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Small area variations and welfare loss in the use of antibiotics in the community

by

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Small area variations and welfare loss in the use of antibiotics in the community

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Abstract

This paper seeks to explain local variations in the use of antibiotics in the community and to assess the welfare loss due to heterogeneous attitudes towards the risk of bacterial infections and resistance. Significant differences are observed in the per capita antibiotic consumption measured in defined daily doses per 1000 inhabitants (DID) across small geographic areas in Switzerland. A model is proposed in which antibiotic use varies according to the socioeconomic characterisitics of the population characteristics, the incidence of infections, antibiotic price and local supply of health care. Quarterly wholesales data on outpatient antibiotics in 2002 were obtained from IHA-IMS Market Research and combined with WHO standardized doses to obtain DID. The paper finds that the most important determinants of variations in outpatient antibiotics use in the community are income, demographic structure of the population and local supply and price of antibiotic treatment. We estimated that unexplained variations may account for 11% of the total antibiotic spending in the community, thus leading to a €6ml loss per year.

Keywords: Antibiotic use. Small area variations. Welfare loss.

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1 Introduction

The utilization of antibiotics is far from being homogeneous across geographic areas. A European cross-country comparison shows that the per capita outpatient antibiotic consumption in the Netherlands is three times lower than in France (Goossens et al., 2005). Significant disparities are also observed across regions within a single country. In Switzerland, the rate of outpatient antibiotic use per inhabitant is almost three times bigger in high-consuming cantons compared to low-consuming cantons (Filippini et al., 2006). Remarkable differences are found at an even smaller scale, across city districts. Nilson and Laurell (2005) suggested that the rate of variation in the city of Malmö was around 42% in 1999.

In the health services research the analysis of small area variations (SAV) constitutes a common approach to investigate determinants of the utilization of medical care (Folland and Stano, 1990). The focus on small and contiguous geographic areas implies that the units under investigation have a good internal homogeneity in terms of health conditions and socioeconomic characteristics of the population. Consequently, the analysis may be useful to draw conclusions on local variations in the use of antibiotics and its determinants. This may then ease the design of effective policies to promote optimal use and reduce the impact of bacterial resistance, which is a primary cause of concern for public authorities.

Small area variations have been inspected for different types of health care services. The research has mainly paid attention to hospital care (Martin and Smith, 1996; Congdon and Best, 2000; Westert et al., 2004) although there are studies focusing on primary care (Parchman, 1995) and the use of drugs (Dubois et al., 2002). However, there is a lack of inspection on the use of antibiotics. Henricson et al. (1998) explore the variability in the use of antibiotics across 17 city districts in Sweden. Their analysis show that antibiotic use significantly varies across groups of individuals and districts.

Many studies on small area variations use standard statistical tools such as high-low ratios, coefficients of variation, systematic components and coefficient of correlation. More powerful results can be obtained by multivariate analysis which simultaneously considers many explanatory factors. This approach has been applied, for instance, by Folland and Stano (1989) to examine the variability in the per capita utilization rates of medical procedures across areas in the state of Michigan. Explanatory variables included patients' health status and other patients' characterisitics, the type of health insurance and access to hospital care. Crosse et al. (1997) regressed six groups of socioeconomic variables on birthweight rates in a Canadian city for a period of 5 years. More recently, Asche and Coyte (2005) focused on the impact of neighborhood socioeconomic status on differences in rates of ventilation tube surgery across 49 counties in Ontario. The multivariate model included a composite index of socioeconomic status, physicians supply and access for patients. Socioeconomic characteristics and supply factors were also considered by Joines et al. (2003) who examined disparities in hospitalization rates for low back problems across 100 counties in North Carolina.

The purpose of this paper is to explore small area variations in outpatient antibiotic use and to provide new insights into the impact of socioeconomic determinants by means of a multivariate approach. Following the approach proposed by Parente and Phelps (1990) we also intend to assess the welfare loss from unexplained variations.

A common denominator in the analysis of small area variations is that wide differences in the utilization of health services remain unexplained after controlling for standard determinants of demand and access. Many authors have argued that heterogeneity in physicians practice styles may be an important cause of differences in medical utilization across small areas (Wennberg, 1984; McPherson, 1990; Westert and Groenewegen, 1999; Grytten and Sorrensen, 2003). In the use of antibiotics, a substantial degree of heterogeneity can be associated to different levels of bacterial resistance and physicians and patients attitudes towards its implied risk (Harbath et al., 2002). Since bacterial resistance reduces the effectiveness of antibiotic treatment, it may affect physicians prescription strategies and patients decisions (Rudholm, 2002; laxminarayan and Weitzman, 2002). The assessment of unexplained variations across small areas may provide an approximate measure of the impact of bacterial resistance on the use of antibiotics in the community, when local data on the level of bacterial resistance are not available.

