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AN INVESTIGATION OF THE KOREAN GENERAL INSURANCE INDUSTRY: EVIDENCE OF STRUCTURAL CHANGES AND IMPACT OF MACRO-ECONOMIC FACTORS ON LOSS RATIOS

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Abstract. In this study, we first present a brief overview of the Korean general insurance market. We then explore the characteristics of the loss ratios of the Korean general insurance industry and apply Markov regime-switching methodology to model the loss ratios of these insurance companies by line of business based on changes in economic regimes. This study applies a number of confirmatory tests such as Zivot-Andrews test (2002), the Chow (1960) test and the Bai and Perron (1998) to confirm the presence of structural breaks in the time series of the loss ratios by line of business. Then, we employ Markov regime-switching methodology to model these loss ratios. We find empirical evidence that the loss ratios reported by insurance companies in Korea is characterized by two distinct regimes; a regime with high volatility and a regime with low volatility, except for vehicle insurance. Our analyses suggest that macro-economic conditions have significant explanatory effect on loss ratios but the direction of effect differs based on the line of business and the regime. Unlike previous studies that have applied linear regressions or divided the samples into different periods and then apply linear regressions to model loss ratios, we argue for the application of Markov regime-switching methodology, which are able to automatically distinguish the different regimes that may be associated with the movements of loss ratios based on differing economic conditions and regulatory upheavals. This study provides a more in depth understanding of loss ratios in the general insurance industry and will be of value to insurance practitioners in modelling the loss ratios associated with their businesses to aid in their decision making. The results may also provide a basis for further studies in other markets apart from Korea as well as for shaping policy decisions related to loss ratios.

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1. Introduction

Loss ratios are a central determinant of the profits and continuous going-concern of insurance firms. Generally speaking, if loss ratios are low, insurance companies are more likely to make positive return on assets for their shareholders while very high levels of loss ratios mean that the insurance firms are likely to suffer losses from their business operations and become unsustainable or exit from the market. Cutler and Ellis reiterate the concern of underwriters concerning loss ratios: loss ratios generally have been growing steadily eroding operating profits in the industry [1]. Thus a number of papers have studied the performance of general insurance firms using the economic loss ratios as a proxy for performance [2]. In this paper, we place a microscope on the general insurance market of the Korean insurance industry. Specifically, we are interested in investigating the general characteristics of the loss ratios reported by the general insurance arm of the insurance industry. Apart from the effect of loss ratios on the level of profits of insurance firms, there are at least three other reasons why loss ratios are of great interest to both insurance professionals and academicians. First, since the remuneration or bonuses of certain high level executives of insurance companies is tied to the profitability of their firms, there is a tendency to window dress or deflate the level of loss reserves to make their firms appear more profitable than they are [3]. Secondly, the loss ratios of insurance companies become a target for manipulation for tax purposes. When a high level of loss ratio is reported with a corresponding low level of profits or even net losses from operations, insurance firms can avoid taxes they would have paid if they had reported profits otherwise [4]. Finally, insurance firms that report low loss ratios and thus high profits are seen by the insured and other stakeholders as healthy firms with whom these parties would opt to continue business activities. A firm seen as poor and having a high risk of not being able to cover losses and indemnify the insured for losses that are insured stands the risk of losing valuable business in a competitive insurance industry and additionally faces the discomfort of attracting regulatory scrutiny [5]. These reasons enumerated though not exhaustive, give economic justification for the empirical need to investigate and learn more about the loss ratios associated with insurance business. Haley [6] shows that there is a long-term relationship between interest rates and underwriting margins while Grace and Hotchkiss [7] study the effect of macro-economic variables on the combined ratio of the property-liability insurance industry and find that although the combined ratio is linked to the long-run performance of the national economy, the short-run changes in economic variables is of little relevance to the combined ratio. Chidambaran, Pugel and Saunders [2], also investigate the characteristics and determinants of loss ratios using US data and analyze 18 lines of insurance business for the period 1984 through 1993 finding that the concentration ratio for the specific line, the share of direct writers in the line are significant determinants of pricing performance proxied by economic loss ratio. Recently Cutler

and Ellis [1], study US domestic stock property-liability insurance industry investigating the relative importance of a set of macro-economic variables and a set of industry-specific predictor variables. Their study concludes that macro-economic variables have little explanatory power for loss ratios. This empirical work attempts to improve upon these previous works in several different respects. First, Chidambaran, Pugel and Saunders [2] employ a generalized least squares regression with year dummies to control for group-wise heteroscedasticity and line-specific autocorrelation but this method may not adequately capture regimes associated with loss ratios in terms of changes in volatilities associated with rapidly changing economic environments. Probably, the sample period in their study from 1984 to 1993 did not contain any significantly known periods of high volatility and may have warranted the approach in their study. However, in applying a similar analysis in this paper to the Korean case as we do, we are careful not to be oblivious to the effect of the periods of high volatility and unstable economic environments which affected Korean businesses and its economic landscape such as the 1997-1999 Asian financial crisis and the 2007-2009 global financial crisis, which make such periods distinct from other periods of low volatility and relative economic stability. In fact, the work of Grace and Hotchkiss [7] criticizes the work of Haley [6] for this same reason indicating that Haley's work includes data from two different regulatory times periods from 1930 to 1989 in the same regression and thus a likelihood that there would be different effects of the explanatory variables depending on the different periods. If the researcher suspects the existence of different regimes and structural breaks in the data series, then in order to obtain a more relevant understanding and modelling of the dependent variable, a model that can automatically capture the switching regimes of the market is imperative to arrive at empirically useful and relevant results for the market in question, hence our choice of the Markov regime-switching methodology of Hamilton [8] to model loss ratios in this study. Secondly, we use recent data to provide an updated and refreshed perspective on underwriting performance in terms of loss ratios: we show updated evidence of how macro-economic variables affect the loss ratios of the general insurance industry, an issue of great interest for decision-making and policy of these firms. Korea is an interesting market for our investigation. Only Korea and Japan's insurance market have long-term insurance classified as part of the general insurance industry. In fact, long-term insurance alone occupies more than half of the market share of the Korean general insurance market in terms of written premiums though it is not traditionally considered as general insurance in other markets. These peculiarities associated with the Korean market makes it another interesting and alternative setting that can give us fresh and alternative insights into the nature of loss ratios and its determinants. A summary of our findings is as follows. First, our results establish the existence of two regimes- a regime with high volatility and a more stable regime with low volatility- in each of the lines of business we consider in the general insurance industry of the Korean insurance market, except for vehicle

