Journal of Economic Dynamics & Control 41 (2014) 69–92

Contents lists available at ScienceDirect

Journal of Economic Dynamics & Control

journal homepage: www.elsevier.com/locate/jedc

Forecasting and decomposition of portfolio credit risk using macroeconomic and frailty factors

Yongwoong Lee [a,*], Ser-Huang Poon [b]

[a] Finance Discipline Group, UTS Business School, University of Technology, Sydney, PO Box 123, Broadway, NSW 2007, Australia
[b] Manchester Business School, Crawford House, University of Manchester, Oxford Road, Manchester, M13 9PL, United Kingdom

ARTICLE INFO

Article history:
Received 27 November 2012
Received in revised form
18 February 2014
Accepted 20 February 2014
Available online 1 March 2014

JEL classification:
C15
C32
C53
E32
G17

Keywords:
Risk contribution
Conditional value-at-risk
Euler capital allocation
Hoeffding decomposition
Default probability

ABSTRACT

This paper presents a dynamic portfolio credit model following the regulatory framework, using macroeconomic and latent risk factors to predict the aggregate loan portfolio loss in a banking system. The latent risk factors have three levels: global across the entire banking system, parent-sectoral for the intermediate loan sectors and sector-specific for the individual loan sectors. The aggregate credit loss distribution of the banking system over a risk horizon is generated by Monte Carlo simulation, and a quantile estimator is used to produce the aggregate risk measure and economic capital. The risk contributions of the individual sectors and risk factors are measured by combining the Hoeffding decomposition with the Euler capital allocation rule. For the U.S. banking system, we find that the real GDP growth rate, the global and sector-wide frailty risk factors and their spillovers significantly affect loan defaults, and the impacts of the frailty factors are not only economy-wide but also sector-specific. We also find that the frailty risk factors make more significant risk contributions to the aggregate portfolio risk than the macroeconomic factors, while the macroeconomic factors help to improve the accuracy and efficiency of the credit risk forecasts.

1. Introduction

In the last two decades, the stability of the U.S. banking system has been severely jeopardized several times, e.g. the recent sub-prime crisis, the IT-bubble crisis around 2002 and the commercial real estate debacle around the early 1990s, due to its sub-sectoral or other related industries' failures and their spillover effects throughout the economy. This has become one of the main concerns of regulators and commercial lenders. Thus, it is important to evaluate and forecast the aggregated risk of the entire banking system by taking its sub-sectors' dependencies on the overall economic condition and their risk spillovers into account, as these dependencies and spillovers can lead to default clustering or contagion within sub-sectors, and ultimately the collapse of the entire banking system. Furthermore, it is an important task to determine the sources of the aggregated risk according to the sub-sectors and their associated risk factors as a priori capital allocation and hedging and a posteriori performance measurement and portfolio optimization. However, none of the existing portfolio credit risk models have dealt with any cross-sector dependencies or risk spillovers, or the risk contributions reflecting such effects.

* Corresponding author. Tel.: +61 2 9514 7770; fax: +61 2 9514 7722.
E-mail address: yongwoong.lee@uts.edu.au (Y. Lee).

http://dx.doi.org/10.1016/j.jedc.2014.02.008
0165-1889

This paper aims to ascertain the effects of macroeconomic environments, frailty risk factors and their cross-sector spillovers on the aggregate loss and risk of an entire banking system, and to attribute the system-wide riskiness to the sub-sectors and risk factors. For these purposes, we analyse the aggregate charge-off rates of eight loan sectors for the U.S. commercial banks. Each loan sector is regarded as a pool of borrowers who are subject to the same sensitivities to risk drivers and the same probability of default. We consider a portfolio credit model that relates a loan sector's charge-off rate to both observable macroeconomic variables and unobservable latent factors in order to predict the loan sector's expected loss and risk in accordance with the current regulatory framework. In particular, the unobservable latent factors may impact on several loan sectors. We also propose a risk decomposition method adapted to our portfolio credit model to separate the effects of the macroeconomic variables, the latent factors and their spillovers on the estimates of the expected losses and value-at-risk of the individual loan sectors and the U.S. banking system as a whole.

