M. Filippini, G. Masiero, K. Moschetti

Regional differences in outpatient antibiotic consumption in Switzerland

Quaderno N. 04-09

Decanato della Facoltà di Scienze economiche
Via G. Buffi, 13 CH-6900 Lugano

Regional differences in outpatient antibiotic consumption in Switzerland

M. Filippini * G. Masiero † K. Moschetti ‡

December 1, 2004

Abstract

This paper investigates regional variations in outpatient antibiotic use and provides a first empirical analysis based on Swiss data. We compare Swiss antibiotic consumption with antibiotic use in other European countries and present descriptive statistics at cantonal level. Preliminary findings show that Switzerland exhibits relatively low levels of consumption. There are significant differences among cantons both in the per capita antibiotic sales and Defined Daily Doses per 1000 inhabitants per day (DID). Regression analysis suggests that demographic factors, density of pharmacies and medical practices, income and the incidence of infections are significantly related to antibiotic consumption.

Keywords: Antibiotic consumption. Regional differences.
JEL Nos.: D12, C13, C31, H73, I10.

---

*University of Lugano; Swiss Federal Institute of Technology, Zurich, CH. Support from the Swiss National Science Foundation is acknowledged. We are grateful to Cristina Masseria for collaboration on early stages of the related research project. The usual disclaimer applies.

†University of Lugano, CH; University of Bergamo, Italy; email: giuliano.masiero@lu.unisi.ch.

‡University of Lugano, CH.

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 physicians 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.

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 then 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 across countries

Large differences in outpatient antibiotic consumption can be observed across European countries. Table 1 is constructed by collecting data from previous studies (Cars et al., 2001; Cizman, 2003; Bergan, 2001; Elseviers et al., 2003) and reports antibiotic use in 24 European countries. Relatively high daily doses are registered for France, Spain, Portugal, Slovak Republic, and Belgium. On the contrary, the Netherlands, Russia, Denmark, Sweden and Germany exhibit significantly lower values.

Cars et al. (2001) analyse a range of five years, from 1992 to 1997, and notice that substantial differences are also confirmed by trends in antibiotic use. Italy and Luxemburg show increasing levels of antibiotic use, whereas other countries, such as Sweden, register a reduction.

Besides differences in total consumption, there is also a large variation

Countries	1998	2001	Countries	1998	2001
Austria	13.80	12.5	Italy	23.99	26.8
Belgium	26.72	24.5	Luxemburg	25.58	26.5
Croatia	NA	17.6	Norway	14.50*	15.7
Czech Republic	19.96*	17.9	Portugal	28.83	24.6
Denmark	11.35	13	Poland	NA	24.7
Finland	19.34	20	Russia	11.20*	NA
France	36.51	33	Slovak Republic	28.75*	24.45
Germany	13.58	13	Slovenia	17.57	17.5
Greece	22.69	29.6	Spain	32.44	18
Holland	8.96	9	Sweden	13.51	16
Hungary	21.10*	19	UK	18.04	14.4
Ireland	18.34	NA	Switzerland	NA	9.46

*: Total use including hospital use; NA: data not available.

Table 1: Outpatient antibiotic sales in DDD/1000 inhabitants (DID).

in the structure of consumption, i.e. the proportion of different classes of antibiotics. Broad spectrum penicillin is the most commonly used antibiotic in 11 countries but there are significant differences in the volume of Defined Daily Doses per 1000 inhabitants (DID) among these countries. The average daily dose is 18.97 in France compared to 2.90 in the Netherlands. In Denmark and Sweden the most common antibiotics are narrow spectrum penicillins. On the other side, Finland and Germany use tetracyclines more frequently. It is worth noticing that the larger amounts of antibiotics are associated to specific classes. Countries with higher antibiotic consumption such as France, Spain and Italy, prescribe large amounts of quinolones and macrolides. Focusing on Nordic countries, Bergan (2001) found that narrow spectrum penicillins represent 20% of DID in Iceland. Phenoxymethyl and benzylpenicillin represent 55% of the Swedish consumption and 40% of the Danish and the Nordish consumption. The use of cephalosporins ranges from 1% in Denmark to 15% in Finland. Finally, floroquinolones are largely used in Sweden only.

Unfortunately, no comparisons between North America and Europe are available in terms of DID or sales per capita. USA and Canadian institutions display data on antibiotic consumption in terms of number of prescriptions (per 1000 inhabitants) but this figure lacks a common denominator (the WHO standard DDD) for an international comparison. Therefore, antibiotic consumption can only be analysed within each country. The Canadian Department of Health (2003) displays the number of oral antibiotic prescriptions by retail pharmacies per 1000 inhabitants per year by the Anatomical

Classification (ATC). In 2001 (2000), total outpatient antibiotic prescriptions were around 619 (642) per 1,000 inhabitants. Broad spectrum penicillins accounted for 32.5% (33%) of the total. Cephalosporins followed with 15.5% (16%), quinolones with 13% (12%), macrolides with 24.5% (24%) and tetracyclines with 6.5% (7%). The remaining 8% (8%) included sulfonamides and other minor classes.

