austria, Estonia, Germany, Latvia, and the Netherlands, for instance, exhibit significantly lower values. Median European consumption of antibiotics in ambulatory care in 2002 is 18.8 DID. The greatest consumption (32 DID) is attained by France. Outpatient antibiotic use in Switzerland measured in DDDs per 1000 inhabitants daily is 9 DID, below the Dutch level of 9.8 DID.

The ranking obtained by ordering European countries as with respect to DDDs per 1000 inhabitants per day in 2002 suggests that Switzerland is indeed the country with the lowest antibiotic consumption in the community.

Not surprisingly, this is in accordance with the 2001 OECD statistics suggesting that Switzerland is among countries with low consumption rates of pharmaceuticals. Among possible explanations is the combination of organizational aspects of the health care system based upon private health insurances and physicians' and patients' attitude towards the use of drugs. The combination of deductible and direct payments may contribute to the prevention of moral hazard behavior. Swiss physicians and patients may either be more aware of the implications of antibiotic consumption, such as bacterial resistance, and face tighter financial incentives. The health economics literature suggests that pure fee-for-service payment schemes, akin to the Swiss one, may increase the volume of services provided compared to capitation regimes. However, the incentive to reduce workload by increasing

prescriptions may be lower (see Scott, 2000).

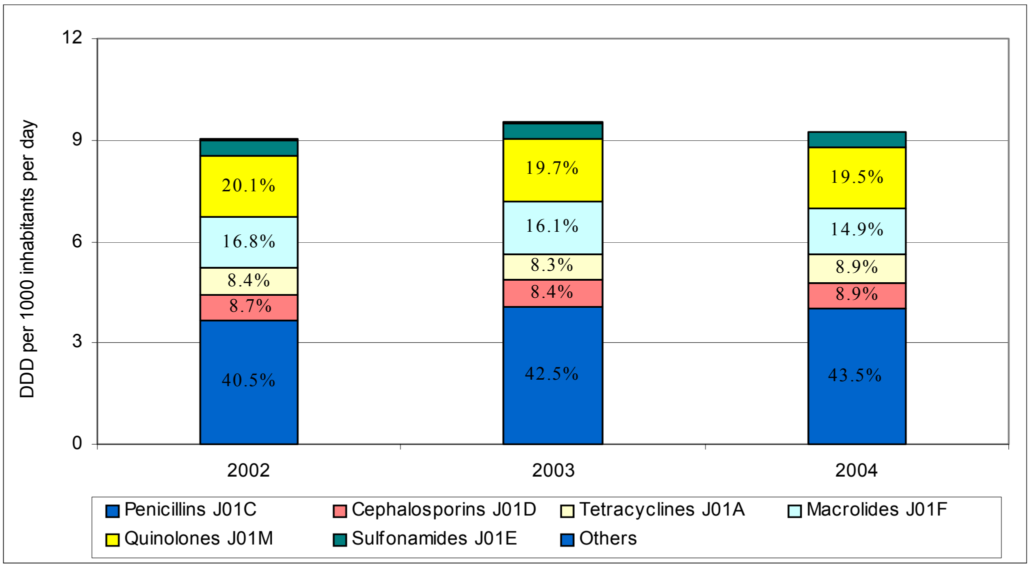

Figure 2: Structure of outpatient antibiotic consumption in Switzerland (2002-2004).

As shown in figure 2, total antibiotic consumption in ambulatory care in Switzerland has been roughly stable over the three years considered. Consumption has slightly increased in 2003 (9.5 DID) but decreased in 2004 (9.3 DID).

Looking at the consumption structure, the literature suggests that there is wide variation in the proportion of different classes of antibiotics between countries (Bergan, 2001; Cizman 2001). The Swiss share of quinolones is 20.1% of total consumption in 2002. Although the Swiss use of quinolones is not far from the European average (1.8 DID against 1.4 DID), Switzerland uses this category of antibiotics in the community in much higher proportions (the European average share of quinolones without Switzerland is