The paper is organized as follows. Section 2 introduces yearly data on outpatient antibiotic use from 240 small areas in Switzerland. In section 3 we present some summary statistics of determinants of small area variations and present a simple model specification of variations in antibiotic consumption in the community. Results are discussed in section 4. Section 5 provides a calculation of the welfare loss associated to unexplained variations in antibiotic use and the paper ends with some conclusions.

2 Data

As part of a larger project investigating consumption of outpatient antibiotics in Switzerland, we were supplied data from 240 contiguous market areas covering the entire Swiss territory (Figure 1). The areas exhibit a good degree of internal homogeneity with respect to the density of the population and health care providers. Administrative units (the cantons) and cultural/linguistic regions can be obtained by aggregating these areas. In a previous study (Filippini et al., 2006) we used data collected at cantonal level. Switzerland is made of 26 cantons. Generally, a canton includes between 10 and 20 market areas. Consequently, in the current paper we can analyse antibiotic consumption in further details using data with a higher degreee of homogeneity. Each area includes at least 4 pharmacies and/or drugstores. Local wholesales quarterly data on outpatient antibiotics at product level were obtained from IHA-IMS Health Market Research for the year 2002. Using information on the number of inhabitants [1] and WHO standard doses we calculated the defined daily doses sold to 1000 inhabitants per day (DID) for each of the areas.

This measure represents a good quality indicator of local outpatient antibiotic use and we assume that antibiotic purchases by individuals outside their area of residence offset purchases by non-residents inside the area. We also neglect any systematic gap between the amount of antibiotics sold to consumers and that actually used. This implies, for instance, that the lack of patients' compliance with prescriptions can be ignored. Finally, the potential mismatch between wholesales and prescribing data due

[1] Information for the year 2002 were derived from projections using the population census of 2000.

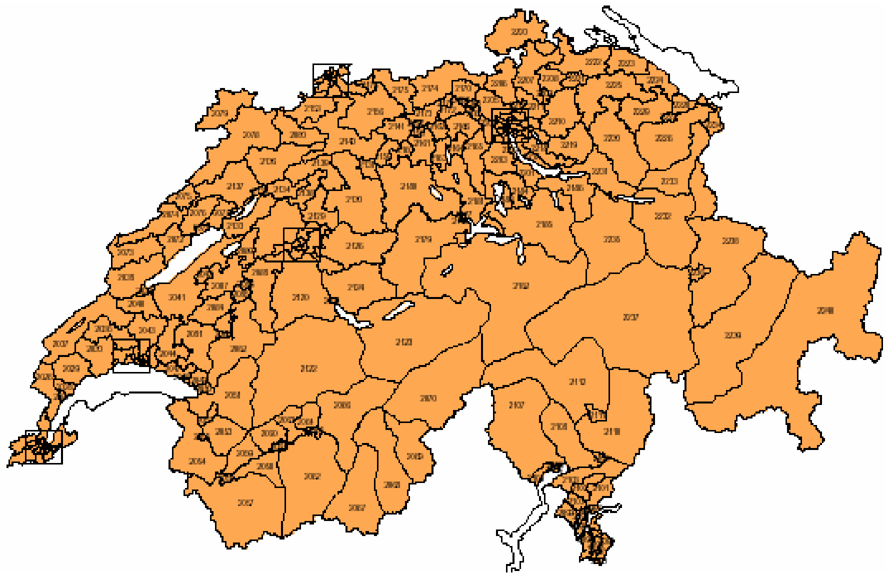

Figure 1: The 240 market areas. Source: IHA-IMS.

to seasonal fluctuations of retailers' stocks is assumed to have only limited temporary effects and hence can be neglected.

The population varies between 4,980 and 125,275 inhabitants per area [2].

As illustrated in Figure 2, there is a strong heterogeneity in antibiotic use across small areas within cantons[3]. The width of the boxes indicates the spread of the second and the third quarters of data and the length of the two whiskers illustrates the spread of the first and fourth quarters of data. The mean DID (across the small areas) is 11.71 and varies between a minimum of 4.65 and a maximum of 16.77 at cantonal level. Note, however, that the within-canton variation is much wider since

[2] This is smaller than the population generally observed in similar studies, for instance in Folland and Stano (1989) who identify 15 areas in the State of Michigan to investigate intermarket variations in the per capita utilization rate of surgical procedures. More recently, Dubois et al. (2002) considered areas with population ranging between 16,052 and 166,316 individuals.

[3] Switzerland is a federal state where cantons have strong power in terms of health care policy.

