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Option Pricing of Weather Derivatives for Seoul

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Abstract. This article analyses temperature data for Seoul based on a well defined daily average temperature (DAT) derived from records dating from 1954 to 2009, and considers related weather derivatives using a previous methodology. The temperature data exhibit some quite distinctive features, compared to other cities that have been considered before. Thus Seoul has: (i) four clear seasons; (ii) a significant seasonal range, with high temperature and humidity in the summer but low temperature and very dry weather in winter; and (iii) cycles of three cold days and four warmer days in winter. Due to these characteristics, seasonal variance and oscillation in Seoul is more apparent in winter and less evident in summer than in the other cities. We construct a deterministic model for the average temperature and then simulate future weather patterns, before pricing various weather derivative options and calculating the market price of risk (MPR).

AMS subject classifications: 91G20, 60H15, 60J65

Key words: Weather derivatives, market price of risk, HDD, CDD, CAT.

1. Introduction

On January 4, 2010 there was a 25.8 centimeters snowfall in the central area of Korea encompassing the Capital Region and Gangwon-do, a record-breaking event since 1937. This heavy snowfall temporarily paralyzed transportation in that large area, and caused numerous accidents on the icy roads. Many agricultural facilities, including the ginseng greenhouses, were also broken by the weight of the piled-up snow. The loss of property caused by this snowfall was estimated to total 10.6 billion won. Apart from heavy snowfalls, the extreme weather events in Korea include unexpectedly intensive typhoons, heavy rains and heat waves in summer, and very cold winters. The cost of the annual average weather damage during the last ten years has been estimated to be more than 2 trillion

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won, so financial losses due to weather risks should be covered by adequate weather-related insurances and derivatives. However, the Korean insurance market is rather stagnant, especially in regard to weather risks. According to the General Insurance Association of Korea, the number of weather-related contracts was thirty-six in 2002, twenty-seven in 2003, and forty-one in 2004. Although the market may be growing, it is restricted to contingency insurance where the insurance companies compensate the insured for damages that actually happen, and the proper estimation of total losses between the policyholders and the companies remains highly controversial.

The importance of weather risk has been recognized in most developed countries, where it is fast becoming customary to provide against uncertain climatic change. The typical provision includes the introduction of weather derivatives and associated Risk Management. An early weather transaction was executed by Aquila Energy, which structured a dual-commodity hedge for the Edison Company in 1996. Over-the-counter (OTC) weather derivatives have been traded since 1997, and at the Chicago Mercantile Exchange (CME) since the summer of 1999. In September 2003, the CME launched seasonality products for ten new cities, and then monthly for a list of twelve cities in the USA that was expanded to include five European cities. The CME now offers temperature products for twenty-four cities in the USA, six in Canada, eleven in Europe, three in Australia, and three elsewhere in the Asia-Pacific — cf. Tables 1 and 2). In addition to the increasing number of cities covered at the CME, the volume of weather derivative contracts issued has significantly increased — from 630,000 in 2005 to 798,000 in 2006, and to nearly 1,000,000 in 2007 [12, 23]. Although the volume did fall by about 16 % in 2008, that occurred during the onset of the current global financial crisis.

With the rapid growth of weather-related industries, relevant futures prices have been studied extensively [2–6,9,11,13,15–17,19–22,25–29]. Since weather derivatives are non-tradable, no-arbitrage models (such as the Black-Scholes model) are inapplicable to pricing weather options. In 2000, Dornier & Querel [13] used mean-reverting Itô diffusions based on a standard Brownian motion to model Chicago temperature data. Brody *et al.*! [9] proposed another dynamical model based on a fractional Brownian motion, and Alaton *et al.* [2] applied the Ornstein-Uhlenbeck process with a monthly variation to analyze the temperature at the Bromma Airport, Stockholm. Benth *et al.* [4, 5] generalized Dornier & Querel's approach by employing continuous autoregressive (CAR) models to analyze temperature data at Stockholm; and Härdle & Cabrera [16] also applied the CAR approach to Berlin temperature data, but they considered a nonzero market price of risk (MPR). To date no significant research for Korean weather derivatives and pricing has been reported, and a weather market has yet to be introduced. However, in order to keep pace with the growth of world-wide weather markets, the Financial Supervisory Commission of Korea now seems to favour the introduction and development of weather derivatives. The Korea Meteorological Administration (KMA) has also recently announced it intends to develop a weather index effective from 2012, to serve as one basic reference.

In this paper, we analyse the Seoul temperature data and then price related weather options, using the approach adopted in Refs. [2], [5] and [16]. The paper is organized as follows. In Section 2, we construct our Seoul temperature model based on observed data.