insurance. We also show that there were structural breaks in the series of the loss ratios of each of the lines of business at different points in time, but most especially during periods of economic instability (such as the 1997-1999 Asian financial crisis and the 2007-2009 global financial crisis) or after major regulatory changes. Digressing from the results of previous studies, though Cutler and Ellis [1] find no support for macro-economic variables, we do find strong support for the explanatory power of macro-economic variables in predicting loss ratios of the Korean general insurance market. Probably, the methodology employed by Cutler and Ellis [1] and other papers which does not identify and distinguish the regimes associated with loss ratios may be one factor accounting for the difference in results. Contribution-wise, we first contribute to the literature by deepening the understanding we have about loss ratios especially in the emerging market context. To the extent that we study loss ratios using an emerging market in the case of Korea, we provide a different and renewed perspective on the general performance of the general insurance industry. This is relevant as has been argued in several previous studies that the economic conditions of developed markets vary greatly from that of emerging markets which warrant caution in generalizing empirical results from developed markets [9], [10]. Secondly, one contribution we make to the literature in this study which we deem worth emphasizing is the application of Markov regime-switching methodology to the modelling and investigation of loss ratios. Our approach deviates from previous studies which mainly apply ordinary least square regressions such as the work of [11], or generalized least squares regression such as the work of [2] and those that apply other time series techniques such as [11]; [6]; [7]; [12]; [1]; and [13]. This study takes advantage of the power of Markov regime-switching models to detect different regimes associated with the movements of the loss ratios. The relevance of the approach we take can be seen in the differing results of the effects of explanatory variables on the loss ratios based on the regime in question, whether stable or volatile. Thus, other works that ignore the possibility of the existence of regimes may have reported empirical results that differ from actuality. Additionally, in terms of contribution, we believe that the results of the study and the consequent recommendations will be a pointing guide to practitioners on policies regarding loss ratios and serve as an empirical evidence to underlie relevant insurance regulation of insurance companies. The rest of this paper proceeds as follows. We review prior works on loss ratios in the literature and give a brief introduction of the regime switching methodology employed in this study in section 2. In section 3, we discuss the size of the Korean insurance market while section 4 introduces the data and summary statistics of the variables used for this study. Section 5 shines light on the general characteristics of loss ratios by line of business in the Korean market, presents the results of our analyses and discusses them. The study finally concludes in section 5.

2. Literature Review and Methodology

2.1. Empirical Works on Loss Ratios

Some of the prior empirical works that have been conducted relating to loss ratios are reviewed briefly in this section with a deliberate focus on works done associating economic conditions with loss ratios. The work of Smith [11] finds evidence that there is a strong relationship between loss ratio and bond yields while Haley [6] shows that there is a long-term relationship between interest rates and underwriting margins. Grace and Hotchkiss [7] commenting on the Myers-Cohn [14] fair rate of return premium model indicate that interest rates are related to the combined ratio due to the negative relation between interest rates and premiums needed to cover future losses. D'Arcy and Au [15] argue that inflation is a key element in loss reserve development which is also a key element of loss ratios. Besides, inflation has an income effect resulting from price changes in premiums and the value of compensation paid out as indemnity for losses [7]. Inflation has also been considered by a number of studies as an explanatory variable in studies on loss ratios [16], [17], [7]. Grace and Hotchkiss [7] employ economic predictor variables including the real gross domestic product, the short-term interest rate and inflation to predict the combined loss ratio. They criticize the work of Haley [6] indicating that the inclusion of data from two different regulatory time periods in the same regression is likely to confound their results and that there is a likelihood that there would be different effects of the variables depending on the different periods. Grace and Hotchkiss [7] find that the property-liability insurance industry is linked to the long-run performance of the national economy but the short-run changes in economic variables is of little relevance to the performance of the property-liability industry as proxied by the combined ratio. In [1], the authors develop a simple model to predict loss ratios of US domestic stock property-liability insurance industry by examining the relative importance of a set of macro-economic variables and a set of industry-specific predictor variables but find little role for macro-economic variables in explaining the loss ratios associated with property-casualty insurance.[1] For studies outside the US, Lai, Chen and Chang [17] recently study the Taiwanese market and investigate the impact of macro-economic factors on the environmental loss ratio. They find that the macro-economic variables that affect the loss ratios of environmental insurance are inconsistent and dependent on the effect of the year's environmental condition, thus requiring constant modification of insurance prices and liability reserves. For the Korean case, the only empirical work we discover from a literature search related to modelling of loss ratios is the work published by Lee and Kim [18]. They model monthly loss ratios observed in car insurance during 1991 to 2003 using the autoregressive

[1]Unlike Grace and Hotchkiss [7] who investigate the combined ratio, Cutler and Ellis [1] investigate loss ratio arguing that the combined ratio is a poor choice since the other component of the combined ratio, the expense ratio is nearly constant over time. We follow Cutler and Ellis by focusing on the loss ratio as a measure of performance.

conditional heteroscedastic model. Their work like the other papers reviewed, do not employ an estimation technique that can identify different regimes related to loss ratios and they examine no explanatory variables that may also influence loss ratios. Doumpos, Gaganis, and Pasiouras [16] find evidence in their study encompassing 91 non-US countries that macroeconomic conditions such as gross domestic product (GDP) growth, inflation, and income inequality are the most robust predictors of performance.

2.2. The Markov Regime Switching Model

Hamilton [8] first proposes the approach to modelling changes in regimes using a two-state Markov process. As have been applied in several other economic and financial time series studies, we follow Hamilton's Markov regime-switching methodology by applying it to our specific case. The Markov regime-switching model with five macro-economic variables and one regulatory change control variable we consider for each line of business can be denoted below as:

$$LR_t|s_t = \mu_{st}+\beta_{1s_t}int+\beta_{2s_t}inf+\beta_{3s_t}gdp+\beta_{4s_t}emp+\beta_{5s_t}expimp+\beta_{6s_t}ifrs4+\epsilon_t|s_t(I)$$

where LR_t represents the current loss ratio of each general insurance line of business; int refers to current short-term interest rates; inf refers to the inflation rate; and gdp refers to the gross domestic product. The variable emp refers to the employment rate; $expimp$ refers to the export-import ratio; $ifrs4$ is a dummy variable equal to 1 during the periods of the introduction of IFRS4 into Korea (from the year 2011) and 0 otherwise; and $s_t, (t = 1, 2)$ are the two states(regimes) and $\epsilon_t|s_t \ N(0, \sigma_(s_t)^2)$. The state variable, s_t, is assumed to follow a standard two-regime Markov process associated with the following transition probabilities:

$$p_{ij} = Prob[s_{(t+1)} = j|s_t = i], i = 1, 2, j = 1, 2, (II)$$

where p_{ij} represents the transition probabilities from state i to state j and $p_{i1} + p_{i2} = 1$, for $i = 1, 2$. It is important to note that we assume that $\sigma_1^2 < \sigma_2^2$. Thus, according to our model, the process at time, t, is said to be in regime 1 with low volatility if its estimated filtered probability is greater than that of regime 2 or else the process is said to be in regime 2 with high volatility [19]. We further assume the explanatory variables do not switch. Korean businesses and its economic landscape have been affected by global, continent-specific and country-specific economic events just like other countries. For example, the 1997-1999 Asian financial crisis, the 2007-2009 global financial crisis and the recent onset of the global Covid-19 pandemic which have caused disruptions in financial markets and these economic conditions present challenges for businesses including insurance companies. These occurrences suggest the existence of structural breaks in the economic environment and the possible existence of distinct regimes; a regime with high volatility and a regime with low volatility in the market. Apart from economic regimes, regulatory changes could be one of the driving forces underlying changing regimes. For example, in a recent study,