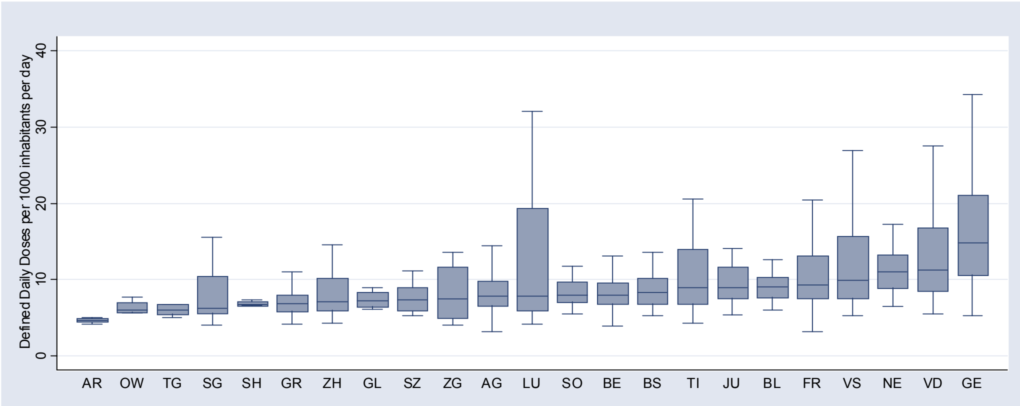

Figure 2: Within-canton variations in the per capita antibiotic use (2002).

the minimum DID in a small area is 3.18 (AG) whereas the maximum DID value is 141.27 (ZH).

3 Modelling variations in the use of antibiotics

Variations in the utilization of antibiotics across small areas can be explained by several causes. All other things being equal, we hypothesize that four main factors affect inter-area variability: the incidence of community acquired infections, the local supply of community care, population characteristics (age and income structure, cultural aspects) and the price of antibiotics.

Differences in the incidence of infections between geographic areas are likely to have an impact on the per capita use of antibiotics. Note, however, that remarkable seasonal fluctuations suggest that the incidence of the most relevant community acquired infections, such as influenza and pneumonia, also vary widely during the year.

Among the peculiar characteristics of the population we find the demographic structure, socioeconomic aspects and cultural attitudes. It can be argued that doctors and patients are somehow concerned with the potential harmful effect of delaying antibiotic treatment for the very young. On the contrary, if the antibiotic therapy represents a time-saving choice for individuals belonging to the labor forces, one might expect that mid-age individuals are more likely to use them, *ceteris paribus*. This hypothesis is in accordance with findings by Mousquès et al. (2003), who studied antibiotic prescriptions for rhynopharingitis infections by general practitioners. On the other side, the elderly may be less exposed to community acquired infections or be more concerned with the implications of bacterial resistance and hence use less antibiotics.

As for socioeconomic factors, Henricson et al. (1998) showed that the level of income is positively related to the use of antibiotics.

Finally, attitudes towards antibiotics may be affected by cultural/linguistic aspects. Elsevier et al. (2006) suggested that southern European countries consume higher doses of outpatient antibiotics per capita. Filippini et al. (2006) showed that French and Italian speaking cantons in Switzerland consume more antibiotics compared to German speaking cantons.

As a third factor we consider the characteristics of the local supply of community health care such as the availability of practices and pharmacies in the area. Looking at variations in hospital rates of discharge, Joines et al. (2003) and Condgon and Best (2000) found that the effect of hospital supply variables is remarkable. In the context of primary care, Grytten and Sorensen (2003) found that physicians specific effects in Norway explain between 47% and 66% of differences in the expenditure.

The fourth factor that may account for variance in the use of antibitoics across the areas is the price. Although individuals only bear a small fraction of the cost of antibiotics, differences in health insurance copayments and deductibles may influence the price elasticity of the demand. Moreover, competition and wholesalers marketing strategies may vary across the areas, thus leading to significant price differences.

We specify a model to explain variations in the per capita use of outpatient antibiotics across the small areas. The dependant variable is the defined daily doses per 1000 inhabitants (DID) as described above. All other things being equal, we assume that for the i^{th} area:

$$DID_i = f(Y_i, POP_{ji}, DLAT_i, DBOR_i, INF_i, DPHY_i, DPHA_i, P_i, DT_t), \quad (1)$$

where Y_i is the average income of residents in the i^{th} area, POP_{ji} is the percentage of the population in the j^{th} range of age, $DBOR_i$ is a dummy that captures any borderland effects with neighboring countries, $DLAT_i$ consider whether an area is mainly characterized by Latin (French and Italian speaking) or German culture, INF_i measures the incidence of bacterial infections at cantonal level, and $DPHY_i$ and $DPHA_i$ are respectively the density of physicians and pharmacies in the area. P_i is the price of a defined daily dose in period $t-1$. Lagged values for prices are used to reduce the risk of endogeneity between quantities and prices. Finally, DT_t are time dummies that identify the four quarters of the year, with DT_4 (October, November, December) being the baseline quarter. Defined daily doses of outpatient antibiotics per capita are expected to be higher during winter and lower in spring and summer periods, as pointed out by Goossens et al. (2005).

Variable	Description
DID	Defined daily doses per 1000 inhabitants
Y	Income per capita defined in CHF
POP_1	Proportion of 0-14 in total population
POP_2	Proportion of 15-25 in total population
POP_3	Proportion of 26-59 in total population
POP_4	Proportion of 60-74 in total population
POP_5	Proportion of over 75 in total population
INF	Incidence of salmonella and campylobacter infections in 100000 inhabitants
$DPHY$	Density of physicians in 100000 inhabitants
$DPHA$	Density of pharmacies in 100000 inhabitants
P	Price of a defined daily dose
$DBOR$	Whether or not the area is a borderland with other countries
$DLAT$	Whether an area has a Latin (French and Italian) or a German culture

Table 1: Variables notation.

