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(Article begins on next page)

Fair Value Measurement Accounting in the Absence of Prudence: An Illustration with Exotic Derivatives

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Abstract

The aim of this paper is to contribute to the current discussion about Fair Value Accounting (FVA), especially, when accounting standard setters have eliminated from their conceptual frameworks any reference to prudence. We discuss the problematic surrounding FVA by relying on the role played by prudence, its meaning, and how the treatment of prudence has changed in the accounting framework of standard setters due to its "apparent" inconsistency with neutrality. To highlight the relevance of this issue, we provide (1) a brief analysis of the high impact that Level 2 fair value estimates have on large U.S. and European banks' financial positions; (2) a "case study" by pricing two common exotic derivatives and comparing the valuation results of two different assumptions of volatility (local vs. stochastic); and (3) a discussion of potential solutions to the problematic surrounding FVA. Ours findings are consistent with the argument that neutrality is supported by the exercise of prudence in achieving a faithful representation, since a non-conservative use of FVA can lead bank managers toward model misspecification error in the valuation of complex financial instruments. We conclude by arguing that the problematic surrounding FVA can be mitigated if prudence is reinstated by standards setters.

Keywords

Fair value, prudence, exotic options, model misspecification error, implied volatility, local volatility, stochastic volatility.

1. Introduction

The subprime crisis has provoked intense debate about the accounting rules employed by banks. The main rule in question is the use of fair value accounting (FVA) for financial instrument as required by International Financial Reporting Standard (IFRS) No. 13. Initially, the major controversy focused on the possibility that FVA contributed to the financial crisis (Bhat et al., 2011) or, at least, aggravated its severity (Laux and Leuz, 2010). It seems now that users, standard setters, and the academia understand better that FVA measurements and other estimates provide benefits in terms of higher potential relevance to users than would be provided by previous accounting measures, such as historical cost (Christensen *et al*, 2012; Song *et al*, 2010). The question is no longer whether we should accept FVA or not (Barth, 2006). The remaining issue is how to estimate FVA, particularly, in the case of extreme fair value measurements.

While we agree that FVA is essentially a valuation problem, we posit that the issue is also exacerbated by standard setters' position. Traditionally, standards setters have established the prudence as the qualitative characteristic of accounting information that implies "the inclusion of a degree of caution in the exercise of the judgments needed in making the estimates required under conditions of uncertainty, such that assets or income are not overstated and liabilities or expenses are not understated" (International Accounting Standards Committee (IASB), 1989, p. 37). However, with the introduction of FVA, the role of prudence was questioned by standard setters (Wagenhofer, 2015). Since fair value is theoretically better represented by a point measure, standard setters argued that holding prudence would be inconsistent with the desired characteristic of neutrality for the financial information, with neutrality meaning lack of influence in user's decisions. By relying on this interpretation, the IASB decided to remove any reference to "prudence" in 2010 from its conceptual framework because of its "apparent" conflict with neutrality. But the debate has been reopened, when the European Financial Reporting Advisory Group (EFRAG) recently noted diverse views on the desirability of prudence, and some constituents again are trying to push the IASB toward including prudence in the accounting framework (Wagenhofer, 2015).

In this paper we share the initiative of reinstating an explicit reference to the notion of prudence consistent with the proposed Exposure Draft on Conceptual Framework for Financial Reporting, the IASB (2015, 2.17-18) and posit that prudence is not only a desirable component of the characteristics of financial reporting but also a proper way to support neutrality, especially, in the case of high uncertain FVA estimates by financial institutions where these measurements seem to be used for a substantial proportion of assets and liabilities (Nobes, 2015).

According to the International Accounting Standards Board (IASB, 2011), fair value is "the price that would be received to sell an asset or paid to transfer a liability in an orderly transaction between market participants at the measurement date" (IFRS No. 13). The standard also introduces the concept of a *fair value hierarchy* based on the observability of the inputs. This hierarchy prioritizes the inputs used to measure fair values into three broad levels. Level 1 inputs are quoted prices in active markets for identical assets or liabilities (i.e., pure mark-to-market). Level 2 valuations are based on directly or indirectly observable market data for similar or comparable assets or liabilities. Two types of valuations are typically distinguished within Level 2: (i) adjusted mark-to-market relies on quoted market prices in active markets for similar items, or in inactive markets for identical items; (ii) mark-to-model valuation uses such inputs as yield curves, exchange rates, implied volatilities, etc. Level 3 valuations are based on unobservable inputs that reflect the reporting entity's own assumptions (i.e., pure mark-to-model).[1]

IFRS No. 13 gives the highest priority to (unadjusted) quoted prices in active markets for identical assets or liabilities and the lowest priority to unobservable inputs. Level 1 inputs (i.e., those with market prices) are the only ones truly meeting the definition of fair value, making the information asymmetry between preparers and users very low (Song *et al*, 2010). However, the standard is silent regarding any difficulties related to market friction, including those resulting from imperfect and incomplete markets (Bratten *et al*, 2012). Thus, the controversial part of the standard is how to value an asset or a liability when an active market does not exist (i.e., in the case of Level 2 and Level 3 valuations). Since it is difficult for users to observe directly how bank managers adapt those inputs to generate reported fair values, the information asymmetry between preparers and users is expected to be very high for Level 2 and Level 3 fair value estimates. For these reasons, fair value estimates of complex or illiquid financial instruments have been denoted by critics as "marking to myth" (Bratten *et al*, 2012).