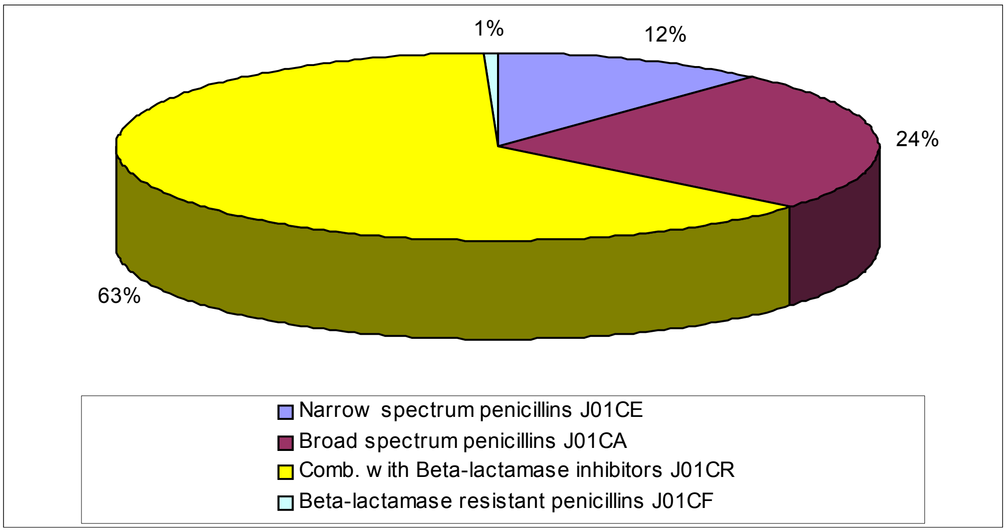

Figure 3: Penicillins composition in Switzerland (2002).

7.3%). This implies that Switzerland uses relatively lower proportions of others classes of antibiotics compared to European countries.

The use of penicillins has slightly increased over time (from 40.5% in 2002 to 43.5% in 2004). The Swiss consumption of penicillins is below the European average both in terms of DID and the share on total consumption (3.7 DID and 40.5% compared to 8.7 DID and 46.4%). Looking at penicillins in more details, we observe that combinations with β-lactamase inhibitors represents 63% of total consumption of penicillins (figure 3). This proportion is similar to the proportion used in Belgium and Portugal, for instance, and above the European average.

Similar figures can be observed for cephalosporins and macrolides. The Swiss consumption for the former category is 0.8 DID (8.7%) whereas the European average is 1.9 DID (10.2%). In the latter category Switzerland

consumes 1.5 DID (16.8%) compared to the European average of 2.7 DID (14.3%).

The ranking of Switzerland between European countries in terms of per capita consumption for different classes of antibiotics can then vary. Switzerland is 18th out of 27 European countries for the consumption of cephalosporins, and the 5th less consuming country for macrolides. On the other side, Switzerland is the 8th most consuming country of quinolones.

It worth noticing that the comparison of Swiss consumption data with those of other European countries as well as between the European countries of the ESAC study requires a bit of carefulness. There may be differences related to the collection of data since not all of the countries derive data from the same source. These may either come from the distributional channel or the reimbursement registrations which may not perfectly match. Moreover, outpatient antibiotic consumption may either include or exclude antibiotic used in nursing homes. Nursing homes are generally counted in outpatient antibiotic consumption of most European countries although for few of them they are included in the hospital consumption.

2.2 Cantonal differences

Switzerland is a federal state made of 26 cantons. Cantons generally differ not only with respect to geographical characteristics, but also for cultural and socioeconomic aspects of the population and the organization of the health care system. The analysis of cantonal differences in antibiotic consumption

may then reflect these aspects besides epidemiological ones. We investigate cantonal antibiotic use in terms of sales (in CHF) per capita and DDDs per 1000 inhabitants daily using yearly data from 2002 to 2004[2].

The average cantonal expenditure in 2002 was around CHF 12 per capita with a standard deviation of 3.72. The expenditure varies from a minimum of CHF 6.44 to a maximum of CHF 22.63. Average per capita expenditure has increased between 2002 and 2003 by 3.2% and decreased afterwards by 4.5%. Differences between cantons appear to be significantly large all over the three years.