To model account-level default, data are generally collected as a panel structure and analysed using survival or binary response models to predict the risks of individual accounts. Survival models are popular in general for modelling continuous-time corporate defaults, e.g. Das et al. (2007) without an unobserved covariate and Duffie et al. (2009) with an unobserved covariate. Binary response models are more common for discrete-time retail consumer defaults, e.g. Crook et al. (2007). However, these account-level models are computationally complicated and intractable, from a pragmatic perspective, for analysing multiple random (latent and frailty) effects and their cross-sector spillovers on top of the fixed effects, with a panel data of infinitely many accounts in a country-level retail loan portfolio, which is our main concern here. This rules these models out for our purposes. As such, we proceed with portfolio credit models, such as Vasicek (1991, 2002) that underlies Basel II, and econometric models such as Jimenez and Mencia (2009). Crook and Bellotti (2010) provide a comprehensive survey on the theoretical and empirical aspects of various credit models for modelling account- and portfolio-level defaults.

For modelling portfolio-level default, most portfolio credit risk models to date focus on the evaluation of a static or unconditional loss for measuring and managing risk and economic capital, as well as for pricing credit portfolio instruments (see Vasicek, 1991, 2002 for a Gaussian risk factor model; Schönbucher, 2001; Hull and White, 2004; Schloegl and O'Kane, 2005; Kalemanova et al., 2007 for non-Gaussian risk factor models; Pykhtin, 2004; Cespedes et al., 2006 for the approximation of multi-factor risk models, and Glasserman, 2008 for a comprehensive survey on measuring portfolio credit risk and related technical issues).

Dynamic or conditional portfolio credit risk models, however, have become important for day-to-day risk measurement and management, since default risks are shown to respond to the macroeconomic environment (see Bangia et al., 2002; Correa et al., 2011; Duffie et al., 2009; Jimenez and Mencia, 2009; Koopman and Lucas, 2005; Koopman et al., 2005, 2011; Kramer and Löffler, 2010; Kwark, 2002; Lando and Nielsen, 2010; McNeil and Wendin, 2007; Meeks, 2012; Nickell et al., 2000; Trück and Rachev, 2005). Also, practitioners who adopt the advanced Internal-Rating-Based approach of Basel II are interested in predicting EAD (Exposure-at-Default), LGD (Loss-given-Default) and default probability to obtain a more accurate prediction of their portfolio credit loss over a given risk horizon.

Specifically, for the prediction of portfolio credit risk, Rösch and Scheule (2004) and Hamerle and Rösch (2006) include the lagged macroeconomic risk factors but numerically integrate out the unobservable systematic risk factor. Jimenez and Mencia (2009) develop a state space model, where both observable macroeconomic risk factors and unobservable systematic risk factors are modelled by a vector autoregressive model, to forecast the aggregate loan loss distribution of the Spanish banking system. References to other empirical studies on loan loss distribution for different countries are available in their paper.

Once economic capital has been calculated using either the static or dynamic approach, it is useful to attribute the risk capital to its sources according to the sub-portfolios or risk factors. This is important for capital allocation, performance measurement, hedging and portfolio optimization (see Tasche, 2007; Mausser and Rosen, 2008 and their huge bibliographies on the calculation of the risk contributions of individual positions based on *marginal contributions* (or *Euler allocation*); Rosen and Saunders, 2009 for portfolio optimization using *least-squares hedging*, and Rosen and Saunders, 2010 for risk attribution to risk factors using and *Hoeffding decomposition*).

In this paper, a dynamic multi-factor state space model is used to model the aggregate loan portfolio loss distribution. Our model is similar to that of Jimenez and Mencia (2009) in providing a dynamic approach to measuring and forecasting the loan portfolio credit risk based on a state space model with multiple risk factors and a time-dependence structure. However, our model differs from that of Jimenez and Mencia (2009) in the following aspects. Firstly, multiple latent risk factors are used to capture three levels of default clustering: global, multi-sectoral aggregate and individual sector. The global latent risk factor captures the economy-wide default clustering as in Jimenez and Mencia (2009), whereas the multi-sectoral and sector-specific latent factors are new, and capture sector-wide default clustering and the cross-sector spillover effects. The latent multi-factors are assumed to be orthogonal to each other and their time dependencies are introduced through autoregressive terms. Secondly, our model is built on the Vasicek model underlying the regulatory framework. Thus, the outcomes of our model are consistent with the regulatory assumptions. Thirdly, in addition to the forecasting of the loan portfolio loss, we apply the marginal contribution rule and the Hoeffding decomposition, but adapted to our dynamic multi-factor setting, for calculating the risk contributions of each loan sector and each risk factor. The orthogonality of the risk factors allows us to easily allocate the risk capital to the relevant risk sources.

As an empirical study, we estimate the aggregate loss distribution for the U.S. commercial banking system using the quarterly charge-off rates archived by the Federal Reserve. We find that the real GDP growth rate, the global and sector-wide