With respect to geographical differences, comparisons can be done across 9 Canadian regions: Alerta, British Columbia, New Brunswick, Manotoba, Nova Scotia, Ontario, PEI and Newfoundland and Labrador, Québec, and Saskatchwan. Wide variations are observed in terms of prescriptions for penicillins (135 to 392 in 2001, and 150 to 400 in 2000), cephalosporins (78 to 147 in 2001, and 80 to 150 in 2000) and quinolones (50 to 110 in 2001, and 40 to 100 in 2000). On the other side, no significant differences are observed in the proportion of macrolides.

2.2 Outpatient antibiotic consumption in Switzerland

In this section, we compare outpatient antibiotics consumption in Switzerland with consumption on other European countries calculated by the European Surveillance of Antimocrobial Consumption (ESAC) project. This is the first European comparison including Switzerland. We consider consumption both in terms of total daily doses and their structure according to classes of antibiotics. Swiss data were provided by IHA-IMS Health Market Research. Since the dataset did not include Defined Daily Doses per 1000 inhabitants per day nor sales per capita, we calculated these latter measures from provided counting units and total sales and using additional demographic information and WHO standard doses (we refer the reader to section 3.2 for further details on data).

Average consumption of antibiotics in ambulatory care is approximately 19 DID (figure 1). It is worth noticing that Swiss data refer to 2002 instead of 2001. This may slightly bias upward the Swiss consumption. As shown by Elseviers et al. (2003), there is a wide variation in consumption patterns between different European countries. The greatest consumption (32 DID) is attained by France (FR). Switzerland exhibits relatively low volumes of antibiotics use (8.97 DID). Only the Netherlands use lower volumes. This ranking, apparently surprising, is in accordance with the 2001 OECD statistics suggesting that Switzerland is among countries with low consumption rates of pharmaceuticals. One possible explanation may be found in the organisation of the health care system based upon private health insurances and physicians' attitude towards drugs prescription. The combination of deductibles and direct payments may contribute to the prevention of moral hazard be-

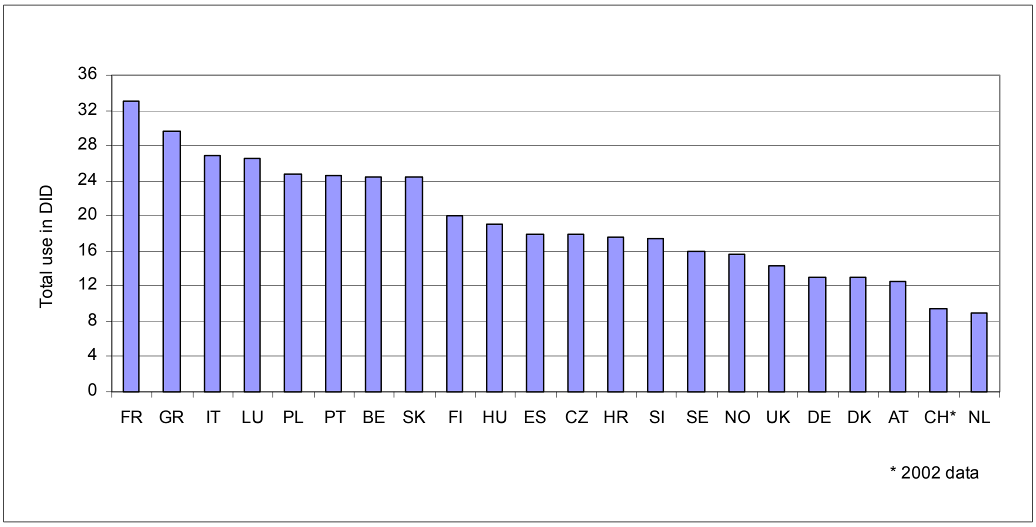

Figure 1: Total antibiotic use per country (2001)

haviour. Swiss physicians and patients may either be more informed about the implications of antibiotics or 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).

When looking at the consumption structure, we observe a wide variation in the proportion of different classes of antibiotics between countries (figure 2). Compared to others countries, the Swiss share of quinolones is twice as bigger as the European average. This also implies that Switzerland uses relatively lower proportions of others classes of antibiotics.