In terms of DDDs per 1000 inhabitants per day, the average cantonal outpatient antibiotic consumption was 9 DID in 2002 (figure 4). Average antibiotic use has slightly increased in 2003 and then reduced to 9.3 DID in 2004. Hence, average individual consumption daily has been roughly stable over the three years. Note, however, the wide differences between cantons. These can be summarized by the variation coefficient[3]: 29 in 2002, 26 in 2003, and 26 in 2004. Given a minimum cantonal consumption of 4.7 DID in 2002 (AR - Appenzell Rhodes), the highest consumption is more than 3 times greater (15.6 DID for GE - Geneva). Similar figures are observed for 2003 (min. 5.3 DID - Max. 16 DID) and 2004 (min. 5.3 DID - Max. 15.4 DID). Median values were 7.7 DID in 2002 (ZH - Zurich), 8.3 DID in 2003

[2] In the analysis which follows 5 small cantons have been aggregated into 2 bigger regions (see section 3.2 for further details).

[3] The variation coefficient is the ratio between the standard deviation and the mean multiplied by 100.

and 2004 (SO - Solothurn and Zurich).

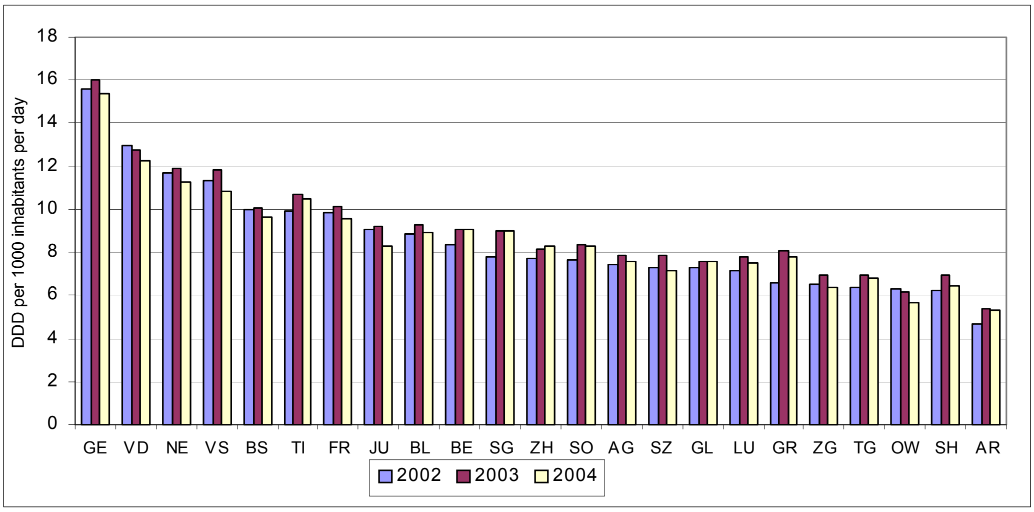

Figure 4: Outpatient antibiotic use per canton.

Although there are substantial cantonal differences in all of the three years observed, the variation coefficient indicates that differences has slightly reduced over time. In 2003 the big majority of cantons have increased antibiotic use expressed in DDDs per 1000 inhabitants daily but two cantons (VD - Vaud and OW - Obwalden) have reduced consumption. On average, consumption has increased by 5.6%. However, cantons such as St. Gall (SG) and Grisons (GR) exhibit more substantial growth. The t-test on the mean equality between 2002 and 2003 confirms that cantonal consumption has significantly increased. In 2004 average outpatient antibiotic consumption expressed in DID has decreased by 2.7% compared to 2003. The reduction characterize all cantons with the exception of Zurich.

Looking more carefully at figure 4, we note that cantons with the highest

consumption (such as Geneva, Vaud and VS - Valais) are generally located in the South-West part of Switzerland. Conversely, cantons with the lowest consumption are located North-East in the country.

Cantonal antibiotic consumption can be disaggregated by main antibiotic classes (figure 2). We summarize the following 6 categories as previously done for the whole Switzerland: penicillins, cephalosporins, tetracyclines, macrolides, quinolones, and sulfonamides. Cantonal differences can be observed in the structure of total consumption (figure 5). The proportion of penicillins use is between a minimum of 33.5% in Obwalden and a maximum of 44.8% in Solothurn. Macrolides range from 12.7% to 22.1% whereas quinolones vary from 17.2% to 23.1%. Although there are clearly differences in the cantonal consumption structure, figures suggest that within country variations are less substantial compared to those observed across European countries (see Goossens et al., 2005, among others). Cantonal differences in terms of the proportion of each antibiotic category on total consumption may be related to local variables such as the prevalence of infections, patients' and doctors' preferences, pharmaceutical marketing strategies, cantonal regulation, and the incidence of bacterial resistance.