Our dataset includes information on all these variables (Table 1). Provided that they explain the largest proportion of small area variations in antibiotic consumption, the remaining unexplained differences are plausibly related to differences in physicians attitudes towards uncertainty on the type of infections and variations in bacterial resistance across small areas. This issue will be addressed later on in section 5.

As for the demographic structure of the population we consider five age groups: 0-14, 15-25, 26-59, 60-74, and over 75. We hypothesize that children are more likely to be prescribed an antibiotic than adults *ceteris paribus*. Resi et al. (2003) found that the percentage of children receiving antibiotics decreases as they grow up and around 70% of children between 1 and 2 years of age received at least one prescription during 2002. The proportion fell to 36% for children over 11 years old.

We capture the effects of cultural differences by the inclusion of two variables: $DBOR$ and $DLAT$. Lecomte and Paris (1994) suggested that sociocultural factors may explain differences in consumption patterns between European countries. Since Swiss regions are characterized by German, French and Italian speaking communities, we want to investigate whether their attitude towards antibiotics displays similar differences as those observed between German, French and Italian speaking countries in Europe. The density of foreigners or working commuters from other countries may also affect the per capita use of antibiotics. This impact has been analysed at cantonal level by Filippini et al. (2006) and is now locally inspected.

Data on bacterial infections are based on information on the incidence of campylobacter and salmonella diseases. Campylobactor and salmonella are two main causes of gastrointestinal infections. In most cases patients recover without any medical treatment. However, patients may be prescribed antibiotics when symptoms are particularly severe, especially children and elderly patients. Although other types of bacterial infections, such as airborne bacterial infections caused by the streptococcus pneumonie, may also be relevant, these data are poorly reliable. Our information was obtained from yearly publications of the Swiss Federal Statistical Office at cantonal level.

Folland and Stano (1990) suggested that the primary care physicians to population ratio reflects the supply of medical services and, hence, constitutes a potential explanation of small area variations in the use of health care services. Similarly, we hypothesize that the density of physicians may affect the probability of antibiotic prescriptions under imperfect information on the type of patients' infections, *ceteris paribus*. As shown in table 2, the number of physicians per 100000 inhabitants ranges from 43 to 10730. The coefficient of variation is around 3 and suggests that there are large variations across the areas.

Besides physicians' density, access to antibiotic treatment may be influenced by the availability of pharmacies in the area. We observe large differences in the density of pharmacies across the small areas. The number of pharmacies per 100000 inhabitants varies between 4.8 to 333.

The price of a defined daily dose is calculated quarterly and varies between CHF 2.81 and CHF 4.80.

To investigate the responsiveness of local per capita antibiotic sales to changes in the explanatory variables, we use a linear specification of the model defined by equation (1). Coefficients represent changes in the value of the dependent variable corresponding to variations in the value of each explanatory variable, *ceteris paribus.* Unexplained variations are assumed to be independently and identically normally distributed.

From the econometric point of view, we should consider that our panel dataset is characterized by 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 explanatory variables. The only two variables that are changing over time are the outpatient per capita consumption and the price of a daily dose. Hence, the least squares dummy variable model, the error components model and the Kmenta model are not appropriate. For this reason we use the Ordinary Least Squares approach (OLS) with robust standard errors.[4] In the standard OLS specification the error term is supposed to be independently and identically distributed. When this assumption is partially relaxed, the linearization/Huber/White/sandwich (robust) procedure allows

[4] For a general presentation of this procedure see Kmenta (1986) and Greene (2003).

to get estimates of the variance of the coefficients that are robust to the distribution assumptions. The estimation has been performed using the econometric software STATA.

4 Results

We shortly investigate the correlation between the dependent variable DID and the four groups of determinants: *(i)* incidence of infections, *(ii)* demographic, socioeconomic and cultural aspects of the population, *(iii)* supply of health care in the community and *(iv)* antibiotic price. Correlation coefficients are all significant on the basis of a two-tailed test and are reported in table 2.

	Min.	Med.	Max.	Correlation coefficients
Y	15422	21133	51446	0.3663
POP_1	0.09	0.16	0.22	-0.2715
POP_2	0.07	0.13	0.20	-0.3699
POP_3	0.42	0.49	0.63	0.4246
POP_4	0.09	0.13	0.25	-0.0266
POP_5	0.03	0.08	0.14	0.0116
INF	92	115	187.7	-0.0157
$DPHY$	43.20	230.18	10730.03	0.4585
$DPHA$	4.80	27.21	333.15	0.8987
P	2.81	3.68	4.80	-0.0817
$DBOR$	-	-	-	-0.0136
$DLAT$	-	-	-	0.1200

Table 2: Summary statistics and correlation coefficients with DID.