Hur [20] examines the impact of regulation affecting deductibles on the loss ratios of auto insurance market in Korea. Hur [20] indicates that in relation to vehicle insurance, there were a number of regulatory interventions in the vehicle insurance market in 2010 such as the raising of the threshold limit that triggers premium surcharge to two million won from five hundred thousand won which resulted in a surge in moral hazard, increasing the loss ratios of vehicle insurance companies. As a remedy, this was immediately followed by another regulation that introduced a proportional deductible system in 2011. Such changes in the regulatory system have a tendency of creating regimes of both highly volatile periods and relatively stable periods. The possibility of structural breaks in the loss ratios and changing regimes motivates our adoption of the Markov regime-switching methodology in this study.

3. Size of the Korean Insurance Market

Generally, in terms of gross premiums, the life insurance market in Korea has consistently been larger than the general insurance market. For the life insurance market, in the year 2019, about 117 trillion won was written in premiums, with the life insurance industry recording a worth of about 918 trillion won in total assets. These figures are substantially higher than that of the general insurance markets which clogged about 96 trillion won in gross premiums written and about 321 trillion won in total assets. As at 2020, there were about 24 life insurance companies and 20 general insurance companies in Korea. Kim and Shin [21] report on data ranging from 2000 to 2012 and indicate that the general insurance industry market in Korea has steadily been increasing in terms of gross premiums; about 2.59% of Korea's GDP in 2000 to about 4.98% of Korea's GDP in 2012. We also show in Figure 1 below, that the gross premiums have steadily increased and continue to increase confirming the findings of [21]. The first graph of Figure 1 shows the steady increase in premiums written of both the life insurance market and the general insurance market in Korea.[2] Since we focus on the general insurance market in Korea, we now zoom in on the general insurance market and discuss its various lines of business. Figure 1 shows that the long-term insurance line of business occupies the largest share of the general insurance market in terms of premiums, a share of about 55.37% of the market in 2020. Because of the peculiarities associated with long-term insurance plans, it is excluded from the lines of business we consider in this study despite its share of the market. Unlike traditional general insurance products that have a validity of 1 year, the long term insurance products have a validity of 3 years or more. Apart from proving indemnity for losses, they comprise a savings portion which is refunded to policyholders at maturity compounded at a predetermined interest rate.

[2]Note that the yearly graphs in Figure 1 show a drop in 2013 because the aggregates for that year only include 9 months (April to December) data due to the change of the fiscal year to January-December from April-March in 2013.

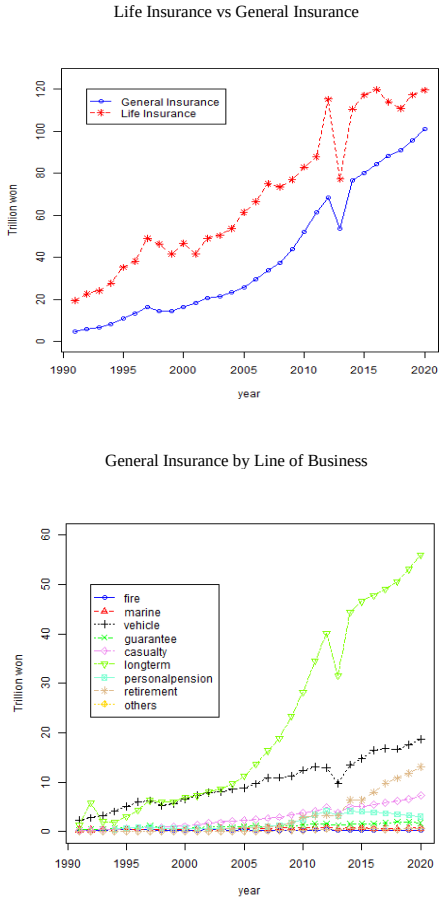

FIGURE 1. Size of the Korean Insurance Industry in terms of Premiums Written

Note: The left panel of the figure presents the aggregate amount of gross premiums written for both life insurance companies and general insurance companies in Korea from 1990-2020. The right panel of the figure zooms in on the general insurance companies and presents the aggregate amount of gross premiums written by line of business also from 1990-2020.

The main lines of business we study include fire, marine, vehicle, liability and accident insurance. For the lines of business we study, vehicle insurance occupies the largest share of the market corresponding to about 18.52% of total premiums written in 2020 followed by casualty insurance (7.22%)[3] , marine insurance (0.69%) and fire insurance respectively (0.27%). Figure 1 confirms the reported figures in previous studies. For example, Jeong and Kang [22] report that for the fiscal year 2005, vehicle insurance in Korea occupied about 40% of the general insurance market in terms of net premiums. As can be seen from the second graph of Figure 1, both long-term insurance and vehicle insurance have occupied the major share of Korea's general insurance market until about the year 2005 after which long-term insurance became consistently more dominant.

4. Data

We collect data on the monthly loss ratios of Korean General Insurance companies from the Insurance Statistics Consumer Service (INcos) portal maintained by the Korean Insurance Development Institute which is mandated by law to collate statistics and data on insurance companies in Korea. This portal provides the monthly insurance statistics which is the data underlying this study.

The data on interest rates, inflation rates, gross domestic product and employment rates are collected from the Organization for Economic Cooperation and development data set (OECD.stat). We also collect data on exports and imports from the International Monetary Fund (IMF). Though the IFRS4 dummy variable is not a macro-economic variable, we use it as a control variable given the possible effect that changes in the accounting standards can have on reported loss ratios. Our sample consists of the period February 1991 to November 2020. The aggregate of loss ratio for all general insurance companies in Korea in each line of business is our main dependent variable. The categories we focus on include fire insurance, marine insurance, vehicle insurance, liability insurance and accident insurance. To curb the possible effect that zero and negative loss ratios have on the results of our analyses, we drop zero and negative loss ratio observations.[4] Figure 2 above plots the graphs of the macro-economic explanatory variables in this study. The figure shows interest rates have hovered around 15% till about 1997 after which there was a very sharp rise during the 1997-1999 Asian financial crisis. After the Asian financial crisis, it has shown a downward drop, with a slight rise during the 2007-2009 global financial crisis but hitting

[3]Casualty insurance here is an aggregate of both liability insurance and accident insurance. We do not have detailed breakdown of the data for liability insurance and accident insurance in terms of the premiums written.