The ranking of Switzerland between European countries in terms of per capita consumption for different classes of antibiotics can vary. Switzerland is between the United Kingdom (UK) and the Slovenia (SI) for cephalosporins, and comparable to the Netherlands for macrolides. On the other side, the consumption of quinolones is relatively higher and Switzerland locates between Greece (GR) and Slovakia (SK).

Switzerland is similar to Austria in terms of consumption structure. Except for the macrolides and the quinolones, the proportion of penicillins, cephalosporins, tetracyclines and sulfonamides are the same. The proportion of macrolides is higher in Austria, whereas the opposite holds for the quinolones.

The comparison of Swiss consumption data with those from other Euro-

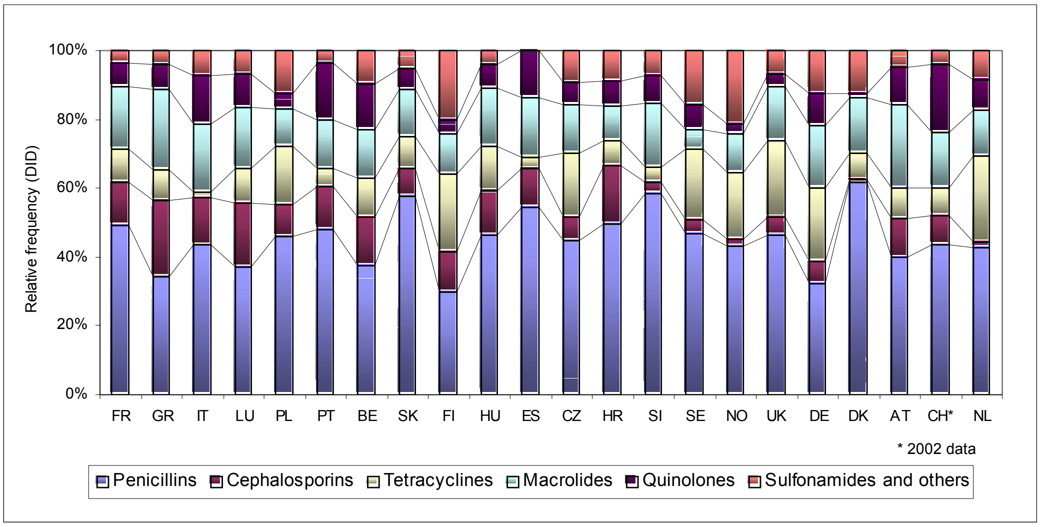

Figure 2: Structure of outpatient antibiotic consumption per country

pean countries derived from the ESAC project requires additional comments. There may be differences related to the collection of data. For instance, antibiotic consumption may be underestimated since nursing homes expenditure is excluded, whereas it is included in the total consumption of other countries (for instance France and Belgium). Another source of bias can be related to standard daily doses for children. Standard daily doses are calculated for adults and daily doses for children are approximately half of the adults' ones. Some countries, such as Germany, distinguish between doses for children and adults.

2.3 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 socio-economic aspects of the population and the organisation 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 per capita and DID using yearly data in 2002 and 2003.

The average cantonal expenditure in 2002 is 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. Differences between cantons appear to be significantly large. The figures show that the per capita expenditure

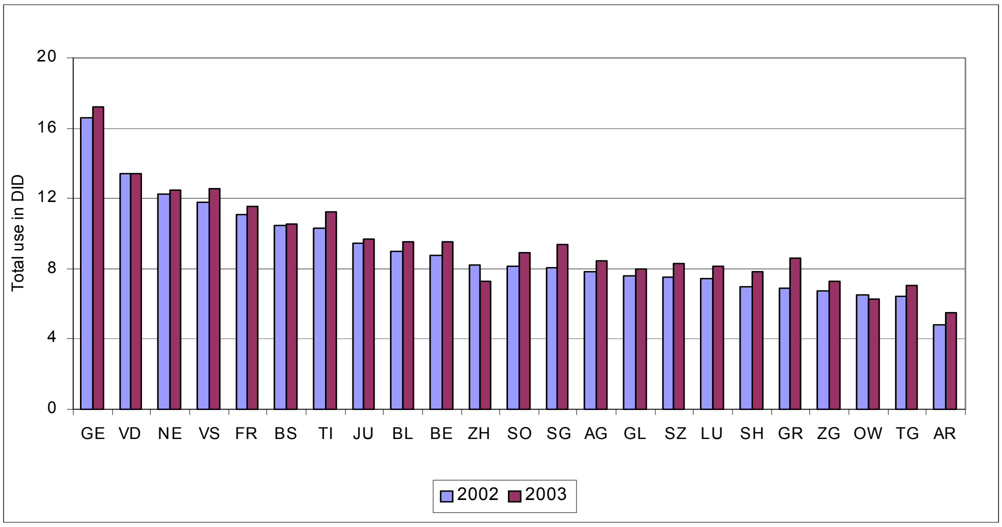

Figure 3: Total antibiotic use per canton

increases between 2002 and 2003 by 3.3% (figure 3).