Univariate correlation may be misleading because other factors are not being held constant. We then use multiple regression analysis to estimate the model defined by equation (1) in the previous section. Conversely from Filippini et al. (2006), we do not take logarithms of variables and use an additive specification. The reason is that the latter specification hypothesizes a linear demand curve for antibiotics in the area. This is convenient for the assessment of the welfare loss due to unexplained variations that we will perform in the following section.

The multivariate model includes all the initial variables. Although some of them are not very significant, the list is relatively short and they are all worth discussing as possible determinants. The fact that some of them are defined at regional rather than at local level may affect their significance in the model. However, our model is parsimonious and well-specified at the same time. Table 3 reports coefficients, robust standard errors and p-values from the estimation.

Observations	720		F(13, 706) = 45.90
Adjusted R^2	0.86		Prob > F = 0.0000
	Coefficients	Robust SE	p-value
Constant	7.347443	4.465691	0.100
Y	0.000160	0.000051	0.002
POP_1	62.33937	15.01044	0.000
POP_2	-29.9565	16.1015	0.063
POP_4	-17.79699	16.05182	0.268
POP_5	-55.61431	13.74722	0.000
DBOR	-0.485005	0.582125	0.405
DLAT	-3.799576	0.694479	0.000
INF	0.006952	0.007385	0.347
DPHY	0.000417	0.000301	0.166
P_{t-1}	-2.301942	0.564256	0.000
DPHA	0.30663	0.020851	0.000
DT_2	-1.979542	0.442832	0.000
DT_3	-2.265763	0.442376	0.000

Table 3: Ordinary Least Squares model of the Defined Daily Doses per 1000 inhabitants (DID).

Perhaps the first point to note is that the adjusted R^2 suggests that selected variables explain around 86% of small area variations in the use of antibiotics in the community.

The positive relationship between DID and income is significant and suggests that richer areas spend more on outpatient antibiotics per capita compared to lower income areas. The result is in accordance with findings by Nilson and Laurell (2005) who analysed the impact of socioeconomic factors on antibiotic prescribing in a Swedish city. Similarly, Henricson et al. (1998) found that antibiotic consumption is higher in higher income districts.

The meaning of demographic variables is plausible. The impact of the proportion of children between 0 and 14 years of age on the total population (POP_1) reflects more health consideration. Since children are largely exposed to infections in child-care facilities and school, imperfect information on the type of infection may lead physicians and parents to provide them with antibiotics in order to minimize the risk of complications.

Also of interest is the negative coefficient of the proportion of individuals over 75 years of age compared to the baseline category. A similar impact, although not significant, is observed for the proportion of individuals between 60 and 74. This suggests that elderly people may be less exposed to the risk of infections in the community or that they are more concerned with the implications of bacterial resistance. Another explanation implies that elderly people are more likely to obtain hospital referrals for community acquired infections, *ceteris paribus*, and hence to receive antibiotic treatment within the hospital. Our result is in accordance with findings by Mousquès et al. (2003), who investigated a panel of general practitioners prescribing antibiotics for rhynopharingeal infections.

Areas at the border between Switzerland and other countries may share similar attitudes towards antibiotics for at least two reasons. Firstly, the foreign workers may influence the perception of the need for antibiotic treatment in the area. Secondly, practice behavior towards antibiotic prescribing may be influenced by practice styles in neighboring countries. We test this hypothesis in the light of differences observed in antibiotic consumption across Europe (Goossens et al., 2005). However, the coefficient of $DBOR$ is not significant.

Surprisingly enough, French and Italian culture areas not associated with lower antibiotic use if compared to German culture areas. The coefficient of $DLAT$ is negative. Note, however, that the univariate correlation with DID is positive. Dropping this variable from the multivariate model will not affect all the other results. The reason of such an effect is plausibly the interaction with local supply factors, i.e. the density of pharmacies. Since French and Italian speaking areas generally exhibit a higher density of pharmacies compared to German speaking areas, the effect of different cultural attitudes on the use of antibiotics may not be easily disentangled.

The coefficient of the incidence of infections exhibits the expected positive sign. However, it is not significant. This result suggests that epidemiological differences may not be very relevant in explaining variations in the use of antibiotics in the community. It is important to point out that the lack of significance may be due to the use of regional data on the incidence of bacterial infections rather than local data, which are not available yet.

Local supply factors are positively associated with the per capita antibiotic use, although the coefficient is statistically significant for the density of pharmacies only.

The poor significance of physicians density is due to the correlation with pharmacies. The correlation coefficient shows that the relationship between DID and the density of pharmacies is stronger than the relationship between DID and the density of doctors.