The problem with the fair value hierarchy is that fair value measurements in the absence of observed prices might be unreliable due to intrinsic model misspecification error (Barth, 2004; Song *et al*, 2010; Derman and Wilmott, 2009). Model misspecification error is rooted in the nonexistence of well-developed models to estimate fair values of all assets and liabilities (Barth, 2004). This error can be defined as the risk to use a valuation model that does not reflect the market conditions for a financial instrument at a particular point in time. An inadequate valuation model produces wrong measures that disturb the decision-making process, either internally or externally, and could deny all

[1] Examples of financial instruments classified as Level 1 fair value estimates include treasuries, derivatives, equity and cash products when all of them are traded on high-liquidity exchanges. Examples of Level 2 fair value estimates include many over-the-counter (OTC) derivatives, such as interest rate swaps, foreign currency swaps, commodity swaps, and certain options and forward contracts. Other financial instruments classified as Level 2 are mortgage-backed securities, mortgage loans, many investment-grade listed credit bonds, some credit default swaps (CDS), many collateralized debt obligations (CDO), and less-liquid equity instruments. Examples of Level 3 estimates include complex and highly structured derivatives, distressed debt, highly-structured bonds, illiquid asset-backed securities (ABS), illiquid CDOs, private equity placements, and illiquid loans.

the benefits associated with the use of FVA if the amount of the associated estimate error is material.[2] While the exposure to model misspecification error is minimum for Level 1 fair value estimates, for Level 2 and 3 fair values model misspecification error depends on the precision of the estimates (Barth, 2004).

Since there has been a remarkable growth of structured products (Hull and Suo, 2002; European Commission Press Releases, 2010), financial institutions that commercialize these products are exposed to the existence of model misspecification risk. The use of inadequate models to price and hedge the risks associated with these options has resulted in large losses for several trading books (see Jeffery, 2004). As pointed out by Loomis (2009), exotic derivatives are quite difficult to value and can lead to misreported profit and assets/liabilities. Indeed, some derivatives are so difficult to value and so model dependent that it is possible for both parties to book a profit on the same contract depending of their valuation models. But the problem of model dependency also affects other products and markets.[3]

This paper contributes to the literature by revisiting the role played by prudence in FVA. Specifically, we posit that the elimination of the concept of prudence may be an important factor of the problematic surrounding FVA estimates. To highlight the relevance of this issue, we briefly analyze the impact that Level 2 fair value estimates have on large U.S. and European banks' financial positions. We also provide a "case study" by pricing two common exotic derivatives and comparing the valuation results of two different but commonly used assumptions of volatility (local volatility vs.

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[2] Bank regulators have claimed sound processes for model development and validation (Basel Committee on Banking Supervision, 2009, Principle §4; Board of Governors of the Federal Reserve System, 2011: Sections IV &V).

[3] For instance, in 2008, mispricing and pricing errors in structured credit products generated huge losses for Credit Suisse (see Mwamba, 2008). More recently, in April and May 2012, large trading losses occurred at JPMorgan's Chief Investment Office, based on transactions booked through its London branch (see, for instance, Ahmed, May 26, 2012; Celarier, May 16, 2012; Zuckerman and Burne, April 6, 2012). In particular, a series of derivative transactions involving credit default swaps (CDS) were entered, reportedly as part of the bank's "hedging" strategy. This strategy generated an estimated trading loss of $2 billion. These events gave rise to a number of investigations to examine the firm's risk management systems and internal controls. It is difficult to have a detailed estimation of the percentage of assets that exotic options represents given that financial institutions do not disclosure this information. But what is clear from the previous examples is the big potential impact that these structures may have in the profit and loss accounts of these companies.

stochastic volatility). The results obtained from our case study are consistent with the argument that neutrality might be actually supported by the exercise of prudence in achieving a faithful representation, since a non-conservative use of FVA can lead bank managers toward model misspecification error in the valuation of complex financial instruments traded in illiquid markets. We conclude by arguing that the problematic surrounding FVA can be mitigated if prudence is reinstated by accounting standards setters. Our results have important implications for both accounting and auditing standard setters, as well as for bank regulators.

The remainder of this paper is organized as follows. In §2, we summarize the meaning of the prudence concept and how the treatment of prudence has changed in the accounting framework of standard setters. In §3, we illustrate the relevance of the issue by providing a brief descriptive analysis of the impact that Level 2 fair value estimates have on large U.S. and European banks' financial positions. In §4, we present a case study on volatility models that we use to examine the problematic surrounding the FVA of two common exotic derivatives. Finally, in §5, we present our conclusions and the implications of our findings.

2. Prudence, neutrality and fair value accounting measurements

The primary objective of financial reporting is to provide financial information that is useful to present and potential investors and creditors for making decisions about capital allocation. To be useful, financial statements must provide information that is relevant and faithfully represents the economic activity it depicts. However, some financial statement items cannot be measured precisely and can only be estimated. Since accounting estimates are made by management teams, they are subject to many incentives that could lead them to introduce an unintentional or intentional bias into financial reporting (Cooper, 2015).

To cope with estimation uncertainty standard setters have traditionally used the concept of "prudence", defined as the qualitative characteristic of accounting information that implies "the inclusion of a degree of caution in the exercise of the judgments needed in making the estimates required under conditions of uncertainty,…" (IASB, 1989, p. 37). Until 2010, the argument was that the application of prudence (conservatism) ensures that gains are reported only if they are highly probable or reasonably certain but that losses are recognized as soon as they are identified (expected), reflecting the view that prudence is necessary to counter the overstatement of income (EFRAG, 2013).[4]

Even though many believe that prudence contributes to the credibility of financial statements, it has been always a contentious concept. It has been also argued that prudence may conflict with the neutral (or unbiased) view that financial statements should provide. In this view, prudence may causes bias in financial reporting by introducing a degree of skepticism that diverges from unbiased or neutral financial reporting. This argument was especially strong with the introduction of FVA, as conceptually fair value is better represented by a point measure. As a result, FASB (2010) and IASB (2010) jointly eliminated from their conceptual frameworks any explicit reference to prudence (conservatism) because it would be inconsistent with the desired characteristic of neutrality for the financial information, with neutrality meaning lack of influence of accounting estimates in user's decisions (i.e., without any systematic bias).