[4]Zero or negative ratios could possibly have resulted from a refund of claims paid, outstanding loss reserves released, subrogation, a mismatch of claims paid and recovered to the relevant month, a data entry error or a combination of these reasons. There are only 5 of such cases in our data set specifically related to marine insurance only.

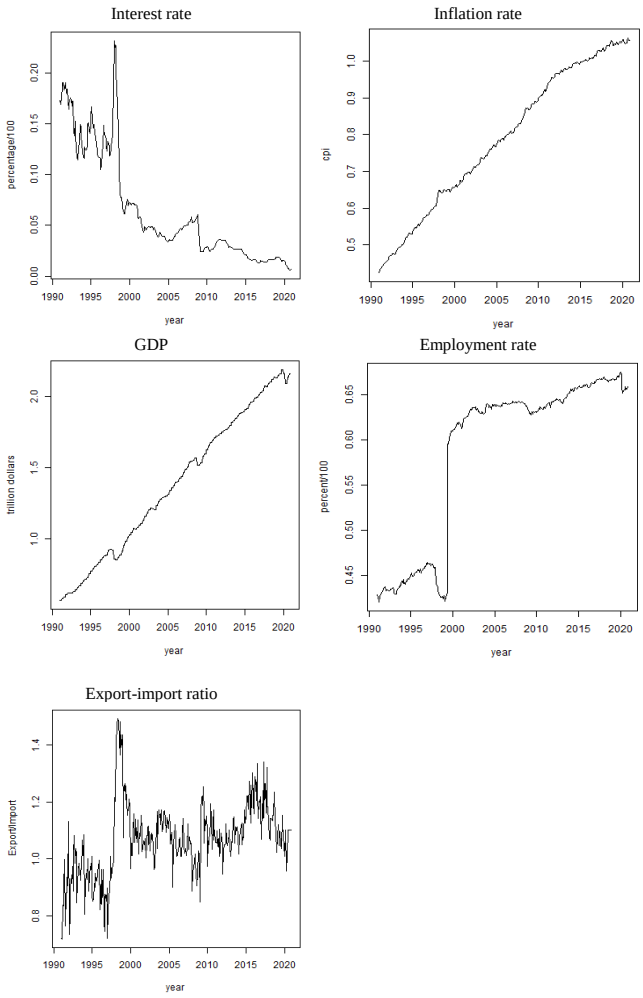

FIGURE 2. Time Series Graph of Explanatory Variables

Note: This figure presents the time series graph of the five macro-economic explanatory variables used in this study for modeling loss ratios. These macro-economic variables are inflation rate, interest rate, GDP, employment rate and export-import ratio.

almost zero level by 2020. As for inflation rate, with a consumer price index reference value of 100 in 2015, the graph shows an increase in inflation levels hovering around 0-6% from 2015 to 2020. With clearly little decreases during the period of the Asian financial crisis, the global financial crisis and the recent covid-19 crisis, the gross domestic product(GDP) of Korea shows an increasing trend. From 1990 until the end of the 1997-1999 Asian financial crisis, employment rates have been below 50%; however, after the Asian financial crisis, employment rates have risen and remained above 60% of the population consistently. Again, for the export-import ratio, the graph indicates that Korea had imported more goods and services than it had exported up until the latter part of the Asian financial crisis. Since then, the export-import ratio has mostly remained above 1 suggesting a greater amount of exports of goods and services out of Korea than imports into Korea. In Figure 3 below, the plots of the main dependent variables are shown. The graphs for each of the five lines of business we study in this paper show periods of high volatility and periods of low volatility. However, to statistically show that there is a two-regime state in the loss ratios of these lines of business in the Korean general insurance market, we model these periods statistically using the Markov regime-switching methodology in the subsequent section of this paper. Apart from the changing regimes, we can observe structural breaks in the loss ratios of each of the lines of business. This is discussed further in the next section.

We conclude this section by examining the correlation among the loss ratios of the five lines of business in Table 1 below. Though a composite number of lines of business are undertaken by the same companies as it is the case in the general insurance market, the table shows that there is little positive correlation among the loss ratios of the businesses undertaken by these firms. If most of the correlation among the loss ratios were positive and very high, these firms cannot benefit from a diversification effect and may run out of business since a high positive correlation means the loss ratios all move in the same direction and these firms can suffer very huge losses during bad periods. Conversely, we observe near zero correlation of loss ratios among most of the lines of business and even negative correlation in some cases.

TABLE 1. Correlation Table

Variables	Fire	Marine	Vehicle	Liability	Accident
Fire	1				
Marine	-0.07	1			
Vehicle	-0.03	-0.004	1		
Liability	-0.03	0.31*	0.49*	1	
Accident	0.08	0.18*	-0.06	0.13*	1

Note: * $p < 0.05$.

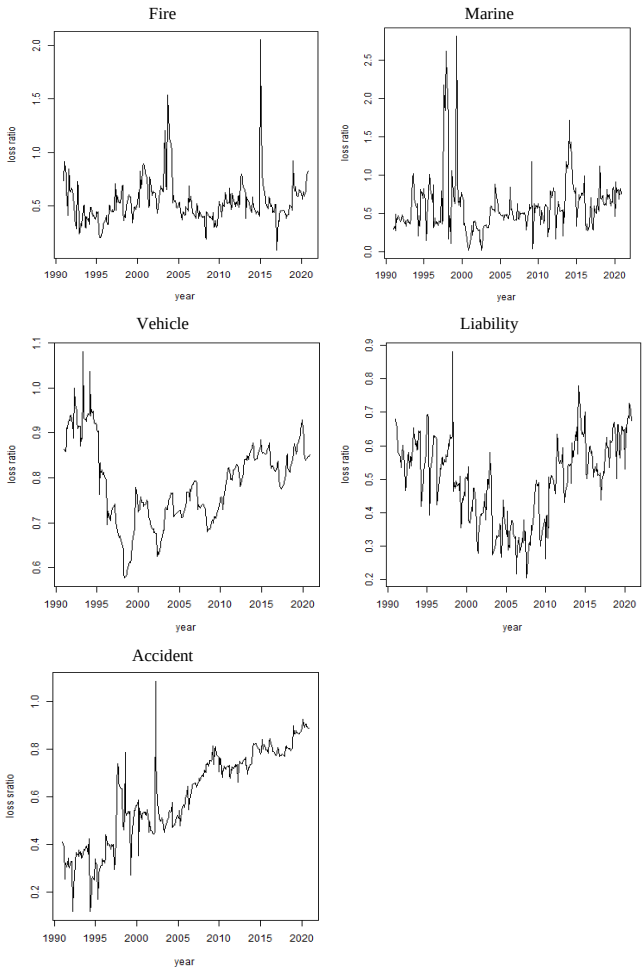

FIGURE 3. Time Series Graph of Loss Ratios by Line of Business

Note: This figure presents the time series graph of the loss ratio of each of the lines of business we study and include the loss ratios for fire insurance, marine insurance, vehicle insurance, liability insurance and accident insurance.