3 Explaining variations

Regional variations in antibiotic consumption may be explained by a variety of factors. Several authors have suggested that doctors' decision to prescribe and patients' use of antibiotics are explained not only by clinical factors and

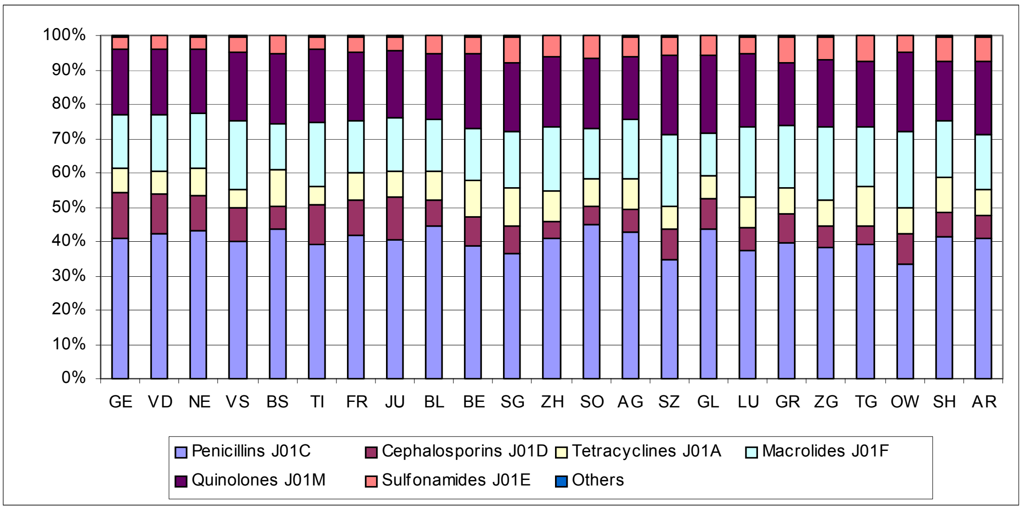

Figure 5: Structure of antibitic consumption in the community per canton.

by differences in bacterial infections across regions. Difference in bacterial infection can hardly explain variation in morbidity as large as four fold among industrialized countries. The literature has suggested the lack of education, physicians and patients' expectations, uncertainty, cultural and social behavior, and differences in regulatory practice, among other factors (Belongia and Schwatz, 1998; Finch et al. 2004).

Previous studies focusing on the determinants of antibiotic consumption have been conducted either in the form of trials or questionnaire surveys. Mecfarlane et al. (2002) investigated the impact of patient's information. Their experiment showed that the distribution of information leaflets to patients not in need for antimicrobials effectively reduced their use without affecting the doctor-patient relationship. Using a questionnaire survey on 22 Australian non-randomly selected general practitioners and 336 patients,

Cockburn and Pit (1997) showed that patients expecting a medication were nearly three times more likely to receive it compared to other patients. Moreover, patients were ten times more likely to receive a medication if practitioners perceived a patient's expectation on prescribing. Doctors' perception and patients' expectations were significantly associated to each other. Webb and Lloyd (1994) suggested that older people are more likely to be prescribed a medication, although this result is not confirmed by Cockburn and Pit's study. Harbarth et al. (2002) suggested that large differences in antibiotic consumption between France and Germany are at least partially related to differences in the concentration of child care facilities and the use of breast feeding between the two countries. Finally, Unsworth and Walley (2001) showed that antibiotic prescribing is related to practice characteristics in the British NHS. Deprived and single-handed practices tend to prescribe more but cheap antibiotics, while dispensers and trainers, with low level of deprivation and early wave fundholders have lower rate of prescriptions.

One alternative approach to investigate the determinants of antibiotic consumption is to use regional consumption data and regress them against a set of variables suggested by the literature as plausible causal factors of the demand for drugs. We apply this approach to regional outpatient antibiotic consumption in Switzerland and discuss it in the following section.

3.1 An econometric approach

From the economic point of view, antibiotics are an input of the health care and the health production process. Therefore, following the Grossman's tradition it is possible to derive the demand for antibiotics directly from the demand for health care. In this framework, the demand for antibiotics is a demand derived from the demand for healthy days and can be specified using the basic framework of household production theory[4]. In this framework, a household combines drugs, health care, time, exercise, education and capital equipment to produce healthy days.