In terms of Defined Daily Doses per 1000 inhabitants, the average cantonal consumption is 8.9 DID in 2002 (9.6 in 2003). The variation coefficient[1] is 30 in 2002 (27 in 2003). Note the wide variation between cantons. Given a minimum cantonal consumption of 4.8 DID in 2002 (5.5 in 2003), the highest consumption is more than 3 times greater. The median value is 8 DID in 2002 (8.9 in 2003).

Cantonal differences appear to be substantial both in 2002 and 2003. However, the variation coefficient indicates weaker cantonal variation in 2003 than in 2002. For most cantons (with the exception of Zurich and Obwalden) consumption per capita has increased. The average increase is 7% , although cantons such as St Gallen (SG) and Graubuden (GR) exhibit more substantial growth. The t-test on the mean equality between 2002 and 2003 confirms that consumption has significantly increased.

Looking more carefully at figure 3, we note that cantons with the highest consumption (such as Geneva, Vaud and Valais) are generally located in the South-West part of Switzerland. Conversely, cantons with the lowest consumption are located North-East in the country.

Total antibiotic consumption can be disaggregated by the ATC classes (figure 4). We summarize the following 6 main categories: penicillins, cepha-

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

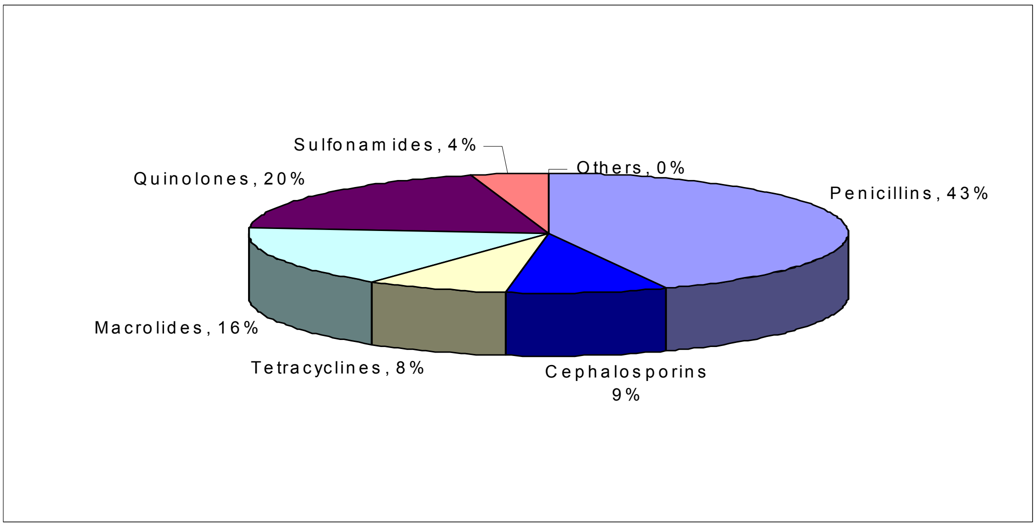

Figure 4: Structure of outpatient antibiotic use in Switzerland

losporins, tetracyclines, macrolides, quinolones, and sulfonamides. Penicillins account for 43% of total use. Quinolones follow with one fifth of the total. Sightly below are the macrolides (16%). Cephalosporins, tetracyclines and sulfonamides account for the remaining 21%.

Substantial local differences in terms of the proportion of each antibiotic class on total consumption may be related to the prevalence of infections, patients‘ and doctors‘ preferences, pharmaceutical marketing strategies, health care regulation, and the incidence of bacterial resistance. At the cantonal level, we observe some variations in the structure of total consumption (figure 5). The proportion of penicillins is between a minimum of 36% in Obwald (OW) and a maximum of 48% in Soleure (SO). Macrolides range from 12.3% to 21.6% whereas quinolones vary from 17% to 23%. At first sight these figures do not suggest any significant variation in the cantonal consumption structure.

