In the late 1990s, previous studies have indicated that suicide rates in Southeast Asia increased in parallel with the Asian economic crisis in 1997-1998 [1]. Suicide has since become a more common cause of death in Asia when compared to previous times, and a number of studies have examined the relationship between socioeconomic status and suicide. Some such studies have indicated that suicide rates increase in parallel with a rise in unemployment [2] or during periods of economic recession [3].

A useful marker to represent macroeconomic recession is declining gross domestic product (GDP). However, there are complex causal pathways from macroeconomic recession to suicide events, such as unemployment status, alcohol consumption [4], and economic-induced mental illness [5]. Therefore, we hypothesize that a time lag is necessary when analyzing how macroeconomic variables affect changes in the rate of suicide mortality.

According to our previous study [6], the most vulnerable occupation during periods of economic recession is the agriculture, forestry, and fisheries (AFF) sector, whose employees exhibited significantly higher standard suicide mortality rate (341) as compared with other occupations in Korea [6]. This finding is consistent with the available report from the United States [7]. Furthermore, the easy assessments to pesticides have been the important cause of high suicide risk in AFF workers [8]. However, the time lag effect between economic recession and suicide rate has not been frequently studied in AFF workers.
Hence, the time lag between economic recession and suicide in AFF workers warrants further investigation as an indicator for the prevention of suicide. Therefore, this study aims to examine the time lag effect of GDP on suicidal rates in AFF workers in Korea.

The information on the cause of death from the period from 1993-2008 was obtained from the records available in Korea National Statistical Office (KNSO). The cause of death certificates provided by the KNSO was classified based on the 10th revision of the International Classification of Disease (ICD-10) for the period from 1993-2008. In this study, intentional self-harm (X60-X84) and sequelae of intentional self-harm (Y870) from the ICD-10 were defined as suicide. Monthly unemployment ratios for 1993-2008 were also obtained from the KNSO.

The AFF occupations were identified using the Korean Standard Classification of Occupations, which comprises nine major occupational groups that have been used in cause of death records in Korea.

We also gathered industry-specific GDP data from the KNSO. However, we were unable to gain an exact monthly GDP level for AFF workers, because the KNSO only offers quarterly GDP data. Therefore, we used a generalized additive model (GAM) to calculate a monthly AFF GDP level using the smoothing method. The percentage changes in AFF GDP from previous months were subsequently calculated.

Suicide data were analyzed using time-series analysis. Analyses were carried out using the statistical program R version 2.12.2 with the packages “mgcv” and “ares” for the time-series analysis using the GAM [9]. The analysis consisted of several procedures. Initially, we tried to control the long-term and seasonal trends through the splines, the smoothing function of the GAM. Next, the final model was selected through several rounds of model fitting. We then used graphical assessments and formal statistical approaches for the model estimation and diagnostics. For graphical assessments, we plotted the model fit, partial autocorrelation function, residual deviance, and periodograms. For formal statistical approaches, the Akaike Information Criterion (AIC), a measure of a model’s goodness of fit, was used. In general, lower AIC values indicate a better model fit.

In the first model (AIC = 6130.42), the suicide rates in each month of the study period were fitted to the long-term trends using the smoothing function with 11 degrees of freedom. In the second model (AIC = 2350.75), seasonal trends were incorporated for each month, again using 11 degrees of freedom. In the final model (AIC = 2327.66), unemployment rates were further incorporated based on two-month moving average values.

Next, relative risks (RR) were calculated to correspond to a 10% decrement in AFF GDP from previous months. To investigate the unconstrained time lag effect between GDP and suicide rates, polynomial distributed lag models were generated using the R package “ares” [9]. The adopted level of statistical significance was alpha = 5% in all analyses.

The long-term and seasonal suicide trends and percentage changes in AFF GDP from previous months are shown in Fig. 1 for the period under study. The figure shows that suicide level peaked during April to July in terms of the seasonal trend and during the period 2004-2005 in terms of the long-term trend. After controlling for the long-term and seasonal trends, the residuals of the suicide rate were also calculated (Fig. 1).

We used polynomial distributed lag models to calculate the lag effect of GDP changes on suicidal rate in AFF workers (Fig. 2). Significant inverse correlations between a 10% decrement in GDP and suicide rate in lags 1-4 (lag 1: RR = 1.07, 95% confidence interval [CI] = 1.00-1.15; lag 2: RR = 1.09, 95%CI = 1.04-1.13; lag 3: RR = 1.09, 95%CI = 1.05-1.13; lag 4: RR = 1.07, 95%CI = 1.03-1.11) were observed. The harvesting effect was observed in lags 7 and 8 (lag 7: RR = 0.96, 95%CI = 0.93-1.00; lag 8: RR = 0.95, 95%CI = 0.92-0.99). The overall RR was 1.69 and 95%CI was 1.57 to 1.81, respectively.

This simple but intriguing investigation highlighted the time lag effect of GDP change on the suicidal rate amongst AFF workers in Korea. The decline in GDP, as a marker of macroeconomic recession, affected suicide events in AFF workers with a time lag of between one and four months. Furthermore, the overall RR of suicide was shown to be high.
enough to bring about social concern.