But this was not the end of prudence. Despite removing the word 'prudence' was never meant to give the green light to imprudent financial reporting (Hoogervorst and Prada, 2015), many now believe it (Meall, 2015). There was an important failure in the rationale of the conflict between prudence and neutrality, because neutrality can hardly be interpreted as lack of influence of accounting numbers in making decisions (EFRAG, 2013; Cooper, 2015). Instead, it seems that neutrality should be conceived as the characteristic of the financial information that by itself (i.e., the form in which are estimated or disclosed) does not intent to influence decision making but facilitate it. Thus, it would be desirable for the financial statements to represent a company's financial results 'neutrally', without any systematic bias (neutral accounting), which "means avoiding the dangers of an optimistic bias, but also not introducing the equally damaging implications of a negative bias." (Cooper, 2015, p.2).

[4] Prudence also provokes an asymmetry in the recognition of assets and liabilities, as it requires a higher degree of certainty before recognition of assets than of liabilities.

In the new proposed Exposure Draft on Conceptual Framework for Financial Reporting, the IASB (2015) reintroduces an explicit reference to the notion of prudence, described as caution when making judgments under conditions of uncertainty, and states that neutrality is supported by the exercise of prudence in achieving a faithful representation.[5] In the particular case of complex financial instruments traded in illiquid markets (Level 2 estimates), prudence is now argued to be the proper way to deal with high uncertainty and neutrality has to be interpreted as the lack of commitment/interest of the valuator in the decisions made by users based on the information provided. In other words, the exposure draft claims that accounting information is not neutral in essence as it depicts economic events and performance, and prompts decisions by interest parties that use financial statements. What has to be neutral is the way to present such information when it relies on severe conditions of uncertainty.

In this paper we share standard setters' proposal to put prudence back and believe that it is possible to have FVA estimates that are both consistently prudent and neutral. As in the case of pension liabilities that are strongly depended on the actuarial method and the assumptions made, the accuracy of measures in the case of FVA for complex financial instruments rests heavily on the model used to made estimation and the specification of variables used as inputs in such models. Consistent with the proposal, we posit that prudence is not only a desirable component of the characteristics of financial reporting but also a proper way to support neutrality in the measurement of high uncertain FVA estimates.

3. Fair value measurements of level 2 financial instruments by banks

To emphasize the importance of FVA estimates, in this section, we provide a brief descriptive analysis of the weight of Level 2 fair value estimates on the financial position of U.S. and European

[5] Prudence (conservatism) would be better conceived as the rejection of a single point measure in the case of high uncertainty in FVA. The single point number must be supplemented with other disclosures in order to clarify the extent of the uncertainty regarding the measure (e.g., by setting the assumptions made, giving the most probable range of values or explaining the sensibility of the value to changes in the inputs used in the valuation techniques). This would be the way to reach neutrality in financial reporting according to the Exposure Draft on Conceptual Framework for Financial Reporting (IASB, 2015).

large banks. To this end, we computed the ratios of (i) total financial assets measured at Level 2 fair value to total equity, and (ii) total financial liabilities measured at Level 2 fair value to equity. The sample consists of a total of 30 banks (i.e., 17 global investment banks and 13 financial-services conglomerates combining commercial and investment banking) for the fiscal years 2011 and 2012. The financial information is taken from the consolidated balance sheets and the notes to the financial statements (i.e., fair value measurements of financial instruments).[6]

Tables 1 and 2 present Level 2 fair value estimates faced by the fifteen largest U.S. and European banks, respectively. The most salient finding is that several large banks faced Level 2 value estimates of financial assets and liabilities that are five times larger than their total equity. This situation is extreme in the case of the largest U.S. global investment banks and certain global investment European banks. Table 1 shows that the total financial assets measured at Level 2 over equity ratio for U.S. banks (both global investment and conglomerates) ranges from 117.6 percent to 1,223.3 percent, with five U.S. global investment banks (JPMorgan Chase, Bank of America, Citigroup, Goldman Sachs, and Morgan Stanley) facing an exposure higher than 500 percent. Only one U.S. conglomerate Bank, State Street, shows an exposure higher than 500 percent in terms of Assets at Level 2. The total financial liabilities measured at Level 2 over equity ratio for U.S. banks ranges from 0 percent to 1,106.4 percent, with four large U.S. global investment firms (JPMorgan Chase, Bank of America, Citigroup, and Goldman Sachs) facing an exposure higher than 500 percent. According to Table 2, the exposition to Level 2 fair value estimates is also considerable and even higher for main European global investment banking firms. The minimum and maximum values for the total financial assets measured at Level 2 over equity ratio are 156.7 percent and 3,489.3 percent, respectively, with seven European global investment banks (BNP Paribas, Deutsche Bank, Credit Agricole, Société Générale, Barclays, UBS, and Credit Suisse) facing an exposure above 500 percent. The total financial liabilities measured at Level 2 over equity ratio ranges from 118.1 to 3,463.0

[6] All data was hand-collected from the Banks' audited financial statements and annual reports.

percent, with same seven global investment banks (facing an exposure above 500 percent. Credit Suisse shows the maximum exposure, which is higher than the exposure of any other U.S. bank.[7]

(Insert Table 1 and 2 about here)

4. Pricing two common exotic derivatives: A "case study" of FVA and the role played by prudence

Once we have illustrated the seriousness of Level 2 fair value estimates faced by the largest U.S. and European banks, in this section we provide a case study of the measurement issue of two common exotic derivatives, named *cliquet* and *barrier options*. We first present the volatility models comparing the valuation results of two different but commonly used assumptions of volatility, i.e., local volatility and stochastic volatility. Then, after calibrating the models to market data, we compare the valuation results of the two volatility assumptions on the aforementioned cliquet and barrier options.