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 by differences in bacterial infections across regions. Difference in bacterial infection can hardly explain variation in morbidity as large as four

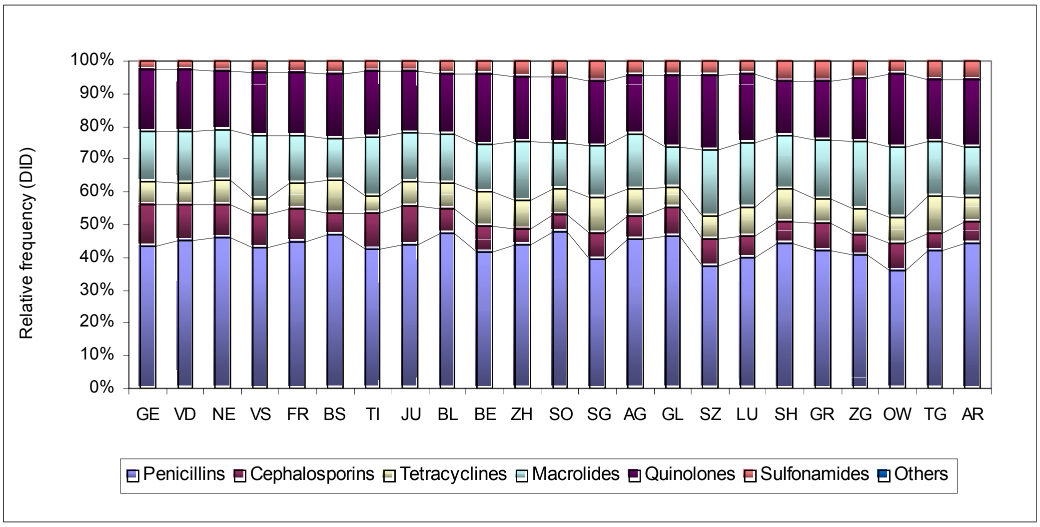

Figure 5: Antibiotics share per canton

fold among industrialized countries. The literature has suggested the lack of education, physicians and patients' expectations, uncertainty, cultural and social behaviour, and differences in regulatory practice, among other factors (Belongia and Schwatz, 1998; Finch et al. 2004).

Previous studies focusing on the determinats 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 explained by 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[2]. 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, 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.[3] 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 to induce the demand for physicians' services[4]. Thus, the demand for antibiotics could also depend on some characteristics of the supply of health care services as physicians' density. Unfortunately, disaggregate data are not available.

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

[2] 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.

[3] 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.

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

capita demand of outpatient antibiotics:

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

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. 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[5]. 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

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

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 for pooled time-series and cross-sectional data suggested by Kmenta (1986)[6]. 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 two years (2002 and 2003) 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.

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 slighly underestimate final consumption for three main reasons. First, data collected correspond to ambulatory care and exclude all drugs delivered in nursing home facilities[7]. 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 dataset.

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

[7] In Switzerland around 50% of nursing homes have an internal pharmacy unit.

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 dataset 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 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[8]. 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 groupped 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 dataset 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 $DOT = (\text{Number of packages})(\text{mmg per package})/DDD$. The latter measure, according to the WHO[9], is the assumed average maintenance 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

[8]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.

[9]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.

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 2 gives summary statistics of variables included in the model.

Variables	Unit of measurement	Min.	Med.	Max.
Per capita outpatient antibiotic consumption (DID)	Defined Daily Doses	4.4	8.2	19.3
Income per capita (Y)	CHF/inhabitant	35952	45746	77583
Physicians' density (Dph)	Physicians/100'000	118	160	353
Pharmacies' density (Dpha)	Pharmacies/100'000	5	18	55
Population age over 65 (over65)	Over 65/pop.	0.12	0.15	0.21
Population age 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
Percentage of people without post-mandatory education	Basic education/pop.	0.19	0.24	0.32

Table 2: 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 3, 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 87% 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.

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,[10] akin to the Swiss one overconsumption of drugs is more likely. On the other side, 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 0.17% increase in the per capita outpatient antibiotic consumption. Cultural differences or differences in the incidence of infectious diseases may account for this result.

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 significatly 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.

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

	OLS		GLS	
	Coefficients	Standard Errors	Coefficients	Standard Errors
Constant	0.498	1.973	−0.807	1.692
ln Y	−0.527**	0.190	−0.527***	0.078
ln P	−0.253	0.160	−0.341	0.252
ln Dph	0.026***	0.078	0.918***	0.094
ln $Dpha$	0.026	0.032	0.024***	0.003
ln $under20$	0.302	0.370	0.089	0.222
ln $over65$	−0.796**	0.286	−0.984***	0.241
ln FO	0.193**	0.066	0.173***	0.049
ln EDU	0.692***	0.174	0.831***	0.211
ln INF_1	0.062**	0.022	0.078***	0.008
ln INF_2	−0.037	0.028	−0.039***	0.006
DT_1	0.077***	0.008	0.073***	0.004
DT_2	−0.197***	0.008	−0.202***	0.004
DT_3	−0.178***	0.006	−0.173***	0.005

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

Table 3: 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 higher 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. This is in accordance with time trends in other European countries.