Inspired by this approach and given the restriction of aggregate data[5], it is possible to specify an ad-hoc demand function for the cantonal per capita outpatient antibiotic consumption, where the demand for antibiotics depends on the individual's stock of health care (H), income (Y), prices of antibiotics and prices of other health care services, the incidence of infectious diseases and other socioeconomic variables such as age, nationality and education.[6] These socioeconomic variables are usually included in the model as proxies for the individual stock of health care, which is difficult to measure. Moreover, under a pure fee-for-service reimbursement scheme, there may be incentives

[4] For a precise presentation of the household production theory, see Becker (1975). See also Grossman (1972) for an application of household production theory to health care.

[5] An alternative approach would be to use more desagreggated data even at individual level. However, such a dataset was not available.

[6] Of course, we are aware that the use of aggregated data to explain individual antibiotics consumption implies the assumption that the hypothesized relationship between the economic variables in question is homogeneous across all individuals. Therefore, using this aggregate date set at the cantonal level we could encounter an aggregation bias.

to induce the demand for physicians' services[7]. Thus, the demand for antibiotics could also depend on some characteristics of the supply of health care services as physicians' density.

Taking into account the availability and the quality of data for the Swiss cantons, we specify the following parsimonious empirical model for the per capita demand of outpatient antibiotics:

$$\begin{aligned} D_{it} &= f(Y_{it}, P_{it}, Dph_{it}, Dpha_{it}, over65_{it}, under20_{it}, FO_{it}, EDU_{it}, INF_{1it}, \\ &\quad INF_{2it}, DT_t), \end{aligned} \tag{1}$$

where D_{it} is the per capita antibiotic consumption in canton i and quarter t, measured in Defined Daily Doses, Y_{it} is the cantonal per capita income, P_{it} is the price of a Defined Daily Dose, Dph_{it} is the cantonal physicians' density, $Dpha_{it}$ is the cantonal pharmacies' density, $over65_{it}$ indicates the percentage of the population older than 65, $under20_{it}$ is the percentage of the population below 20, FO_{it} is the share of foreigners on total population and ED_{it} is the percentage of individuals without post-mandatory education. Two indicators of infections are also included in equation (1): the number of campylobacter infections (per 100,000 inhabitants per year) and the number of streptococcus pneumonie infections (INF_{1it}, INF_{2it}). Finally, DT_t is a dummy variable to control for seasonal effects of antibiotic consumption. This takes value equal to 1 for season t $(t = 1, 2, 3, 4)$; otherwise is 0.

Estimation of equation (1) requires the specification of a functional form.

[7] For a summary reading of the supply-induced demand theory see McGuire (2000).

The log-log form offers an appropriate functional form for answering questions about antibiotic consumption elasticities. The major advantage is that the estimated coefficients amount to elasticities, which are, therefore, assumed to be constant. By applying the log-log functional form, the model can be written as:

$$\begin{aligned} \ln D_{it} &= \beta_0 + \beta_1 \ln Y_{it} + \beta_2 \ln P_{it} + \beta_3 \ln Dph_{it} + \beta_4 \ln Dpha_{it} \\ &\quad + \beta_5 \ln under20_{it} + \beta_6 \ln over65_{it} + \beta_7 \ln FO_{it} + \beta_8 \ln EDU_{it} \\ &\quad + \beta_9 \ln INF_{1it} + \beta_{10} \ln INF_{2it} + \beta_{11} DT_1 + \beta_{12} DT_2 + \beta_{13} DT_3 + \varepsilon_{it}. \end{aligned} \tag{2}$$

As to the choice of the econometric technique, it should be noted that in the econometric literature we find various types of models focusing on cross-sectional variations, i.e. heterogeneity across units. The four most widely used approaches are: the OLS model, the least squares dummy variable (LSDV) model, the error components model (EC) and the Kmenta approach[8]. Moreover, we should consider that our panel data set is characterized by a relatively small number of time periods, a limited number of cross-sectional units and a zero within variation for most of the explanatory variables. The only two variables that are changing over time are the outpatient per capita consumption and the price of an antibiotic daily dose. Hence LSDV and EC models are the less appropriate ones. The estimation of equation (2) was carried out using OLS and GLS estimation procedures

[8] For a detailed presentation of the econometric methods that have been used to analyse panel data, see Greene (2003).

for pooled time-series and cross-sectional data suggested by Kmenta (1986)[9]. Since many explanatory variables are repeated over time, we might have problems with the estimation of the variance of the coefficients. For this reason we estimated the model by OLS using the linearization/Huber/White/sandwich (robust) estimates of variance. The correlation within cantons was also taken into account by clustering the error as suggested by Roger (1993).