4.1. Stochastic volatility models and local volatility models

In the case of derivatives, potential model misspecification error exposure in Level 2 fair value estimates may be due to different assumptions regarding the evolution of the underlying assets. In this sense, one of the key assumptions has to do with the behavior of the instantaneous volatility. Hence, in the following subsections, we review two of the most widely used models to price equity derivatives by financial institutions.

4.1.1. Local volatility model

The local volatility model was introduced by Derman and Kani (1994), Dupire (1994), and Rubinstein (1994). This model postulates that the instantaneous volatility corresponding to the underlying asset, called local volatility, is a deterministic function of time and the asset price. In particular, let S_t denote the price associated with the underlying asset at time *t*. The local volatility

[7] We also run the analysis for the largest Asian banks. Untabulated results show that weight of Level 2 fair value estimates is relatively low for most Asian banks. Only one Asian bank (HSBC) faces an exposure above 500 percent.

model postulates the following process to characterize its behavior under the risk-neutral probability measure Q:

$$\frac{dS_t}{S_t} = (r-q)\,dt + \sigma(t,S_t)\,dW_t^Q \tag{1}$$

where $\sigma(t,S_t)$ is the local volatility function and W_t^Q is a Wiener process under the risk-neutral probability measure. For simplicity, we assume that the continuously compounded risk-free rate r and the dividend yield q are constant. The local volatility model is able to capture quite accurately the existence of volatility skew (Derman and Kani, 1994; Dupire, 1994; Derman, 2003). The term volatility skew accounts for the negative relation between strike prices and volatilities widely observed in equity options markets since the stock market crash on October 1987. In particular, Dupire (1994) shows that the following relationship holds between time t = 0 European call option prices of strike price K and maturity T, $C_{0T}(K)$, and the one dimensional local volatility function:

$$\sigma(T,S_T=K) = \sqrt{2\left[\frac{\frac{\partial C_{0T}(K)}{\partial T} + K\frac{\partial C_{0T}(K)}{\partial K}(r-q) + qC_{0T}(K)}{K^2\frac{\partial^2 C_{0T}(K)}{\partial K^2}}\right]} \tag{2}$$

Equation (2) shows that it is possible to recover the local volatility function using the market price of European options. Let $D(S_t,t)$ denote the time t price of a derivative, which can be path-dependent, on an asset whose time t price is given by S_t. If the underlying asset price follows the risk-neutral process of equation (1), replication arguments show that the derivative asset satisfies the backward-Kolmogorov equation:

$$\frac{\partial D(S_t,t)}{\partial t} + (r-q)S_t\frac{\partial D(S_t,t)}{\partial S_t} + \frac{1}{2}\sigma^2(t,S_t)S_t^2\frac{\partial^2 D(S_t,t)}{\partial S_t^2} - rD(S_t,t) = 0 \tag{3}$$

where $\sigma(t, S_t)$ is given by equation (2). Hence, options can be priced through a Monte Carlo simulation, based on the asset price dynamics of equation (1) or through a finite-difference scheme, based on equation (3). This approach is particularly useful for instruments with early-exercise features.

4.1.2. Heston model

The second group of models considered is the class of stochastic volatility models. These models assume that the asset price and its instantaneous volatility follow stochastic processes that may be correlated. These models are able to account for second order effects, such as the existence of volatility in the volatility, that are of key importance in the correct valuation of some exotic derivatives. Moreover, under the assumption of a negative correlation between the asset price process and its instantaneous volatility, these models are able to generate a negative volatility skew. Within the group of stochastic volatility models, this article considers the Heston (1993) model, which is one of the most commonly used among financial institutions to price exotic derivatives. This model offers semi-closed form solutions for the price of European options and, hence, it is possible to calibrate the model parameters to the market prices of the European options quoted in the market.

The Heston model (1993) postulates the following dynamics for the asset return and its instantaneous volatility v_t, under the risk-neutral measure *Q*:

$$\frac{dS_t}{S_t} = (r - q)\,dt + \sqrt{v_t}\,dW_{S,t}^Q \qquad (4)$$

$$dv_t = \kappa(\theta - v_t)\,dt + \eta\sqrt{v_t}\,dW_{v,t}^Q \qquad (5)$$

where θ represents the long-term mean corresponding to the instantaneous variance, κ denotes the speed of mean reversion, and η is the volatility of variance. $W_{S,t}^Q$ and $W_{v,t}^Q$ are two Wiener processes under the risk-neutral probability measure *Q*. Both processes are correlated so that:

$$dW_{S,t}^Q\,dW_{v,t}^Q = \rho\,dt$$

There are two parameters that affect crucially options prices regarding the distribution corresponding to asset returns. The correlation parameter ρ affects the symmetry of the distribution and, hence, it accounts for the volatility skew. In this sense, a negative correlation level implies higher variance in the market downside. This fact generates higher prices for out-of-the-money puts.