5. Characteristics of Loss Ratios of Korean General Insurance Market

5.1. Structural Changes

To start the analyses in this section, we start off by showing that structural breaks exist in the loss ratios in each of the lines of business we study. First, in Figure 4, we present the graphical results of the Zivot-Andrews test for stationarity in the presence of structural breaks [23] as well as a set of confirmatory tests of structural breaks in Table 2 using the strucchange program in r written by Zeileis et al. [24], [25].

The Zivot-Andrews test automatically predicts the possible structural breakpoints in the series as follows: March 2004 for fire insurance, April 1999 for marine insurance, March 1995 for vehicle insurance, February 2008 for liability insurance and May 1997 for accident insurance. It can be seen that the breakpoints for marine insurance and accident insurance as suggested by the Zivot-Andrews test fall within the period of the Asian financial crisis of 1997-1999 while that of liability insurance falls within the period of the global financial crisis of 2007-2009.

TABLE 2. Structural Change Test: Confirmatory Analyses from Various Tests

Variables	F-tests			Generalized Fluctuation Test	
	SupF	aveF	expF	OLS-CUSUM	Rec-CUSUM
Fire	$F = 64.2^{***}$	$F = 28.2^{***}$	$F = 27.1^{***}$	$S0 = 1.4^{**}$	$S = 1.9^{***}$
Marine	$F = 123.2^{***}$	$F = 31.9^{***}$	$F = 56.1^{***}$	$S0 = 1.1$	$S = 1.9^{***}$
Vehicle	$F = 679.0^{***}$	$F = 247.8^{***}$	$F = 334.0^{***}$	$S0 = 3.1^{***}$	$S = 2.4^{***}$
Liability	$F = 112.0^{***}$	$F = 52.8^{***}$	$F = 50.6^{***}$	$S0 = 1.6^{***}$	$S = 1.1^{**}$
Accident	$F = 110.0^{***}$	$F = 24.0^{***}$	$F = 49.5^{***}$	$S0 = 1.1$	$S = 1.3^{***}$

Note: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

For the purpose of robustness, we further undertake a set of confirmatory statistical tests to ascertain the breakpoints in each of the series. These include the tests based on F statistics ([26], [27], [28]) and the generalized fluctuation tests [29]. For the Chow tests [30], which is a subset of the F-tests, we manually identify possible breakpoints by observing the time series data in Figure 3 above and test those points for the presence of structural breaks. Our results suggest structural breaks for marine insurance and liability insurance in the Asian financial crisis period and additionally for liability insurance during the global financial crisis using the Chow test. Unlike the Chow test, the other confirmatory statistical tests do not require identification of the breakpoints in advance; rather the possible breakpoints are identified by the tests. The results for each of the F tests as well as the generalized fluctuation tests confirm the presence of structural breaks in the times series of the loss ratios of each line of

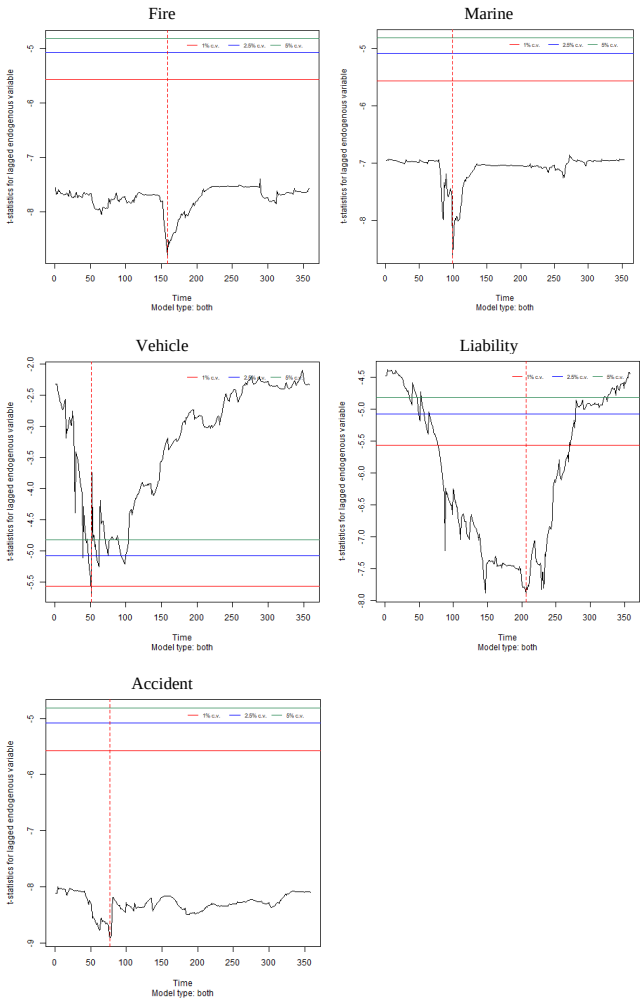

FIGURE 4. Zivot-Andrews Unit Root Test of Loss Ratios by Line of Business

Note: This figure presents the Zivot-Andrews (2002) unit root test in the presence of structural changes for the loss ratios by line of business and shows possible breakpoints as suggested by the test.

business in the general insurance industry of Korea as shown in Table 2 above. To identify the specific multiple breakpoints, we follow the algorithm described by Bai and Perron [31] and implemented by Zeileis et al. [25]. A summary of the breakpoints is shown in Table 3 below and the discussion focuses on periods of financial crisis and regulatory changes. For fire insurance, the Bai and Perron algorithm identifies March 1997 as a possible breakpoint corresponding to the Asian financial crisis. For marine insurance, none of the breakpoints identified by the Bai and Perron algorithm corresponds to either the Asian financial crisis or the global financial crisis. A possible explanation for this observation is that the uniqueness of marine insurance makes it more susceptible to other factors such as weather rather than general economic conditions so that even though there are structural breaks in the movement of the marine insurance loss ratio, they may not necessarily be economically induced.

TABLE 3. Summary of Structural Breaks

Variables	Zivot-Andrews test	Chow test	Bai and Perron algorithm	
Fire	2004-03	2003-09	1995-08	1997-03
		2015-01	2000-01	2004-06
			2010-08	2015-08
Marine	1999-04	1997-12	1995-06	2000-02
		2014-01	2004-07	2011-01
			2013-01	2015-09
Vehicle	1995-03	1994-03	1995-05	1996-01
			2000-04	2003-03
			2005-08	2010-08
			2015-01	
Liability	2008-02	1998-04	1998-04	1999-03
		2007-08	2003-03	2007-08
			2008-06	2010-05
			2011-05	2012-01
			2013-04	2016-06
Accident	1997-05	1994-05	1997-07	2002-03
		2002-04	2006-08	2007-06
			2011-07	2013-12
			2015-12	

Note: The table is a summary of the breakpoints in the movement of loss ratios by line of business. We show the breakpoints suggested by the Zivot-Andrews test (2002), the Chow (1960) test and the Bai and Perron (1998) test for the presence of structural breaks.