3.2 The data

The data for the estimation of equation (2) were obtained from three sources. Information on the per capita income, physicians' and pharmacies' density, demographic structure of the population, the share of foreign people, and the level of education, were extracted from yearly publications by the Swiss Federal Statistical Office. Information on the number of streptococcus pneumonie infections were obtained from the Swiss Federal Office of Public Health, whereas the data on antibiotic consumption and price were obtained from a data set created by IHA-IMS Health Market Research. The latter includes aggregate outpatient antibiotic expenditure and consumption of different classes of antibiotics for Switzerland. Quarterly data were available for three years (2002-2004) and detailed at cantonal level. Five small cantons have been aggregated to obtain two "macro" cantons so that the total number of cantons was reduced to 23 instead of 26.

[9]For a general presentation of this econometric procedure see Kmenta (1986) and Greene (2003). The estimation has been performed using the econometric software "Limdep8".

Data on antibiotic consumption derives from transactions between wholesalers and pharmacies and physicians in Switzerland. Since the retailers' stock of drugs is roughly constant over time, wholesales data provide a good estimation of outpatient antibiotic consumption in the country. However, our data may slightly underestimate final consumption for three main reasons. First, data collected for ambulatory care at least partially exclude drugs delivered in nursing home facilities[10]. Second, errors in data collection measurements may account for approximately 5% of the data which are missing. Third, since the aim of our analysis is to focus on ambulatory care, few antibiotic classes mainly related to hospital care (representing less than 2% of the data) were excluded from the purchased data set.

The data were available on a specific software, "ORACLE sales Analyser", having a multidimensional cube structure: the product, the region, the time period, the channel of sales, and measures of consumption. The data set was partially exported into MS Excel, LIMDEP and STATA8 formats to perform the analysis.

The Anatomical Classification (AC-system) provided by the European Pharmaceutical Market Research Association (EphMRA) classifies drugs into 16 groups at three or four levels with an alpha-numeric coding structure. All anti-bacterial agents (antibiotics) are identified by the alpha-numeric code J01. Antibiotics were disaggregated into different classes (for example, J01F

[10] In Switzerland around 50% of nursing homes have an internal pharmacy unit. Antibiotics delivered by the internal pharmacy are not included in the dataset and counted as hospital consumption.

macrolides) to investigate the consumption structure in section 2. Because the classification system of EphMRA does not perfectly match the international one, we rearranged some of the classes to obtain the standard antibiotic classes commonly used in international studies[11]. In particular, according to the EphMRA classification, broad spectrum penicillins (coded J01C) and medium and narrow spectrum penicillins (coded J01H) define two separate groups but have been grouped together in the ATC classification (J01 C penicillins). Quinolones are included in class M in the ATC international classification, whereas they fill class G for EphMRA. We finally summarized seven different classes : J01 A tetracyclines, J01 C penicillins, J01 D cephalosporins, J01 F macrolides, J01 M quinolones, J01 E sulfonamides and others.

Consumption is measured in terms of currency units (CHF) and the number of sold packages. Furthermore, the data set provides a third measure named Counting Units (CU). CU are defined in terms of milligrams and days of treatment (DOT). DOT are derived from milligrams using the total number of sold packages, the milligrams per package and the Defined Daily Dosage (DDD) as $DOT =$ (Number of packages)(mg. per package)$/DDD$. The latter measure, according to the WHO[12], is the assumed average main-

[11]The ATC classification used in international studies is an extension of the EphMRA classification suggested by Norwegian researchers in the 70's. Since 1996, the use of the ATC and, more generally, of the ATC/DDD system is recognized by the WHO as the international standard.

[12]This is a constant for each active pharmaceutical ingredient. As the WHO emphasized, the DDD is a unit of measurement and does not necessarily reflect the recommended or the prescribed daily dose". For example, doses may depend on individual characteristics such as age and weight.

tenance dose per day for a drug used for its main indication in (by) adults. For some products like Penicillins, the standard counting unit is not the milligrams but the International Unit (IU) established by the UK National Institute for Medical Research. Hence, we adapted the above expression to consider IU instead of milligrams.