On the other hand, the volatility of variance η has an effect on the kurtosis of the distribution. The higher η, the fatter the tails of the distribution. This effect increases the prices corresponding to out-of-the-money calls and puts, given that it is more likely that these options expire in-the-money.

Let us consider a European call with strike price *K* and maturity *t=T*. Its payoff at maturity can be expressed as:

$$\left(S_T - K\right)^+ = \left(S_T - K\right)1_{(S_T > K)}$$

where $1_{(S_T>K)}$ is the indicator function of Heaviside step function. Hence, the option price under the risk-neutral probability measure is given by:

$$C_{0T}\left(K\right) = e^{-qT} S_0 P_1 - P\left(0,T\right) K P_2 \qquad (6)$$

where $P\left(0,T\right) = e^{-rT}$ is the time $t=0$ price of a zero coupon bond that pays a monetary unit at time $t=T$ and $E_Q\left[.\right]$ represents the expected value under the risk neutral probability measure *Q*.

Heston (1993) shows that the functions P_j (for $j=1,2$) can be obtained via the Fourier inverse transform:

$$P_j = \frac{1}{2} + \frac{1}{\pi}\int_0^\infty Re\left[\frac{e^{-iz\ln(K)} f_j}{iz}\right] dz \qquad (7)$$

where $i=\sqrt{-1}$ and f_j for $j=1,2,$ are the characteristic functions corresponding to P_j . The detailed expressions for these equations can be found in appendix A.

To calculate the price of a European option, using the formula of equation (6), it is necessary to solve the integrals of equation (7) numerically.

Let $D\left(S_T\right)$ denote the terminal value corresponding to a derivative on *S*. Its time *t* value, denoted as $D\left(S_t, v_t, t\right)$, verifies the following partial differential equation:

$$\begin{aligned} rD_t &= \frac{\partial D_t}{\partial t} + \left(r-q\right)S_t \frac{\partial D_t}{\partial S_t} + \kappa\left(\theta - v_t\right)\frac{\partial D_t}{\partial v_t} + \\ &\frac{1}{2}\frac{\partial^2 D_t}{\partial S_t^2} v_t S_t^2 + \frac{1}{2}\frac{\partial^2 D_t}{\partial v_t^2} v_t \sigma^2 + \frac{\partial^2 D_t}{\partial S_t \partial v_t} v_t S_t \rho\sigma \end{aligned} \tag{8}$$

Note that the previous equation includes additional terms that were not present in the backward-Kolmogorov equation associated with the local volatility model. In particular, the term $\frac{\partial D_t}{\partial v_t}$ is related to the vega of the derivative, the convexity factor with respect to volatility $\frac{\partial^2 D_t}{\partial v_t^2}$ has to do with the volga and, finally, the cross-convexity term $\frac{\partial^2 D_t}{\partial S_t \partial v_t}$ is related to the vanna of the derivative. The use of valuation models that do not properly account for these effects to price derivatives, which are sensitive to them, can lead to important price discrepancies as we will see in this article.

4.2. Calibration to market data

To calibrate the models, in this section we follow the methodology introduced by Hull and Suo (2002) to measure the model risk embedded in the pricing of exotic options. To this end, we mimic the way in which practitioners price these options. They typically use a model to price a particular exotic option in terms of the observed market prices at a particular time. In this sense, they calibrate the model parameters to the market prices of vanilla instruments at a point in time and use the model parameters to price exotic options at the same time. Following Hull and Suo (2002), we assume that market prices are governed by a stochastic volatility model. In particular, we consider the Heston (1993) model and we determine the model parameters fitting it to representative market data. The main reason for this choice is that this model is one of the most popular models within the class of stochastic volatility models.

Option prices are usually quoted using implied volatilities obtained from the Black-Scholes (1973) option pricing formula. Let C^*_{KT} denote the market price of a European call with strike price *K* and maturity *T*, on an asset whose time *t* price is given by S_t. The Black-Scholes (1973) implied volatility Σ is defined by:

$$C^*_{KT} = C^{BS}_{KT}\left(\Sigma\right)$$

where C^{BS}_{KT} is the option price obtained using the Black-Scholes (1973) formula. The implied volatility expressed as a function of the strike price and the maturity is known as the time *t* implied volatility surface.

When we calibrate a model, we have to specify if we choose a set of options quoted at a fixed day or a times series of option prices. The market practice is to perform a calibration per day. Bakshi et al. (1997), Carr *et al* (2003) and da Fonseca and Grasselli (2011), among others, follow this approach. In fact, as explained by da Fonseca and Grasselli (2011) in the context of multifactor stochastic volatility models, if we perform a calibration on a time series of option prices, since the volatility is not observable, it would have to be considered as a parameter and then estimated together with the other parameters. But this strategy leads to optimize a function with respect to a large number of variables which can become too difficult numerically and can give odd solutions. Hence, it is desirable that the calibration process involves the optimization of a function that should be as simple as possible. In this sense, we consider the implied volatility surface, associated with listed options, for the Standard and Poor's 500 equity index corresponding to February 3, 2012. The implied volatilities, as well as dividend yield and interest rate, are obtained from Bloomberg. We have 12 maturities and 13 values of moneyness, ranging from 70% to 130%. Therefore, a total of 156 points on the implied volatility surface are provided. The reference spot price for the index was 1,344.9 and the data include options expiring in September 2012, December 2012, March 2013, June 2013, September 2013, December 2013, June 2014, December 2014, December 2015, December 2016, December 2017, and December 2018.