As for vehicle insurance, the algorithm identifies a possible breakpoint at August 2010 among other breakpoints; it is not surprising as this period was

flooded with major regulatory changes in Korea, specifically the regulation concerning deductibles on the loss ratios of vehicle insurance market as discussed by Hur [20]. Thus, while we do not observe a structural break in vehicle insurance during any of the financial crises, the algorithms suggest a structural break that corresponds to a period of regulatory upheaval in the vehicle insurance industry. Further, we report that for liability insurance, the algorithm suggests structural breakpoints in the loss ratios during April 1998, March 1999, August 2007 and June 2008 all corresponding to the Asian financial crisis and the global financial crisis. Finally, the statistical algorithm for breakpoint detection by Bai and Perron give strong support for the possible structural breakpoints in the loss ratio of accident insurance to be around July 1997 and June 2007, again corresponding to the period of the Asian financial crisis and the global financial crisis respectively.

5.2. Model Fitting and Results

In this section, we fit the Markov regime-switching model with macro-economic explanatory factors and discuss the results. For comparison purposes, we first present an ordinary least square regression (OLS) of loss ratios on the explanatory factors in Table 4 below. First the r-squared associated with fire insurance and marine insurance shows a poor fit of the data, while the r-squared related to vehicle, liability and accident insurance show a good fit, howbeit one which can be improved with a better estimation technique as we show in the case of the Markov regime-switching model subsequently.

In the foregoing analysis, we are greatly interested in the improvement in the fit in comparing the results between the ordinary least square regression and the Markov regime-switching model. The Markov regime-switching models are estimated using msmFit in the MSwM package in the statistical program r by [19]; the reported results are shown in Table 5 below. A comparison of the r-squared shows improvement in the fit for all lines of business for both regimes or at least one of the regimes compared to the OLS results, giving support to the choice of the Markov regime-switching model as a better fit of the loss ratio data. For instance, we observe the r-squared for regime 1 for marine insurance is 69% and for regime 2 to be 35%, a non-trivial improvement compared to the r-squared using OLS of 21%. Similar non-trivial improvements in r-squared can be seen in all the other cases.

When checking the volatilities by making reference to the standard error, it can be seen that for all lines of business, the volatilities of the regime 2 is at least twice the volatilities of regime 1, except for vehicle insurance. Thus, except for vehicle insurance, these results clearly suggest the existence of two regimes in terms of the loss ratios in each line of business considered in the Korean general insurance market. We provide an explanation for possible reasons why vehicle insurance is empirically shown not to be associated with regimes when we use the Markov regime-switching model. In fact, we are not surprised to not have observed different regimes associated with vehicle insurance. Generally, the loss

TABLE 4. OLS Regression of Loss Ratios by Category on Explanatory Variables

Variables	Fire Model 1	Marine Model 2	Vehicle Model 3	Liability Model 4	Accident Model 5
Intercept	-0.09	-0.07	1.42***	0.85***	−0.47***
	(0.24)	(0.42)	(0.08)	(0.10)	(0.09)
Inflation rate	-0.53	3.48***	−1.64***	−0.49*	1.19***
	(0.53)	(0.91)	(0.17)	(0.21)	(0.21)
Interest rate	0.13	1.92*	0.06	0.81***	0.88***
	(0.54)	(0.93)	(0.17)	(0.22)	(0.21)
GDP	-0.18	−0.71*	0.55***	0.25**	0.03
	(0.20)	(0.35)	(0.07)	(0.08)	(0.08)
Employment rate	1.66***	−2.51***	-0.01	−0.71***	-0.05
	(0.32)	(0.55)	(0.10)	(0.13)	(0.12)
Export-import ratio	0.23*	0.25	−0.13***	-0.02	0.08*
	(0.10)	(0.17)	(0.03)	(0.04)	(0.04)
IFRS4	0.18***	-0.03	0.15***	0.20***	−0.08***
	(0.04)	(0.08)	(0.01)	(0.02)	(0.02)
N	358	353	358	358	358
R-squared	0.12	0.21	0.57	0.63	0.86

Note: The response variable is loss ratio by category. The explanatory variables are inflation rate, interest rate, GDP, employment rate, export-import ratio and the IFRS4 dummy variable.
*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

ratios of the vehicle insurance industry have relatively been stable as we found from our earlier confirmatory tests that the loss ratios of vehicle insurance in Korea was not influenced by any of the two financial crises that have been discussed so far. We only observed structural breaks that corresponded to a period of regulatory changes in 2010 2011. As we modelled the loss ratios using macroeconomic variables, which is the scope and focus of our present study, it makes intuitive understanding that we do not observe a clear and distinct separation of regimes in the loss ratio of vehicle insurance. To confirm the validity of our results concerning the case of vehicle insurance, in results which we do not report, we further add a dummy variable to represent the period of regulatory changes unique to vehicle insurance to the regression in vehicle insurance. This dummy variable was defined as 1 if the period corresponds to the year 2010 and after (the period of major regulatory changes and after), and equal to 0 for the periods before 2010. We report that our results remain quantitatively and qualitatively the same and thus suggest that despite the regulatory upheavals in 2010 2011, the loss ratios of vehicle insurance has not been associated with

TABLE 5. Parameter Estimates of Markov Regime-switching Models of Loss Ratios by Category

Regime	Variables	Fire	Marine	Vehicle	Liability	Accident
Regime 1 with low-volatility	Intercept	0.19	0.89^{***}	1.76^{***}	2.00^{***}	0.07
	Inflation rate	1.86^{***}	-0.74^{***}	0.06	-0.92^{***}	1.14^{***}
	Int. rate	-1.17^{***}	-0.38	-0.33^{**}	-1.58^{***}	0.56^{***}
	GDP	-0.73^{***}	0.61^{***}	0.15^{***}	0.37^{***}	0.15^{***}
	Empl. rate	-0.10	-0.95^{***}	-1.99^{***}	-2.19^{***}	-0.84^{***}
	Exp.-imp. ratio	-0.06	-0.07	-0.04	-0.01	-0.08^{***}
	IFRS4	0.01	0.02	0.06^{***}	0.19^{***}	-0.09^{***}
	Resid. std. error	0.06	0.08	0.026	0.03	0.03
	Multiple R^2	0.47	0.69	0.92	0.93	0.96
Regime 2 with high-volatility	Intercept	0.49	-1.35^{**}	0.99^{***}	0.30^{***}	-0.99^{***}
	Inflation rate	-1.90^{**}	6.17^{***}	-1.48^{***}	-0.07	1.25
	Int. rate	-1.22	6.79^{***}	0.10	1.40^{***}	1.36^{***}
	GDP	-0.11	-1.06	0.43^{***}	0.17^{**}	0.14
	Empl. rate	1.76^{**}	-2.84^{***}	0.57^{***}	-0.15	0.54^{***}
	Exp.-imp. ratio	0.65^{***}	0.05	-0.04^{***}	0.01	0.11
	IFRS4	0.53^{***}	-0.40^{**}	0.19^{***}	0.12^{***}	-0.30^{**}
	Resid. std. error	0.21	0.38	0.027	0.06	0.10
	Multiple R^2	0.27	0.35	0.88	0.65	0.71
Transition prob.	p_{12}	0.05	0.08	0.04	0.08	0.02
	p_{21}	0.08	0.10	0.03	0.07	0.06
	AIC	-483.16	-137.47	-1480.80	-1037.38	-1122.73
	BIC	-346.50	-1.20	-1344.15	-900.72	-986.07
	Loglik	255.58	82.73	754.40	532.69	575.36