In addition to the original variables we calculated total per capita sales and days of treatment per 1000 inhabitants per day (DID) using demographic data at cantonal level. The latter measure constitutes the explained variable in the econometric model defined by equation (2).

Since many explanatory variables were available for 2002 only, we estimated equation (2) using four quarters. As an exception, the level of education (EDU) refers to year 2000. Table 1 gives summary statistics of variables included in the model.

Variables	Unit of measurement	Min.	Med.	Max.
Outpatient antibiotic consumption (DID)	DDDs per 1000 inhabitants per day	4.28	7.89	18.49
Income per capita (Y)	Income (CHF)/pop.	35952	45746	77583
Price of a daily dose (P)	Sales (CHF)/DDDs	3.40	3.72	4.32
Physicians' density (Dph)	Physicians/100000 inhab.	118	160	353
Pharmacies' density (Dpha)	Pharmacies/100000 inhab.	5	18	55
Population age over 65 (over65)	Over 65/pop.	0.12	0.15	0.21
Population under 20 (under20)	Under 20/pop.	0.17	0.24	0.26
Share of foreign population (FO)	Foreign people/pop.	0.09	0.19	0.38
Incidence of campylobacter infections (INF_1)	Number/100000 inhab.	21.5	188	908
Incidence of strep. pneumonie infections (INF_2)	Number/100000 inhab.	2	25	144
Percentage of people without post-mandatory education	Basic education/pop.	0.19	0.24	0.32

Table 1: Variables notation and summary statistics

3.3 Estimation results

The estimation of the ad-hoc demand equation specified by (2) gives satisfactory and stable results. We summarize them in table 2, both for the OLS and the GLS methods.

In both models the majority of the coefficients are significantly different from zero and carry the expected sign. Moreover, differences in coefficients between the two models are relatively small. The adjusted R-squared in the OLS estimation suggests that the model explains around 85% of total variations.

Since per capita antibiotic consumption and regressors are in logarithm form, the coefficients can be interpreted as health expenditure elasticities. For instance, the income elasticity of health expenditure is negative and significantly different from zero. This result entails that income have a significant influence on the level of per capita antibiotic consumption. Similarly for education, the coefficient shows that an increase in the percentage of people without post-mandatory education increases the per capita antibiotic consumption. The impact of income and education confirm that income is highly correlated with the level of education: the higher the level of income and education, the lower the per capita consumption of antibiotics.

In terms of the investment in health function in the Grossman model the results suggest that relatively rich and highly educated people either use health care inputs (antibiotics) more efficiently or have higher initial health stocks. Higher levels of productivity imply that the same amount of health

investment can be obtained by a lower amount of health care services. Also, higher initial health stocks imply that lower investment in health, and hence in health care inputs, are required for any given level of optimal health stocks, ceteris paribus.

Price of a daily dose does not have any significant impact on consumption, although it exhibits the expected sign: the higher the price of a daily dose, the lower the demand for antibiotics. The rationale for such a low level of significance may that Swiss consumers bear only a small fraction of the total cost of drugs. Although they directly pay for antibiotic when purchasing them, they are at least partially reimbursed afterwards by the insurance provided that total health expenditure overcomes the yearly deductible applied in the contract. Moreover, the demand for antibiotics may be more inelastic compared to other types of drugs since antibiotics are generally purchased under doctor's prescription.

Elasticities of physicians' density show positive values. This implies that an increase in the number of physicians at cantonal level causes an increase in the cantonal per capita antibiotic consumption. A 10% increase in physicians' density increases per capita daily doses approximately by 9%.

The result suggests some evidence of supply-induced demand in the Swiss health care sector. This is in accordance with the literature suggesting that systems where physicians are paid under a fee-for-service scheme,[13] akin to the Swiss one overconsumption of drugs is more likely. On the other side,

[13] For further details on the supplier induced demand theory see McGuire (2000).

the coefficient on the density of pharmacies is not significant. The rationale may be that antibiotics can only be bought under physician's prescription.

Elderly people are less likely to use antibiotics compared to other categories. This is suggested by the negative coefficient of the percentage of population aged over 65. The reason may be found in the fact that elderly people living at home, and not in nursing homes, experience a low incidence of illness. On the other side, the percentage of population aged under 20 has a positive impact on consumption but this is not significant.