Table 3 provides the market implied volatility surface for the Standard and Poor's 500 index corresponding to February 3, 2012, whereas figure 1 shows the data graphically. The figure reveals the existence of a negative volatility skew, which is most pronounced for near-term options. This is a common pattern of behavior that has been widely observed in equity options markets. Some examples can be found in Derman *et al* (1995) or Gatheral (2006).

(Insert Table 3 about here)

(Insert Figure 1 about here)

We choose the model parameters to provide as close a fit as possible to the observed implied volatility surface associated with the Standard and Poor's 500 index. Table 4 provides the fitted values corresponding to the parameters of the Heston (1993) model.

(Insert Table 4 about here)

The calibration results are fairly good. In particular, the total mean absolute error (MAE) corresponding to the difference between the market implied volatility surface and the implied volatility calibrated using the Heston (1993) model is 0.766%, whereas the MAE associated with at-the-money options is 0.539%. Hence, the Heston (1993) model provides an accurate fit to the market implied volatility surface corresponding to the Standard and Poor's 500 index. Figure 2 shows the implied volatility surface generated by the calibrated parameters corresponding to the Heston (1993) model.

(Insert Figure 2 about here)

We calibrate the local volatility model to the implied volatility surface generated by the Heston (1993) stochastic volatility model using the approach introduced by Marabel-Romo (2012) to calculate the local volatility. This methodology consists of smoothing the implied volatility through a flexible parametric function, which is consistent with the no-arbitrage conditions developed by Lee

(2004) for the asymptotic behavior of the implied volatility at extreme strikes. The local volatility function is then calculated analytically. This approach allows obtaining smooth and stable local volatility surfaces while capturing the prices of vanilla options quite accurately. In this sense, the MAE corresponding to the difference between the implied volatility surface calibrated using the local volatility model and the implied volatilities generated by the Heston (1993) specification of Table 4 is 0.102%, whereas the MAE associated with at-the-money options is 0.120%. Figure 3 provides the implied volatility surface associated with the local volatility specification. We can see from the figure that it is quite similar to the implied volatility surface of Figure 2 associated with the Heston (1993) model.

(Insert Figure 3 about here)

4.3. On the fair valuation of exotic options

This section provides a numerical illustration, which shows the importance of using a valuation model that properly accounts for potential model misspecification error associated with the exotic derivatives. The key point of the model risk is that different models can yield the same price for European options but, at the same time, very different prices for exotic options depending on their assumptions corresponding to the evolution of the underlying asset price and its volatility.

4.3.1. Barrier option

The up-and-out calls have become a pretty used derivative by the investors who are interested in assuming a long exposure in the underlying asset. If investors believe that the underlying asset price is going to increase without exceeding a certain level, they can invest in an up-and-out call at a cheaper price than a European call or a call spread.

Formally, the payoff at maturity of an up-and-out call with barrier H, strike price K, and maturity $t=T$ is given by:

$$\left(S_T - K\right)^+ 1_{(N_T < H)}$$
$$N_T = \max_{0 \le t \le T}\left(S_t\right) \qquad H > K$$

where $1_{(N_T<H)}$ represents the indicator function. Under the assumptions of the Black-Scholes (1973) model[8], it is well known (see for instance Derman and Kani, 1997) that it is possible to calculate the price associated with the up-and-out call using the following expression:

$$\begin{aligned} UOC_{0T}(K,H) &= C_{0T}^{BS}(S_0,K) - C_{0T}^{BS}(S_0,H) - (H-K)DC_{0T}^{BS}(S_0,H) \\ &- \left(\frac{S_0}{H}\right)^{2\lambda}\left[C_{0T}^{BS}\left(\frac{H^2}{S_0},K\right) - C_{0T}^{BS}\left(\frac{H^2}{S_0},H\right) - (H-K)DC_{0T}^{BS}\left(\frac{H^2}{S_0},H\right)\right] \end{aligned} \quad (9)$$

with:

$$\lambda = \frac{1}{2} - \frac{(r-q)\Sigma^2}{4}$$

where Σ is the implied volatility and where $C_{0T}(K)$ represents the price of a European call with strike price *K* and maturity *T*, and $CD_{0T}(K)$ is the price of a digital call that pays one currency unit if, at the expiration of the option, the asset price is above the strike price. Under the assumptions of the Black-Scholes (1973) model, it is easy to obtain analytic solutions for the price of these options. Therefore, in this case, equation (9) offers a closed-form solution for the price of an up-and-out call as a function of the prices corresponding to plain vanilla options.

Unfortunately, under the other two models considered in the article we do not have closed-form solutions for the price of barrier options. Therefore, it is necessary to use numerical methods to calculate the prices. To this end, we use Monte Carlo simulations with daily time steps and 80,000 trials and we apply the antithetic variable technique described in Boyle (1977) to reduce the variance of the estimates. For the Heston (1993) model, we implement a Milstein discretization scheme as described in Gatheral (2006). Finally, for the Black-Scholes (1973) model, we use the analytic expression of equation (9).

[8] The Black-Scholes (1973) model is a simplified version of the Local Volatility model where the instantaneous volatility $\sigma(t,S_t)$ is assumed to be constant.

Table 5 displays the prices, expressed as a percentage of the asset price, corresponding to up-and-out calls with maturity within two years and at-the-money strike price for different barrier levels. The table offers the prices obtained under the Heston (1993) model. For the rest of the models, the table shows the percentage error defined as $P_{model}/P_{Heston} - 1$, where P_{model} is the price under the corresponding model and P_{Heston} is the price obtained under the Heston (1993) model.