The investigation of cantonal differences led to wide variations between cantons. Variations are less remarkable in terms of consumption structure.

Regional variations in antibiotic use within the country can hardly be explained by epidemiological reasons. Multiple regressions on quarterly data for 2002 using OLS and GLS estimators suggested that demographic factors, density of pharmacies and doctors, income and price may contribute to explain cantonal differences in antibiotic use.

Our findings may suggest the direction of more effective policies to improve the efficient use of antibiotics in the community. Incentives affecting the impact of crucial determinants of antibiotic consumption should be designed to obtain more appropriate consumption and resistance levels.

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 and additional determinats of local differences, including endogenous bacterial resistance.

References

Becker GS. "A Theory of the Allocation of Time", *Economic Journal*, 75, S, 493-517, 1965.

Belongia EA, and Schwartz B. "Strategies for promoting judicious use of antibiotics by doctors and patients", *BMJ*, 317, 668-671, 1998.

Bergan T. "Antibiotic usage in Nordic countries", *International Journal of Antimicrobial Agents*, 2001.

Bremon AR, et al. "Non-hospital consumption of antibiotics in Spain: 1987-1997", *Journal Antimicrobial Chemotherapy*, 2000.

Butler CC, et al. "Understanding the culture of prescribing: qualitative study of general practitioners' and patients' perceptions of antibiotics for sore throats", *BMJ*, 317, 637-642, 1998.

Cantrell R, Young AF, and Martin BC. "Antibiotic prescribing in ambulatory care settings for adults with colds, upper respiratory tract infections, and bronchitis", *Clinical Therapeutics*, 24, 170-182, 2002.

Canadian Compuscript Audit and Statistics Canada, *www.ccar-ccra.com/english/-dateline-e.shtml*, October 2003.

Cars O, Molstad S, and Melander A. "Variation in antibiotic use in the European Union", *Lancet*, 357, 1851-1853, 2001.

Cizman M. "The use and resistance to antibiotics in the community", *International Journal of Antimicrobial Agents*, 21, 297-307, 2003.

Cockburn J, and Pit S. "Prescribing behaviour in clinical practice: patients' expectations and doctors' perceptions of patients' expectations - a questionnaire study", *BMJ*, 315, 520-5231997.

Coast J, Smith RD, and Millar MR. “An economic perspective on policy to reduce antimicrobial resistance”, *Social Science and Medicine*, Vol 46, No1, 29-38, 1998.

Elbasha EH. “Deadweight loss of bacterial resistance due to overtreatment”, *Health Economics*, 12, 125-138, 2003.

Elseviers M, Ferech M, Van der Stichele R, and Goossens H. Consumption of antibiotics in ambulatory care in Europe", *www.ua.ac.be/main.asp?c=*ESAC.*, 2003.

Finch RG, Metlay JP, Davey PG, Baker LL. “Educational interventions to improve antibiotic use in the community: report from the International Forum on antibiotic resistance (IFAR) colloquium”, *Lancet*, 4, 44-53, 2004.

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

Grossman M, "On the Concept of Health Capital and the Demand for Health," *JPE*, 80, 223-255, 1972.

Harbarth S, Albrich W, and Brun-Buisson C. “Outpatient antibiotic use and prevalence of antibiotic-resistance pneumococci in France and Germany: a sociocultural perspective”, *Emerging Infectious Diseases*, Vol 8, No 12, 2002.

Homer J, et al. “Toward a dynamic theory of antibiotic resistance”, *System Dynamics Review*, Vol. 16, 4, 287-319, 2000.

Scott T. “The economics of general practice”, in: AJ Culyer and JP Newhouse, eds., *Handbook of Health Economics*, Vol. 1, Ch. 22, 2000.

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

Laxminarayan R, and Weitzman ML. “On the implications of endogenous resistance to medications”, *Journal of Health Economics*, 21, 709-718, 2002.

Levy SB. "The challenge of antibiotic resitance", *Scientific American*, 46-53, 1998.

McCaig LF, Besser RE, and Hughes JM. “Antimicrobial drug prescriptions in ambulatory care settings, Unites States, 1992-2000”, *Emerging Infectious Diseases*, Vol 9, No 4, 432-437, 2003.

Mecfarlane J, et al. “Reducing antibiotic use for acute bronchitis in primary care: blinded, randomised controlled trial of patient information leaflet”, *BMJ*, 315, 1211-1214, 2002.

McGowan JE. “Economic impact of antimicrobial resistance”, *Emerging Infectious Diseases*, Vol 7, No 2, 286-292, 2001.

McGuire T. "Physician agency", in the *Handbook of health economics*, Volume1. Chapter 9, 461-536, Ed. Elsevier Science. 2000.

