Explanatory Factors and Causality in the Dynamics of Volatility Surfaces Implied from OTC Asian–Pacific Currency Options

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Abstract Volatility implied from observed option contracts systematically varies with the contracts’ strike price and time to expiration, giving rise to an instantaneously non-flat implied volatility surface (IVS) that exhibits substantial time variation. We identify a number of latent factors that drive the dynamics of the IVSs from options on 11 Asian–Pacific exchange rates and show that these have a natural interpretation in the law of motion of each surface. We present evidence that these latent factors are related due to their common dependence on exogenous economy-wide variables. Findings suggest that the factors capturing (i) the volatility level of the Japanese yen and the Chinese yuan, (ii) the volatility term structure of the Japanese yen, Taiwanese and Australian dollars and (iii) the risk aversion towards the Australian dollar, Japanese yen and Chinese yuan seem to incorporate first the investors’ expectations regarding the volatility in the region.

Keywords Implied volatility surfaces · Factor model · Causality

1 Introduction

Not a single feature of the Black–Scholes–Merton framework (Black and Scholes 1973; Merton 1973) has attracted more research effort from academics and practitioners than the deviations of observed implied volatilities from a theoretically flat instantaneous profile.

Indeed, when plotted against moneyness, the volatilities implied from observed option contracts exhibit a “smile” or a “skew” (see Canina and Figlewski 1993;
Rubinstein 1994), which is also a function of the option’s time to expiration (see Heynen et al. 1994; Xu and Taylor 1994; Campa and Chang 1995).

To complicate things, this non-flat implied volatility surface (IVS hereafter) changes significantly through time: the “term-structure” changes steepness and sign while the “smile” changes slope from period to period (see Rubinstein 1985; Dumas et al. 1998; Christoffersen and Jacobs 2004).

Many argue (e.g. Bates 1996) that this possibly reflects the fact that option pricing models are partial equilibrium in nature and can not directly account for economy-wide fundamentals that might be causing the significant time variation in the calibrated parameters needed to capture the dynamics of the observed IVS.

Under this argument, the significant time variation in the surface implied from option contracts is partly caused by economy-wide explanatory variables and partly by variables specific to the option contracts and their underlying assets. Moreover, and in some respects more importantly, if such economy-wide explanatory variables are present, their effect should manifest in a time-series dependence of the surfaces implied from options written on different underlying assets.

The purpose of this paper is to characterise the dynamics of IVSs through time, investigate their relationship with changes in observable, economy-wide and contract-specific variables, and examine whether linear causal effects are present in the time evolution of surfaces implied from different underlying assets.

Towards this end we use daily time-series of implied volatilities for a cross-section of currency options on 11 different Asian–Pacific currencies quoted against the U.S. dollar from the OTC market. In a first stage, without having to resort to the tightly parameterised ad hoc implied volatility models that practitioners often employ (see for example the discussion in Dumas et al. 1998), we are able to identify and characterise the systematic movements in the 11 IVSs by extracting a few orthogonal statistical factors that are driving their dynamics. These factors are shown to have a natural interpretation in the law of motion of each IVS that is straightforward and intuitively appealing to practitioners.

In a second stage, we examine the time-series properties of the factors that are identified in the dynamics of the 11 IVSs, their seasonality and the extent to which their variation can be explained from exogenous economic variables.

In contrast to studies that focus on equity index options, we find no evidence of daily seasonality in the IVS dynamics of FX options on Asian–Pacific currencies. However there is weak evidence of monthly seasonality: the “term-structure” of the surface is lower during the last months of a year in more than half of the IVSs in our sample. Turning to the determinants of the factors driving the IVS dynamics of FX options, we show that a combination of variables that are specific to the underlying currency and others that proxy for the relative momentum of the underlying economy and economic conditions worldwide can vastly explain the factors that drive the dynamics of the surfaces.

At a final stage, we ask whether linear causal effects are present in the systematic movements of the IVSs of Asian–Pacific currencies. We report strong evidence that (a) the level of volatility in the region is driven primarily by the volatility of the Japanese currency (and by that of the Chinese yuan at a lesser extent), (b) the term-structure of implied volatilities in the region appears to lag the expectations regarding the Jap-