Note: The response variable is loss ratio categorized by type of insurance. The explanatory variables are inflation rate, interest rate, GDP, employment rate, export-import ratio and IFRS4 index variable.
*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

differing regimes.[5] In exploring the economic significance of the effect of the macro-economic factors on the loss ratios, we observe that the effect of the macro-economic factors differs based on the line of business and the particular regime in question. In the absence of a theory that specifically specifies the empirical relationship between the loss ratio and the macro-economic factors, we employ the Markov regime-switching model to allow the data to determine the dynamic structure of the relationship among the variables. Thus, for each of the results we discuss below, there may be a number of effects at play, with the greater effect dominating the eventual relation based on the line of business in question and by the regime in question. It is worth noting that in comparing

[5]These additional results are readily available from the authors upon request.

our work with that of [7], they study the aggregate loss ratio of the property-liability insurance industry while we study the general insurance industry by line of business. Our approach enables us to observe the differing impacts of macro-economic conditions on loss ratios based on both the line of business and the regime in question. Take for example, the case of GDP. We observe that in regime 1, GDP has a significant positive relation with loss ratio in the marine, vehicle, liability and accident lines of businesses. An economic intuition behind this result is as follows. A positive shock to GDP could be interpreted as a rise in general economic activity reflecting in a higher level of peril and accidents indicating higher possibility of losses. Such a situation would reflect in a positive relation between GDP and loss ratio as seen in the marine, vehicle and accident lines of business in regime 1. On the other hand, Grace and Hotchkiss [7] discuss a pure income effect associated with a shock to GDP to explain the negative relationship between GDP and loss ratios. When there is a positive shock to GDP, total income will rise all things being equal resulting in a rise in demand for all normal goods and services and thus an increase in revenue and profits of insurers (or inversely a decrease in loss ratios). We observe a negative relation between GDP and loss ratio in fire insurance in regime 1. Similar arguments hold for the observed results in regime 2. The arguments and interpretation for GDP also holds for the employment rate and the export-import ratio as a positive shock to the employment rate or the export-import ratios signifies a rise in general economic activity with the expectation of a higher level of losses, all other factors being equal. Again, the positive shock to these economic variables could possibly mean a positive shock to income and thus an indirect decrease in loss ratios of insurance firms through the income effect as argued above in the case of GDP. Additionally, taking a look at the positive relationship between interest rates and loss ratios, competitively determined market insurance premiums should incorporate discounted expected losses and presupposes a direct and positive link between loss ratio and interest rates [7], [32]. However, increases in interest rates are associated with economic recessions reflecting a decrease in economic activity in general. All things being equal, the decrease in economic activity would reflect in lower levels of accidents and losses suggesting a negative relationship between interest rates and loss ratios. Thus we find it not surprising observing both positive and negative effect of interest rates on loss ratios depending on the line of business and the regime in question. Again, for inflation rate, Grace and Hotchkiss [7] discuss the competing effects of the income and substitution effect associated with a shock to inflation rates. With a rise in inflation, there is the direct income effect of an increase on claims after policies are sold, and conversely a substitution effect engendered by the prices of other goods and services competing with insurance products for the consumer's limited income. The dominant effect of the two will eventually determine the direction of the relation between inflation rate and loss ratio. The results in Table 5 also show a high level of persistence in each regime in each line of business. For example, the highest probability shown for a switch from regime 1 to

regime 2 is 0.08 in the case of marine insurance and liability insurance, while the highest probability of switching from regime 2 to regime 1 is 0.10 still in the case of marine insurance.

The volatility plots of the loss ratios by line of business is shown in Figure 5. The plots suggest that each line of business have experienced both highly volatile periods (regime 2), and periods of stability (regime 1). Again, the specific periods identified as stable (regime 1) or highly volatile (regime 2) differs based on the line of business. This is a welcoming observation that supports the results in the correlation analysis of Table 1 above. That all the lines of business do not exhibit high volatility at the same time is an important underscoring characteristic which enables the insurance companies which transact business in a number of lines of business at the same time to be shielded from adverse losses in terms of the cushioning effect of possible diversification. Though we do not study the extent of diversification and quantify it in this paper, diversification in loss ratios seems to be clear inferences that can be made from the correlation table and the existence of different volatilities at varying periods of time as shown in the volatility plot.

5.3. Model Validation

For model validation purposes, we briefly show the pooled residuals of the Markov regime-switching model and also test the residuals for stationarity. The pooled residual plots in Figure 6 show both periods of high volatility and periods of low volatility. Additionally, the residuals do not remain only above zero or below zero but do cross the zero line from above as much as they also cross it from below.

As for the augmented Dickey Fuller stationarity tests [33] on the residuals of the Markov regime-switching models, we report that the null of unit root is rejected in the case of each line of business at the 5% level of significance in Table 6 below.