Regarding the price denoted as *Black-Scholes atm* in the table, we consider that the implied constant volatility is equal to the at-the-money implied volatility associated with the options with maturity within two years corresponding to the specification of Table 4. On the other hand, regarding the price denoted as *Black-Scholes barrier*, we use the implied volatility corresponding to European options with maturity within two years and strike equal to the barrier level.

(Insert Table 5 about here)

The results obtained under the Black-Scholes (1973) model using the at-the-money volatility do not account for the existence of volatility skew and for the existence of stochastic volatility. Hence, the prices obtained under this approach are much lower than the ones generated by the other two models. When we use the implied volatility associated with the barrier level, the prices are higher than in the previous case. The reason is that, in this case, the lower the implied volatility, the lower the probability of reaching the barrier and, hence, the higher the price of the call up-and-out. But, even in this case, we have important discrepancies with respect to the local volatility model and the stochastic volatility model. In the past, some financial institutions used this kind of rude adjustment in the implied volatility to price barrier options using the Black-Scholes (1973) model. This example shows that this practice can generate quite big valuation errors.

The local volatility function accounts for the existence of a volatility skew. Hence, the prices obtained under this model are closer to the prices generated by the Heston (1993) model. Nevertheless, the local volatility model does not properly account for second order effects such as the volatility of volatility. The omission of these effects generates the price differences between the local volatility model and the stochastic volatility model.

4.3.2. Monthly cliquet option

Let us consider a cliquet option with maturity equal to three years, whose payoff at expiration is given by the accrued sum of monthly returns with a maximum monthly revalorization of 2% and a minimum monthly revalorization equal to -2%. Moreover, the investor has a performance of 2% guaranteed at maturity. The maximum monthly revalorization of 2% is the *local cap*, whereas the minimum monthly revalorization is denoted *local floor*. Finally, the 2% coupon guaranteed at expiration is the *global floor*.

This strategy is denoted as cliquet option with caps and floors and it represents an example of structured products that financial institutions typically offer to their clients. The reason why investors can be interested in this product is because this cliquet option allows them to benefit from the possible increase of the underlying asset while, at the same time, they have a minimum coupon guaranteed.

The payoff at maturity associated with this strategy is given by the following expression:

$$\max\left\{\sum_{t=1}^{36}\max\left[\min\left(\frac{S_t}{S_{t-1}}-1,2\%\right),-2\%\right],2\%\right\}$$

In the previous expression, *t* represents the month, where the total number of months is equal to 36. The fact that, under the cliquet option, the performance of the underlying asset is measured, at any observation date, with respect to the price of the underlying asset in the previous period instead of with respect to the initial level, makes the cliquet option quite sensitive to the forward volatility skew. Therefore, this kind of option is pretty model-dependent.

Table 6 compares the prices corresponding to the cliquet option of the previous example obtained under the three models considered in the article. We use Monte Carlo simulations with daily time steps and 80,000 trials. The table displays the price obtained under the Heston (1993) model as well as the percentage error associated with the local volatility model and the Black-Scholes (1973) model. In this case, we use the market at-the-money volatility associated with options that have expiry within three years to calculate the price under the Black-Scholes (1973) specification.

(Insert Table 6 about here)

As in the previous example, the lowest price corresponds to the Black-Scholes (1973) model. As said previously, cliquet options are quite sensitive to the forward volatility skew. But, as Derman (2003) points out, the local volatility model generates future volatility skews much flatter than the current ones. This is an uncomfortable and unrealistic forecast that contradicts the omnipresent nature of the skew. As a consequence, the prices obtained under the local volatility model are considerably lower than the ones generated by the Heston (1993) model.

Hull and Suo (2002) use the finite-difference method introduced by Andersen and Brotherton-Ratcliffe (1998) to price exotic options on equities and exchange rates under the local volatility model. They also used a stochastic volatility model similar to the Heston (1993) model. These authors conclude that the goodness of the local volatility model with respect to the stochastic volatility framework is a function of the degree of path dependence in the exotic option being priced, where the degree of path dependence is defined as the number of times that the asset price must be observed to calculate the payoff. The higher the degree of path dependence, the worse the local volatility model is expected to perform. Importantly, note that, in the example in Table 6, corresponding to a monthly cliquet option with lower degree of path dependency, the percentage error associated with the local volatility model is considerably high. This result shows that, although the degree of path dependency has influence on the model error associated with the price of an exotic option, there are other key factors, such as the convexity of the option premium with respect to volatility.

Importantly, the previous examples show that the local volatility model generates lower prices than the stochastic volatility framework for barrier and cliquet structures. The main reason is that the local volatility model does not consider that the volatility is stochastic and misprices the effects of volatility movements in option prices. One could tend to think that maybe the pricing discrepancies between both models can be positive sometimes, whereas sometimes can be negative leading to the possibility of compensation. But the reality is that financial institutions face a structural short position regarding this kind of derivatives, they sell to their clients, and, hence, the bias is always in the same way. This is the reason why using an adequate model to price complex derivatives is a key question. Importantly, under prudence we would use the stochastic volatility model (instead local volatility model) which, given the assumptions behind each particular model, provides more accurate option prices and, hence, is more in line with neutrality in the valuation of these products.

We consider equity derivatives as an example of the model misspecification error associated with complex derivatives. But the problem of lack of prudent FVA measurement estimates is not only present in equity derivatives but also in credit, interest rates of foreign exchange derivatives. The important question is not the underlying asset but the characteristics of the derivatives. In this sense, all kind of structured products with relatively complex payoffs and without a liquid market are affected by the existence of model misspecification error. In this study, as an illustration, we focus on some of them but the results are easily extensible to other exotic options and/or underlying assets.