The density of physicians is often used to measure the extent of the supplier-induced demand (SID) phenomenon in the empirical literature.[5] This variable is likely to be associated with higher per capita use of antibiotics, if physicians can compensate the increased pressure on their income due to the reduced number of patients per doctor by increasing the amount of services provided to each individual (Carlsen and Grytten, 2004). This is even more likely under the fee-for-service payment scheme adopted in the country under investigation. Recently, however, Davis et al. (2000) analysed medical practice variations in New Zealand and did not find any evidence of SID. On the other hand and more related to antibiotic consumption, Garcia-Rey et al. (2004) found a negative correlation between the number of physicians per capita and differences in antibiotic use across Spanish provinces.

The strong impact of the density of pharmacies suggests that pharmacies are likely to directly affect the consumption of antibiotics through advice or advertising. It may also suggest that patients are more likely to purchase antibiotics if a pharmacy is located nearby their residence, *ceteris paribus*.

As expected, price has a negative and significant impact on antibiotic use in the area. The result indicates that antibiotic sales are affected by price changes, although patients are covered by insurance plans.

We also found remarkable seasonal effects. The estimated coefficients of the second

[5] See McGuire (2002) for a review.

and the third quarters of the year (DT_2 and DT_3) are both negative and highly significant. This connotes lower per capita outpatient antibiotic use during spring and summer periods, plausibly because the risk of bacterial infections is reduced.

5 Welfare loss from attitudes towards risks of antibiotic use

In this section we focus on the analysis of unexplained variations in the use of antibiotics after controlling for the demand and supply-side determinants considered above. The literature suggests that unexplained variations may be associated to unobserved heterogeneity in physicians practice styles. However, it is worth pointing out that omitted factors may also be related to patients preferences. As advocated by Stano (1993) this aspect may interfere with the impact of practice style in the residual variations.

To assess the impact of unobserved heterogeneity in practice style, Folland and Stano (1989) assumed that this is an omitted variable complementary to all the explanatory variables considered in their model. Consequently, the unexplained variance can be interpreted as a measure of the impact of practice style on the consumption of medical services.

As suggested in the Introduction, in the case of antibiotics unexplained variations may be plausibly related to differences in the local levels of bacterial resistance and in doctors and patients attitudes towards its implied risk. Therefore, our empirical model hypothesizes that unexplained variations provide an estimate of the welfare loss due to this source of heterogeneity and implicitly assumes that physicians practice

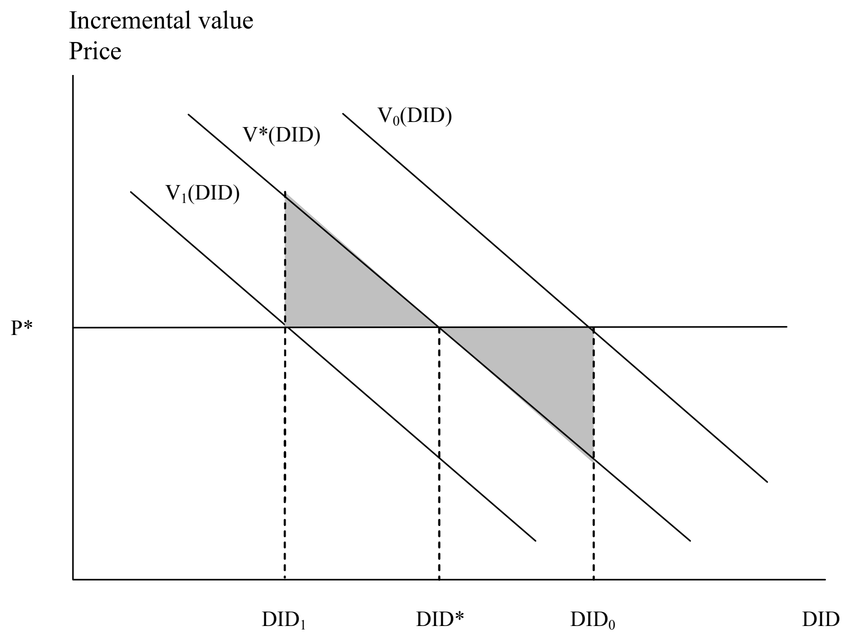

Figure 3: The loss of consumer surplus due to variations in the use of antibiotics.

styles are somehow affected by local levels of bacterial resistance.

Following Parente and Phelps (1990) we apply a method for the assessment of the welfare loss from unobserved heterogeneity in the use of outpatient antibiotics. The method relies on the determination of the loss of consumer surplus due to a shift in the linear demand curve (figure 3). Under perfect information about the true value of antibiotics, hence the local level of bacterial resistance, consumer surplus would be maximized in each area. However, the marginal individual benefit, $V(DID)$, can be distorted by the level information available on variations in the level of bacterial resistance across the areas, from $V^*(DID)$ to $V_0(DID)$ or $V_1(DID)$. The welfare loss due to the inefficient use of antibiotics is represented by the shaded areas in the figure. The total loss can be defined as

$$W = \frac{1}{2}\sum\nolimits_{i=1}^{N} \Delta DID_i \Delta V_i, \tag{2}$$

where ΔDID_i and ΔV_i are the deviation from the optimal level of the per capita antibiotic use and the deviation from the optimal value of a defined daily dose in the i^{th} area.[6]

If we define $\overline{DID}$ as the average number of daily doses across all the areas and V' as the slope of the value curve, we can write $\Delta DID_i = DID_i - \overline{DID}$ and $\Delta V_i = \left(DID_i - \overline{DID}\right) V'$. We then have

$$W = \frac{1}{2}\sum\nolimits_{i=1}^{N} \left(DID_i - \overline{DID}\right)^2 V' = \frac{N}{2}\sigma^2 V', \tag{3}$$

where σ^2 is the variance in the defined daily doses across the areas.