Newhouse JP. *Free for all? Lessons from the Rand Health Insurance Experiment Group.* Harward University press, Cambridge, 1993.

OCECD. *OECD Health Data*, 2003.

Roger WH. "Regression standard errors in clustered samples" " , *Stata Technical Bulletin*, 13: 19-23 (reprinted in emphStata Technical Bulletin Reprints, Vol.3, 88-94), 1993.

Rowthorn R, and Brown GM. "Using antibiotics when resistance is renewable" in Laxminarayan R, *Battling resistance to antibiotics and pesticides*, 1994.

Rudholm N. "Economic implications of antibiotic resistance in global economy", *Journal of Health Economics*, 21, 1071-1083, 2002.

Steinman MA, Gonzales R, Linder JA, Landefeld CS. "Changing use of antibiotics in community-based outpatient practice 1991-1999", *Annals of Internal Medicine*, Vol 138, N0 7, 525-534, 2003.

Unsworth L, and Walley T. "Trends in primary care antibiotics prescribing in England 1994-1998", *Pharmacoepidemiology and Drug Safety*, 10, 309-314, 2001.

Weeb S, Lloyd M. "Prescribing and referral in general practice: a study of patients' expectation and doctors' actions", *Br J Gen Pract*, 44, 165-169, 1992.

WHO, "Overcoming antimicrobial resistance ", *World Health Report on infectious diseases*, 2000.

WHO, *The WHO Global Strategy for Containment of Antimicrobial Resistance*, 2001.

Wise R, et al. "Antimicrobial resitance. Is a major threat to public health", *BMJ*, 317, 609-610, 1998.

QUADERNI DELLA FACOLTÀ

I quaderni sono richiedibili (nell'edizione a stampa) alla Biblioteca universitaria di Lugano
via G. Buffi 13 CH 6900 Lugano
e-mail: biblioteca@lu.unisi.ch

The working papers (printed version) may be obtained by contacting the Biblioteca universitaria di Lugano
via G. Buffi 13 CH 6900 Lugano
e-mail: biblioteca@lu.unisi.ch

Quaderno n. 98-01
P. Balestra, *Efficient (and parsimonious) estimation of structural dynamic error component models*

Quaderno n. 99-01
M. Filippini, *Cost and scale efficiency in the nursing home sector : evidence from Switzerland*

Quaderno n. 99-02
L. Bernardi, *I sistemi tributari di oggi : da dove vengono e dove vanno*

Quaderno n. 99-03
L.L. Pasinetti, *Economic theory and technical progress*

Quaderno n. 99-04
G. Barone-Adesi, K. Giannopoulos, L. Vosper, *VaR without correlations for portfolios of derivative securities*

Quaderno n. 99-05
G. Barone-Adesi, Y. Kim, *Incomplete information and the closed-end fund discount*

Quaderno n. 99-06
G. Barone-Adesi, W. Allegretto, E. Dinenis, G. Sorwar, *Valuation of derivatives based on CKLS interest rate models*

Quaderno n. 99-07
M. Filippini, R. Maggi, J. Mägerle, *Skalenerträge und optimale Betriebsgrösse bei den schweizerische Privatbahnen*

Quaderno n. 99-08
E. Ronchetti, F. Trojani, *Robust inference with GMM estimators*

Quaderno n. 99-09
G.P. Torricelli, *I cambiamenti strutturali dello sviluppo urbano e regionale in Svizzera e nel Ticino sulla base dei dati dei censimenti federali delle aziende 1985, 1991 e 1995*

Quaderno n. 00-01

E. Barone, G. Barone-Adesi, R. Masera, *Requisiti patrimoniali, adeguatezza del capitale e gestione del rischio*

Quaderno n. 00-02

G. Barone-Adesi, *Does volatility pay?*

Quaderno n. 00-03

G. Barone-Adesi, Y. Kim, *Incomplete information and the closed-end fund discount*

Quaderno n. 00-04

R. Ineichen, *Dadi, astragali e gli inizi del calcolo delle probabilità*

Quaderno n. 00-05

W. Allegretto, G. Barone-Adesi, E. Dinenis, Y. Lin, G. Sorwar, *A new approach to check the free boundary of single factor interest rate put option*