With respect to the share of foreign people on the total population, a 1% increase is associated to 0.18%-0.20% increase in the per capita outpatient antibiotic consumption. Cultural differences or differences in the incidence of infectious diseases may account for this result.

Epidemiological factors such as the incidence of bacterial infections give some ambiguous results. The incidence of campylobacter infections exhibit the expected positive sign in all the estimations. However, the level of significance varies with the estimated model. Surprisingly, the incidence of streptococcus pneumonie infections has a negative impact on consumption although the coefficient is not significant in two cases. To summarize, the estimates suggest that the incidence of infections may not have a strong impact on the demand for antibiotics compared to other factors although there is some evidence of a slightly positive effect. One reason for this not so clear evidence may be found in the reliability of data on the local incidence of infections which are difficult to measure.

Time dummies suggest that there are some seasonal effects in antibiotic consumption in ambulatory care. The coefficient of the *winter* dummy, β_{11}, is positive and significantly different from zero. On the other side, *spring* and *summer* dummies are negative and significant. Hence, the hypothesis that cantonal consumption is indeed higher in winter periods and lower in spring and summer periods compared to autumn periods could not be rejected. This may capture the seasonal trend in the incidence of respiratory tract infections which affects the use of antibiotics in ambulatory care.

	OLS Coefficients	Std. Err.	OLS corr. Coefficients	Robust Std. Err.	GLS Coefficients	Std.Err.
$Constant$	-0.869	1.953	-0.868	1.784	-0.807	1.692
lnY	-0.525**	0.197	-0.524**	0.073	-0.526**	0.190
lnP	-0.158	0.324	-0.157	0.179	-0.211	0.163
$lnDph$	0.923***	0.116	0.923**	0.087	0.886***	0.076
$lnDpha$	0.015	0.041	0.015*	0.003	0.015	0.032
$lnunder20$	0.134	0.425	0.134	0.193	0.284	0.367
$lnover65$	-0.970***	0.292	-0.970*	0.207	-0.825**	0.282
$lnFO$	0.176**	0.065	0.176*	0.050	0.201**	0.066
$lnEDU$	0.787***	0.163	0.787*	0.203	0.690***	0.171
$lnINF_1$	0.081*	0.033	0.081**	0.009	0.064**	0.021
$lnINF_2$	-0.043	0.029	-0.042**	0.005	-0.039	0.027
DT_1	0.070*	0.034	0.070***	0.002	0.073***	0.009
DT_2	-0.196***	0.034	-0.196***	0.003	-0.195***	0.009
DT_3	-0.170***	0.034	-0.170***	0.003	-0.180***	0.007

* significant at 5%, ** significant at 1%, *** significant at 0.1%.

Table 2: Estimated coefficients obtained by OLS and GLS methods.

4 Conclusions

The investigation of regional variations in outpatient antibiotic consumption may help to understand the determinants of the demand for antibiotics and contribute to the discussion on the reduction of antibiotic resistance. There

is a lack of empirical evidence both in the analysis of within country and within country variations in antibiotic consumption.

We investigated outpatient antibiotic consumption in Switzerland at cantonal level and by comparison with other European countries. We showed that Switzerland uses relatively low volumes of antibiotics in ambulatory care. In terms of consumption structure, Switzerland is characterized by high proportions of quinolones.

Antibiotic consumption in ambulatory care has significantly increased in terms of Defined Daily Doses per 1000 inhabitants per day (DID) and sales per capita between 2002 and 2003 in most Swiss cantons. Conversely, consumption has generally decreased in 2004.

The investigation of cantonal differences shows that there are wide variations across cantons. Variations are less remarkable in terms of consumption structure.

Regional variations in outpatient antibiotic use within the country can hardly be explained by epidemiological factors only. Multiple regressions on quarterly data for 2002 using OLS and GLS estimators suggest that per capita income, demographic factors, including the proportion of foreign residents, and the density of medical practices may contribute to explain cantonal differences in antibiotic use.

More effective policies to improve the efficient use of antibiotics in the community may be driven by these findings. Appropriate incentives affecting antibiotic consumption and hence levels of bacterial resistance can be

designed by looking at crucial determinants suggested in the model and their relative impact.

Econometric models using data at local level and the application of multiple-choice models to selected categories of antibiotics are required to confirm previous findings and capture the effects of seasonal consumption patterns. Additional determinants of regional differences, including endogenous bacterial resistance, could be included depending on the availability of local data.

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