Credibility Models with Cross-Section Effect and with both Cross-Section and Time Effects

Georgios Pitselis (Piraeus)*

1 Introduction

Credibility is a ratemaking technique predicting future premiums for a group of insurance contracts for which we have some claim experience for that group and a lot more experience for a larger group of contracts that are similar but not exactly the same.

Bühlmann (1967) and in the sequel Bühlmann & Straub (1970) established the theoretical foundation of modern credibility theory presented as a distribution free credibility estimation. The method extended in Hachemeister (1975) regression model, where the credibility premium depends linearly on a number of risk characteristics. Jewell (1975), Taylor (1979), Sundt (1979, 1980) and Norberg (1986) presented hierarchical models assuming that the existing portfolio can be split into sub-portfolios (sectors) and each of these sectors contains individual contracts. Jewell (1974) has shown that credibility is exact Bayesian for a certain exponential family of distributions with natural conjugate priors. Klugman (1992) gives an introduction to the use of Bayesian methods covering particular aspects of credibility theory. Makov et al. (1996) provided a review of Bayesian models in actuarial science.

Empirical credibility estimation, which is the credibility counterpart of empirical Bayes estimation, in a multidimensional setting was presented by Norberg (1980) for the classical as well as for the regression credibility case. In this paper for the development of our credibility model we also adopt the empirical Bayes estimation approach.

Dannenburg (1996) introduced the cross classification credibility models, where the contracts are divided into cells that are determined by qualitative risk factors and Frees et al. (1999, 2001) incorporated credibility techniques in the investigation of longitudinal data.

The purpose of this work is to show how to incorporate cross section regression models into a credibility framework and to allow for differences in behavior over cross section units and/or variation in time (or other characteristic). The basic assumption, that can be considered [see Hsiao (1986)], of such cross section models is that, conditional on observed explanatory variables, the effects of observed variables are driven by three types of variables. First, the individual time invariant variables that are the same for a given cross-sectional unit through time but that vary across cross-sectional units (e.g., attributes of individual-firm management, ability, sex, and socioeconomic-background). Second, the period individual invariant variables that are the same for all cross-sectional units at a given point in time but they vary through time (e.g., prices, interest rates, and widespread optimism.

*Email: pitselis@unipi.gr
or pessimism). Third, the individual time varying variables that vary across cross-sectional units at a given point in time and also exhibit variations through time (firm profits, sales and capital stock). All other kinds of effects of omitted variables, either remain constant through time for a given cross-sectional unit or they can be observed into intercept term of the regression model.

Here we consider a general regression credibility model, assuming that each contract is subdivided to a (predefined or not) number of units (geographical regions, industrial zones, type of activities, different groups of people), with every unit having a certain behavior and attributes. Within each unit the data are varying over time or over some other characteristic. The dependent variable is the claim experience for certain unit and time period and the explanatory variables are quantitative or qualitative variables that can effect the appearance of claims for corresponding unit and time.

There are several advantages for applying our cross-section model. First, constitutional laws forcing the insurance companies to apply the same tariffs to cars that have been classified in the same group (contract) even though they drive in different regions (units) of the country. Second, for competition or management reasons. Third, one could apply a multi-level hierarchical model, but it is very difficult for an insurance company to build into a credibility model many of the characteristics and experiences of the individuals drivers, because this can imply a very complicated and inconvenient premium estimation model. It is also much easier to treat outliers in our cross-section-model than in a hierarchical model.

Here are some examples that illustrate how such a modelling might be useful in actuarial practice. We apply a common tariff for those individuals that have been classified into the same group (contract) regardless of whether they come from the same or different regions (units).

**Example A.** We consider an automobile insurance portfolio. The behavior of individuals across geographical areas (units) is different for a variety of reasons. For example the structural of transportation network is different from one region to another (better arterial roads) resulting in different portfolio behavioral responses (claim reporting). Explanatory variables are the age, gender, driving experience, year of the car etc.

**Example B.** We consider a portfolio of mortgage insurance claim experience. Mortgage insurance compensates a mortgage lender against loss of default by the borrower. In this example as units we consider different regions of a country (industrial, agricultural or touristic regions) each one having a different risk behavior of claim reporting, with real estate prices varying from one year to another due to the market demand or due to increase of interest or inflation rates.

**Example C.** Workers' Compensation provides benefits for occupational injuries or disease suffered by an employee, regardless of fault. The benefits include payment of medical services and lost wages, subject to a limit set by law. Workers' compensation premium is calculated based on the wages actually paid in each job classification. The portfolio can be divided into different industrial zones (contract)