To the best of our knowledge, this is the first investigation on the time lag effect of economic recession on suicide in AFF workers. Macroeconomic recession is often accompanied by decreasing incomes for individuals, which may lead to a reduction in life opportunities and an growing financial burden, thereby increasing the likelihood of other stressful life events [11]. Further, because the AFF working group consists of small-scale industries or individual proprietors, the financial burden could be sharply increased during periods of economic recession. AFF worker output is often perishable, and economic recession can lead to long waits until new or alternative products generate economic benefits. In particular, it can take several months for workers to gain economic benefits from new agricultural products. These economic characteristics of AFF workers support the findings of this study, which states that economic stress increases the risk of suicide in AFF workers for between one and four months. In term of interventions for preventing the suicide amongst AFF workers, this finding suggests that social support should be initiated with consideration of suicide fluctuation linked in economic recession [12].

Tapia Granados and Diez Roux [13,14] indicated the long term trend of death rate caused by traffic injuries and chronic disease such as cardiovascular disease, cancer, liver cirrhosis and respiratory infections increased with economic expansion. Ruhm [15] suggested that lifestyles and health behavioral changes in temporary economic recession might play an important role for the occurrence of such a phenomenon. In contrary to chronic diseases, suicide rates fall in economic expansion and parallel with unemployment ratio [13,14]. Previously, well designed systemic analysis had been undertaken in Korea; Khang et al. [16] highlighted some different trends of death rate in Korea when compared to other countries. With respect to suicide, they suggested the social supporting system, which plays a major role as the buffer system for suicide fluctuation, as the foremost cause for the presence of main difference when compared to other countries.

The present study has several limitations. We could not fully explain the reason for time lag effect between macroeconomic recession and suicide. Suicide is affected by several risk factors [17]. These include bio-psychosocial risk factors such as mental disorders, alcohol and other substance abuse, physical illness, and family history; environmental risk factors such as social loss, easy access to lethal means, and economic recession; and socio-cultural risk factors such as a lack of social support and a sense of isolation, certain cultural and religious beliefs, and exposure to and influence by others who have died by suicide. Moreover, we did not adjust for these co-risk factors in this model. Because of selected time lags in time series analysis have apparent arbitrariness, there might be lack of ability to replicate finding from the same data [18]. Hence, to avoid the arbitrariness, we permitted the time lag period from 0 to 12 months in model fitting. However, the period of time lag effect could be changed by different model fitting.

Although this investigation has several limitations, if we focus on the fluctuation between macroeconomic recession and suicide, the results of this study might contribute to gain understanding and preventing on suicide amongst AFF workers.

**Conflict of Interest**

No potential conflict of interest relevant to this article was reported.

**References**

1. Chang SS, Gunnell D, Sterne JA, Lu TH, Cheng AT. Was the economic crisis 1997-1998 responsible for rising suicide rates in East/Southeast Asia? A time-trend analysis for Japan, Hong Kong, South Korea, Taiwan, Singapore and Thailand. Soc Sci Med 2009;68:1322-31.
2. Kaga M, Takeshima T, Matsumoto T. Suicide and its prevention in Japan. Leg Med (Tokyo) 2009;11(Suppl 1):S18-21.
3. Kondo N, Subramanian SV, Kawachi I, Takeda Y, Yamagata Z. Economic recession and health inequalities in Japan: analysis with a national sample, 1986-2001. J Epidemiol Community Health 2008;62:869-75.
4. Luoto R, Poikolainen K, Uutela A. Unemployment, sociodemographic background and consumption of alcohol before and during the economic recession of the 1990s in Finland. Int J Epidemiol 1998;27:623-9.
5. Jahoda M. Economic recession and mental health: Some conceptual issues. J Soc Issue 1988;44:13-23.
6. Yoon JH, Lee KH, Hahn KY, Chang SJ, Cha BS, Min SH, Lee KS, Chae HS, Eom A, Koh SB. Suicide trend of standarized mortality ratio and age standardized proportion mortality ratio according to occupational groups in Korea: 1993-2007. Korean J Occup Environ Med 2011;23:173-82.
7. Kposowa AJ. Suicide mortality in the United States: differentials by industrial and occupational groups. Am J Ind Med 1999;36:645-52.
8. Lee WJ, Cha ES, Park ES, Kong KA, Yi JH, Son M. Deaths from pesticide poisoning in South Korea: trends over 10 years. Int Arch Occup Environ Health 2009;82:365-71.
9. Junger W, de Leon AP. Ares: A library for time series analysis in air pollution and health effects studies using R. Epidemiology 2009;20:S217.
10. Schwartz J. The distributed lag between air pollution and daily deaths. Epidemiology 2000;11:320-6.
11. Barth A, Sögner L, Gnambs T, Kundi M, Reiner A, Winker R. Socioeconomic factors and suicide: an analysis of 18 industrialized countries for the years 1983 through 2007. J Occup Environ Med 2011;53:313-7.
12. McKee M, Suhreke M. Commentary: health and economic transition. Int J Epidemiol 2005;34:1203-6.
13. Tapia Granados JA. Increasing mortality during the expansions of the US economy, 1900-1996. Int J Epidemiol 2005;34:1194-202.
14. Tapia Granados JA, Diez Roux AV. Life and death during the Great Depression. Proc Natl Acad Sci U S A 2009;106:17290-5.
15. Ruhm CJ. Commentary: mortality increases during economic upturns. Int J Epidemiol 2005;34:1206-11.
16. Khang YH, Lynch JW, Kaplan GA. Impact of economic crisis on cause-specific mortality in South Korea. Int J Epidemiol 2005;34:1291-301.
17. Li Z, Page A, Martin G, Taylor R. Attributable risk of psychiatric and socio-economic factors for suicide from individual-level, population-based studies: a systematic review. Soc Sci Med 2011;72:608-16.
18. Berkman LF, Kawachi I. Social epidemiology. New York (NY): Oxford University Press; 2000. 382 p.