Finally, using the coefficient of variation, $CV = \sigma / \overline{DID}$, and the elasticity of the demand, $\varepsilon = \overline{V} / \left(V' \overline{DID}\right)$, we can write the welfare loss from variations in the use of antibiotics as

$$W = \frac{1}{2\varepsilon} CV^2 \overline{V}(DDD), \tag{4}$$

where $\overline{V}$ is the marginal value of a daily dose and $DDD = N\ \overline{DID}$ is the total number of doses.

We estimate equation (4) by mean of residuals from the reduced form of the demand curve. Using this procedure we control for differences in the socioeconomic characteristics of the areas, the incidence of infections and access to physicians and

[6] The approach relies on the assumption that the average daily doses across all the areas are the appropriate levels of antibiotic consumption and both the marginal cost and the marginal benefit of a daily dose are the same across the areas.

pharmacies. Hence, the residuals of the econometric estimation provide a measure of the unexplained utilization of antibiotics in ambulatory care across the areas. The variance of the residuals is given by $\sigma^2(1-R^2)$, where R^2 is the adjusted coefficient of determination. This is also used to calculate the CV in equation (4).

The adjusted coefficient of determination derived in section 4 denotes that heterogeneity in physicians and patients attitudes towards antibiotic use and the implications of bacterial resistance account for 14% $(1-0.86)$ of total variations. Table 4 summarizes the results of the assessment of the welfare loss.

σ^2	$\overline{DID}$	$(1-R^2)CV^2$	$1/\varepsilon$	Total spending		Welfare Loss		%
				CHF	€	CHF	€	
170.60	11.71	0.17	1.37	88404476	56358839	10056251	6081429	11.38

Table 4: Assessment of the welfare loss from attitudes towards antibiotic use and bacterial resistance.

We calculated that the annual misuse of antibiotics amounts to € 6081429, representing 11% of the total spending in outpatient antibiotics in 2002. This in turn provides a measure of the expected gain from improving the information available on bacterial resistance at local level and reducing the heterogeneity in antibiotic prescriptions.

6 Conclusion

The purpose of this study was to investigate the sources of small area variations in the use of antibiotic in the community and to measure the impact of unexplained variations. We proposed a model in which antibiotic use varies according to the demographic and socioeconomic characteristics of the population, the incidence of infections, the local supply of health care and the price of antibiotics. Estimations were carried out on 2002 quaterly data of defined daily doses per 1000 inhabitants per day (DID) available for 240 small areas in Switzerland. Results suggest that demographic and socioeconomic aspects only partially account for variations in outpatient antibiotic use across small areas. Characteristics of the local supply, such as the density of pharmacies, are also relevant.

Since antibiotics are a peculiar type of medications in that they are associated with bacterial resistance, differences in practice styles among physicians and patients attitudes are also plausibly related to differences in rates of resistance at local level. A higher level of bacterial resistance in an area induces physicians to switch to newer and more expensive antibiotics in order to effectively fight the infection. The final effect may be either and increase or a decrease in the per capita defined daily doses.

Looking at unexplained variations across the small areas, we assessed the impact of heterogeneity in bacterial resistance at local level. Although the literature suggests that there is a positive correlation between antibiotic use and resistance (Nilsson and Laurell, 2005 and Garcia-Rey, 2004), the economic impact has not been yet assessed.

The availability of information on the rate of bacterial resistance at local level would improve our estimation of the welfare loss. The lack of this information prevents us from testing directly the effect of bacterial resistance on the use of antibiotics. Data on bacterial resistance may also allow to distinguish between physicians responsiveness to variations in bacterial resistance and other differences in practice style.

Despite these limitations the analysis provided a first assessment of the impact of determinants of small area variations in the use of antibiotics in the community. The literature on small area variations argues that differences in the utilization of health care resources are largely driven by physician practice style and supply variables rather than patient characteristics. Our findings add to the body of studies showing the significant impact of local supply variables although patients attributes are also shown to be an important factor of small area variations. We also provided a first estimate of the maximum welfare loss associated with heterogeneity in local levels of bacterial resistance.

7 References

Asche C and P Coyte, "Effect of Socio-Economic Status on Area Variation in Ventilation Tube Insertion Rates in Ontario", *Working Pape*r, University of Utah College of Pharmacy, 2006.