TABLE 6. Augmented Dickey Fuller Test on Markov Regime-switching Residuals

Variables	ADF Test	Interpretation
Fire	Dickey-Fuller = -5.4191^{***}	Stationary
Marine	Dickey-Fuller = -5.7183^{***}	Stationary
Vehicle	Dickey-Fuller = -5.7888^{**}	Stationary
Liability	Dickey-Fuller = -7.0415^{***}	Stationary
Accident	Dickey-Fuller = -5.48^{***}	Stationary

Note: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

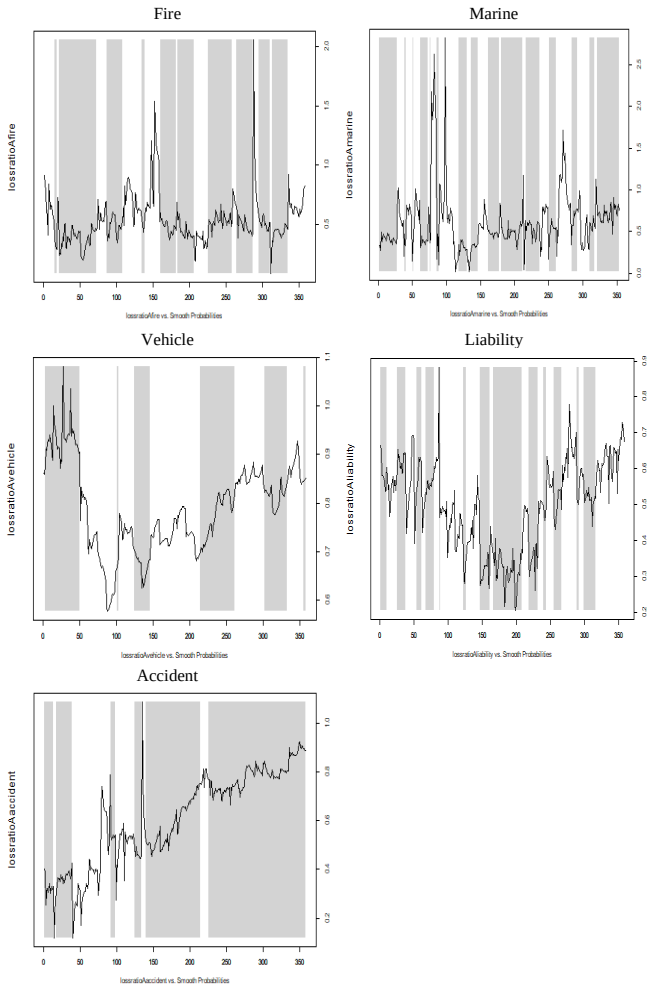

FIGURE 5. Volatility Plots of Loss Ratios by Line of Business

Note: This figure shows the volatility plots of loss ratios by line of business in the Korean general insurance industry. The shaded portions in each graph represent regime 1 (low volatility) while the unshaded portions represent regime 2 (high volatility).

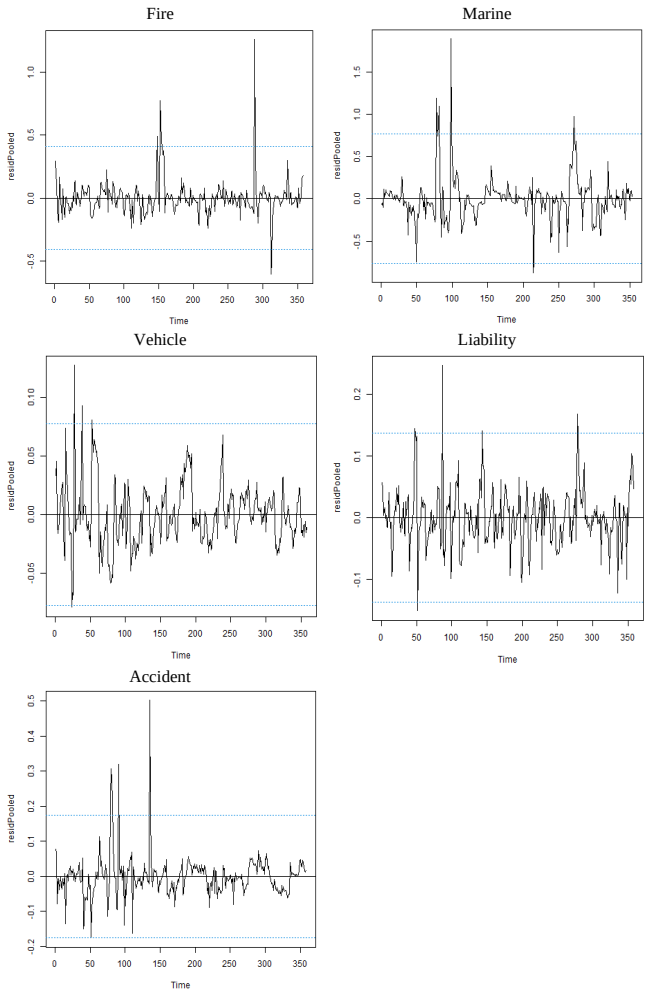

FIGURE 6. Pooled residuals of Markov Regime-switching Models by Line of Business

Note: This figure presents, by line of business, the pooled residuals after running the Markov Regime-switching models.

6. Conclusion

This paper has identified a need of revisiting the research on loss ratios reported by general insurance industry and to model the loss ratios based on the existence of changing regimes. Structural changes existent in the time series movement of loss ratios as well as the varying economic and regulatory environments possess challenges to the modelling and investigation of the explanatory factors influencing the loss ratios. Differing from the methodological approach of previous studies, this may be the first to employ Markov regime-switching methodology of Hamilton [8] to model the loss ratios and investigate the impact of macro-economic factors on the loss ratios of each line of business in each regime. First, we found structural breaks associated with the loss ratios of Korean general insurance companies for each of the lines of business we study. These structural breaks mostly occurred during the 1997-1999 Asian financial crisis and the 2007-2009 global financial crisis; and periods of regulatory volatility such as during 2010-2011 particularly for vehicle insurance. Second, we find empirical evidence that the loss ratios reported by insurance companies in Korea is characterized by two distinct regimes; a regime with high volatility and a regime with low volatility, except for vehicle insurance. Our analyses suggest that macro-economic conditions have significant explanatory effect on loss ratios but the direction of effect differs based on the line of business and the regime. Finally, though not quantitatively determined, the correlations and differing periods of structural breaks and volatility among the lines of business suggests possible diversification effect for the general insurance companies that conduct business including a composite number of the lines of business studied in this paper. Our proposition and results suggest that it may be not enough to model the loss ratios of insurance firms only employing traditional linear regression techniques, given the possibility of the existence of structural breaks in the movement of the loss ratios. While in some cases, using a linear regression may be appropriate as we find for the particular case of vehicle insurance because it is not associated with distinct regimes, it is more appropriate to model loss ratios with a methodology which can distinguish regimes such as we do especially if structural breaks are suspected to be existent. Of course, the determination of which lines of business will be appropriate to model with Markov regime-switching methodology depends on the market in question as well as a preliminary confirmation of structural breaks in the movement of the loss ratios before applying the regime-switching methodology. To the extent that we conduct our study using only Korean data, our results may not be generalizable to all markets; yet our analyses provide a refreshed understanding of loss ratios in the general insurance industry and may provide a bases for further studies in other markets as well as for policy and decision making. As a side recommendation from our study for the Korean special case, we recommend the need for the Korean general insurance market to shift its overdependence from long-term insurance and vehicle insurance which occupy almost three-fourth of

the size of the market alone in terms of premiums written. Finally, our study is limited to the extent that we are unable to explore all the possible explanatory factors for the movements and regime shifts in loss ratios.

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