Quaderno n. 00-06

G.D.Marangoni, *The Leontief Model and Economic Theory*

Quaderno n. 00-07

B. Antonioli, R, Fazioli, M. Filippini, *Il servizio di igiene urbana italiano tra concorrenza e monopolio*

Quaderno n. 00-08

L. Crivelli, M. Filippini, D. Lunati. *Dimensione ottima degli ospedali in uno Stato federale*

Quaderno n. 00-09

L. Buchli, M. Filippini, *Estimating the benefits of low flow alleviation in rivers: the case of the Ticino River*

Quaderno n. 00-10

L. Bernardi, *Fiscalità pubblica centralizzata e federale: aspetti generali e il caso italiano attuale*

Quaderno n. 00-11

M. Alderighi, R. Maggi, *Adoption and use of new information technology*

Quaderno n. 00-12

F. Rossera, *The use of log-linear models in transport economics: the problem of commuters' choice of mode*

Quaderno n. 01-01

M. Filippini, P. Prioni, *The influence of ownership on the cost of bus service provision in Switzerland. An empirical illustration*

Quaderno n. 01-02

B. Antonioli, M. Filippini, *Optimal size in the waste collection sector*

Quaderno n. 01-03

B. Schmitt, *La double charge du service de la dette extérieure*

Quaderno n. 01-04
L. Crivelli, M. Filippini, D. Lunati, *Regulation, ownership and efficiency in the Swiss nursing home industry*

Quaderno n. 01-05
S. Banfi, L. Buchli, M. Filippini, *Il valore ricreativo del fiume Ticino per i pescatori*

Quaderno n. 01-06
L. Crivelli, M. Filippini, D. Lunati, *Effizienz der Pflegeheime in der Schweiz*

Quaderno n. 02-01
B. Antonioli, M. Filippini, *The use of a variable cost function in the regulation of the Italian water industry*

Quaderno n. 02-02
B. Antonioli, S. Banfi, M. Filippini, *La deregolamentazione del mercato elettrico svizzero e implicazioni a breve termine per l'industria idroelettrica*

Quaderno n. 02-03
M. Filippini, J. Wild, M. Kuenzle, *Using stochastic frontier analysis for the access price regulation of electricity networks*

Quaderno n. 02-04
G. Cassese, *On the structure of finitely additive martingales*

Quaderno n. 03-01
M. Filippini, M. Kuenzle, *Analisi dell'efficienza di costo delle compagnie di bus italiane e svizzere*

Quaderno n. 03-02
C. Cambini, M. Filippini, *Competitive tendering and optimal size in the regional bus transportation industry*

Quaderno n. 03-03
L. Crivelli, M. Filippini, *Federalismo e sistema sanitario svizzero*

Quaderno n. 03-04
L. Crivelli, M. Filippini, I. Mosca, *Federalismo e spesa sanitaria regionale : analisi empirica per i Cantoni svizzeri*

Quaderno n. 03-05
M. Farsi, M. Filippini, *Regulation and measuring cost efficiency with panel data models : application to electricity distribution utilities*

Quaderno n. 03-06
M. Farsi, M. Filippini, *An empirical analysis of cost efficiency in non-profit and public nursing homes*

Quaderno n. 03-07
F. Rossera, *La distribuzione dei redditi e la loro imposizione fiscale : analisi dei dati fiscali svizzeri*

Quaderno n. 03-08
L. Crivelli, G. Domenighetti, M. Filippini, *Federalism versus social citizenship : investigating the preference for equity in health care*

Quaderno n. 03-09
M. Farsi, *Changes in hospital quality after conversion in ownership status*

Quaderno n. 03-10
G. Cozzi, O. Tarola, *Mergers, innovations, and inequality*

Quaderno n. 03-11
M. Farsi, M. Filippini, M. Kuenzle , *Unobserved heterogeneity in stochastic cost frontier models : a comparative analysis*

Quaderno n. 04-01
G. Cassese, *An extension of conditional expectation to finitely additive measures*

Quaderno n. 04-02
S. Demichelis, O. Tarola, *The plant size problem and monopoly pricing*

Quaderno n. 04-03
F. Rossera, *Struttura dei salari 2000 : valutazioni in base all'inchiesta dell'Ufficio federale di statistica in Ticino*

Quaderno n. 04-04
M. Filippini, M. Zola, *Economies of scale and cost efficiency in the postal services : empirical evidence from Switzerland*

Quaderno n. 04-05
F. Degeorge, F. Derrien, K.L. Womack, *Quid pro quo in IPOs : why book-building is dominating auctions*

Quaderno n. 04-06
M. Farsi, M. Filippini, W. Greene , *Efficiency measurement in network industries : application to the Swiss railway companies*

Quaderno n. 04-07
L. Crivelli, M. Filippini, I. Mosca, *Federalism and regional health care expenditures : an empirical analysis for the Swiss cantons*

Quaderno n. 04-08
S. Alberton, O. Gonzalez, *Monitoring a trans-border labour market in view of liberalization : the case of Ticino*

Quaderno n. 04-09
M. Filippini, G. Masiero, K. Moschetti, *Regional differences in outpatient antibiotic consumption in Switzerland*