Carlsen F and Grytten J, "More physicians: improved availability or induced demand?", *Health Economics*, 7, 495–508, 1998.

Condgon P and Best N, "Small areas variation in hospital admissions rates: bayesian adjustement for primary care and hospital factors", *Applied Statistics*, 49, 2, 207-226, 2000.

Crosse EA, Alder RJ, Ostbye T and Campbell MK, "Small area variation in low birthweight:looking beyond socioeconomic predictors", *Canadian Journal of Public Health*, 88 (1), 57-61, 1997.

Davis P, Gribben B, Scott A and Lay-Yee R, "The supply hypothesis and medical practice variation in primary care:testing economic and clinical models of inter-practitioner variation", *Social Science and Medecine*, 50, 407-418, 2000.

Dubois R, Batchlor E and Wade S, "Geographic variation in the use of medications: Is uniformity godd news or bad?", *Health Affairs*, 21, 1, 2002.

Filippini M, Masiero G and Moschetti K, "Socioeconomic determinants of regional differences in outpatient antibiotic consumption: Evidence from Switzerland", *Health Policy*, 2006.

Folland S and Stano M, "Sources of small are variations in the use of medical care", *Journal of Health Economics*, 8, 85-107, 1989.

Folland S and Stano M, “Small area variations: a critical review of propositions, methods and evidence”, *Medical care review*, 47, 4, 419-465, 1990.

Garcia-Rey C, Fenoll A, Aguilar L and Casal J., "Effect of social and climatological factors on antimicrobial use and Streptococcus pneumoniae resistance in different provinces in Spain", *Journal of Antimicrobial Chemotherapy*, 54, 465-471, 2004.

Goossens H, Ferech M, Vander Stichele R, Elseviers M, for the ESAC Project Group, “Outpatient antibiotic use in Europe and association with resistance: a cross-national database study”, *Lancet*, 365, 579-587, 2005.

Greene WH,. *Econometric Analysis*, New York: Prentice Hall, 2003.

Grytten J and Sorensen R, “Practice variation and physician-specific effects”, *Journal of Health Economics*, 22, 403-418, 2003.

Henricson K, Melander E, Molstad S, Ranstam J, Hanson BS, Rametsteiner G, Stenber GP and Melander A, “Intra-urban variation of antibiotic utilization in children: influence of socioeconomic factors”, *The Journal of Clinical Pharmacology*, 54 (8), 653-657, 1998.

Joines JD, Hertz-Picciotto I, Carey TS, Gesler W, Suchindran C, “A spatial analysis of county-level variation in hospitalization rates for low back problems in North-Carolina” *Social Science & Medicine*, 56, 2541–2553, 2003.

Kmenta J, *Elements of Econometrics*, 2d edition. New York: Macmillan Publishing Company, 1986.

McGuire T, “Physician agency”, in the *Handbook of health economics*, Volume 1. Chapter 9, 461-536, Ed. Elsevier Science. 2000.

Martin S and Smith P, “Explaining variations in inpatient length of stay in the

National Health Service", *Journal of Health Economics*, 15, 279-304, 1996.

McPherson K, "Why do variations occur?" in: Andersen TF, Mooney G (Eds.), *The challenges of Medical Practice Variations*. MacMillan Press, London, pp. 19-35 (Chapter 2), 1990.

Mousquès J, Renaud T, and Scemama O, "Variabilité des pratiques médicales en médecine générale: la prescription d'antibiotiques dans la rhinopharyngite aigue", Centre de Recherche d'Etude et de Documentation en Economie de la Santé, CREDES, *Série analyse*, 2003.

Nilson P and Laurel MH, "Impact of socioeconomic factors and antibiotic prescribing on penicillin-non susceptible Streptococcus pneumoniae in the city of Malmo", *Scandinavian Journal of Infection Diseases*, 37 (6-7), 436-441, 2005.

Parchman ML, "Small area variation analysis: A tool for primary care research", Family Medicine, 27, 4, 272-276, 1995.

Parente S and Phelps CE, "Priority setting in medical technology and medical practice assessment", *Medical Care*, 28, 8, 703-723, 1990.

Stano M, "Evaluating the policy role of small area variations and physician practice style hypotheses", Health Policy, 24, 9-17, 1993.

Resi D, Milandri M , Moro ML and the Emilia Romagna Study Group on the Use of Antibiotics in Children, "Antibiotic prescriptions in children", *Journal of Antimicrobial Chemotherapy*, 52, 282–286, 2003.

Wennberg JE, "Dealing with medical practice variations: a proposal for action", Health Affairs, 3, 6-18, 1984.

Westert GP, Groenewegen PP, "Medical practice variations: changing the theoretical approach", *Scandinavian Journal of Public Health*, 27, 173-180, 1999.

Westert GP, Groenewegen PP, Boshuizen HC, Spreeuwenberg PMM and Steultjens MPM, "Medical practice variations in hospital care; time trends of a spatial phenomenon", *Health & Place*, 10, 215–220, 2004.