5. Conclusion and implications

In this paper, we examine whether prudence (conservatism) helps mitigate the bias in FAV estimates under conditions of uncertainty and supports neutrality for financial information. Therefore, after illustrating the significant weight of financial instruments measured at Level 2 fair vale estimates in the financial position of large U.S. and European banks, we show that FVA can lead bank managers toward model misspecification error in the valuation of complex financial instruments traded in illiquid markets. Specifically, we illustrate the existence of model misspecification error when comparing two different assumptions pertaining to volatility (local volatility vs. stochastic volatility) and suggest that the exercise of prudence in choosing the volatility model supports neutrality in the valuation of such instruments.

We argue that our results are relevant for accounting standard setters who consider the reintroduction of prudence in the Conceptual Framework for Financial Reporting. While we agree that FVA is essentially a valuation problem, we suggest that model misspecification bias can be easily mitigated if prudence is reinstated in the Conceptual Framework. In Particular, prudent criteria should be applied when estimates and measurements are made in conditions of high uncertainty.

Further, our findings have important implications for accounting, auditing, and bank regulators. Current accounting standards are not only ambiguous pertaining to the valuation of complex financial instruments traded in illiquid markets but also opaque. Accounting regulators could help reduce users' uncertainty regarding Level 2 and 3 fair value estimates by requiring additional disclosure. A plausible solution could be to convey on the *face* of the main financial statements (i.e., balance sheet, profit and loss, and cash flows) the accounts whose values are subject to extreme fair value estimates (Christensen *et al*, 2012). Preparers could be required to either flag or highlight critical accounts with significant uncertainty surrounding Level 2 and 3 financial instrument estimates to draw users' attention. Accounting regulators could also consider further disclosure on the notes to the financial statements by requiring firms to provide specific information of the selected estimation model used to price high-uncertainty fair value estimates as well as a set of sensitivity analyses.[9]

An issue in auditing is that the approach normally used to verify the estimations is one based on the consistency over time of the calculations (correctness), when the main problem in fair value is one of precision, as long as the estimation is just an attempt to determine the market price (accuracy). Therefore, auditing standard setters should consider the challenges of dealing with high-uncertainty fair value estimates. Most derivatives, like barrier options and cliquet options, are not quoted in markets in any time over their lives, and, therefore, the estimations of their fair values never can be contrasted by means of observable transactions. Auditing standard ambiguity and the lack of valuation knowledge may lead auditors to collude with bank managers' fair value estimates and merely serve to rubber stamp the preparer's report (Bratten *et al*, 2012). Perhaps one possibility to improve the current situation could be to require auditors to provide negative assurance with respect to high-uncertainty

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[9] For instance, consider the case of Deutsche Bank for the fiscal year 2011, where just the fair value estimates of derivatives assets and liabilities classified as Level 2 (822,009 and 814,696 million euros, respectively, non-tabulated) represent 164.4 and 163.0 percent of the bank's total equity (49,981 million euros), respectively. In spite of the significant weight of these fair value estimates in the financial position of this bank, the financial statements did not show a disaggregated disclosure of such derivatives by type of product or valuation technique.

fair value estimates (Christensen *et al*, 2012; Public Company Accounting Oversight Board, 2009, 2010).[10]

If bank regulators truly want to enhance the credibility of Level 2 fair value estimates, more specific guidance should be provided to preparers. Similar to U.S. companies which have disclosed the inputs they use to calculate the Black-Scholes values for employee stock options (ESOs), it would be helpful to elaborate guidelines to select the most appropriate assumptions, including volatility, and valuation techniques for illiquid financial instruments. Importantly, financial innovation continues to develop new derivatives that increase the set of investment opportunities.[11] Hence, such guidelines should be updated in a timely manner to include guidance for the valuation of new complex financial products. Despite the fact that the provision of specific regulation on financial instruments seems to run counter to the IFRS conceptual framework, we believe that it would be necessary for at least those financial instruments with high exposure to model misspecification error. Further, according to our results, bank regulators should reconsider the debate about establishing special regulatory capital requirements for those banks with a high exposure to critical FVA estimates. Even though certain regulators have expressed some degree of concern (Basel Committee on Banking Supervision, 2009), there exists no clear position on this issue yet.

[10] Alternatively, instead of negative assurance, auditing standard setters could consider different levels of assurance for extreme fair value estimates, such as high, moderate and low (Christensen *et al*, 2012).

[11] In recent years there has been a remarkable growth of volatility options (European Commission Press Releases, 2010). These options exhibit upward sloping volatility skew and the shape of the skew is largely independent of the volatility level. In equity options markets, the slope of the skew is also quite independent of the volatility level.

Appendix A. Heston model (1993) equations

$$f_j = e^{C_j + D_j v_0 + iz\ln(S_0)}$$

$$C_j = (r-q)izT + \frac{\kappa\theta}{\eta^2}\left[\left(b_j - \rho\eta iz + d_j\right)T - 2\ln\left(\frac{1-g_j e^{Td_j}}{1-g_j}\right)\right]$$

$$D_j = \frac{b_j - \rho\eta iz + d_j}{\eta^2}\left[\frac{1-e^{Td_j}}{1-g_j e^{Td_j}}\right]$$

$$g_j = \frac{b_j - \rho\eta iz + d_j}{b_j - \rho\eta iz - d_j}$$

$$d_j = \left[\left(\rho\eta iz - b_j\right)^2 - \eta^2\left(2u_j iz - z^2\right)\right]^{\frac{1}{2}}$$

with $u_1 = \frac{1}{2}$, $u_2 = -\frac{1}{2}$, $b_1 = \kappa - \rho\eta$ and $b_2 = \kappa$.

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