DVA for assets

Debit valuation adjustments are becoming well understood for derivatives and liabilities – but can affect the asset side of the balance sheet too. Specifically, assets such as so-called goodwill depend on the creditworthiness of the firm. ***Chris Kenyon*** *and* ***Richard Kenyon*** *model this relationship and show how it can be hedged*

The effect of own-default on liabilities and derivatives through the debit valuation adjustment (DVA) has been widely discussed in pricing literature (Burgard & Kjaer, 2011, Brigo, 2011, Cesari *et al*, 2010, Pallavicini, Perini & Brigo, 2011, and Crépey, 2012). However, the effect of own-default on assets has yet to attract similar attention (Kenyon & Stamm, 2012, being an exception), although it is clear that default will affect any asset that depends on company existence or performance.

We provide a hedging strategy for pricing DVA on assets, extending Burgard & Kjaer (2011), and consider an example, so-called goodwill, in depth. We calibrate our model to seven US banks over the crisis period of mid-2007 to 2011 and show how their reported profits would have changed if DVA on this asset, as well as liabilities, had been included. This effect is highly significant for at least four of the seven banks.

Financial Accounting Standard (FAS) 157 requires US banks to reflect their own potential non-performance, which includes creditworthiness, in the fair value of their liabilities (Financial Accounting Standards Board, 2010). However, creditworthiness has effects on balance-sheet items beyond liabilities. This can be observed by their change in value upon default of the company holding them. This may appear surprising, but it is clear that any asset that relies on the company being a going concern will exhibit this behaviour, for example, goodwill, brand values, etc. In fact, goodwill can be written down prior to default, and thus have a major effect on balance sheets even for going concerns. We include this in our model and calibration, and demonstrate how FAS 157 can be applied to the asset side of the balance sheet as well as the liability side. We do not propose a change in how goodwill is derived (Ramanna & Watts, 2010). Instead, we propose an adjustment that is applied subsequently to reflect creditworthiness effects.

Hedging DVA on assets

We take the view that own-assets can be sensitive to own-stock price levels as well as own-default. We can model, for example, progressive writedowns on a bank's goodwill as its stock price decreases. We modify Burgard & Kjaer (2011) in that we have no risky counterparty, and extend it in that the own-asset (the bank stock) $S(t)$ jumps to zero on bank default. Like Burgard & Kjaer (2011), we assume that a risk-free bond can be purchased. So under the historical measure we have:

$$\begin{aligned} dP(t)/P(t-) &= r\,dt \\ dP_b(t)/P_b(t-) &= r_b\,dt - dJ_b \\ dS(t)/S(t-) &= \mu\,dt + \sigma\,dW - dJ_b \end{aligned} \tag{1}$$

where P, $P_b(t)$ are the price of risk-free and risky bonds respectively; r, r_b are the corresponding risk-free and risky interest rates; W is a Brownian driving process; J_b is the jump-to-default process of the bank; and S is the stock of the bank. Note that the only jump in S-value comes on bank default. There are no market-based jumps in S-value. We could use a non-zero recovery on the bank's issued bonds, but we assume zero recovery for computational convenience, as in Burgard & Kjaer (2011).

Let $\hat{V}$ be the value of an asset that depends on the bank's own stock and existence. If the bank defaults at τ then:

$$\hat{V}(\tau,S) = M^+(\tau,S) + R_b M^-(\tau,S)$$

where M is the value of the own-asset at default. We keep this value general for now, allowing positive and negative values. This enables us to model either hedging the asset or hedging the loss on the asset upon default, which will be important later.

Our setup is simpler than that of Burgard & Kjaer (2011) in that we only need to consider own-default. However, we include a risky underlying, $S(t)$, which has consequences. The value $V^\Pi(t)$ of the hedging portfolio $\Pi(t)$ can be written in terms of the price processes $\mathcal{P}_*$ of its components:

$$-V^\Pi(t) = \Pi(t) = \delta(t)\mathcal{P}_S(t) + \alpha_b(t)\mathcal{P}_{P_b}(t) + \mathcal{P}_\beta(t)$$

where $\delta(t)$ is the quantity of stock held, $\alpha_b(t)$ is risky bond holdings, and $\mathcal{P}_\beta(t)$ is the price of the cash. We require the portfolio to be self-financing, so (bearing in mind Brigo *et al*, 2012) we have the following gain $\mathcal{G}_*$ processes:

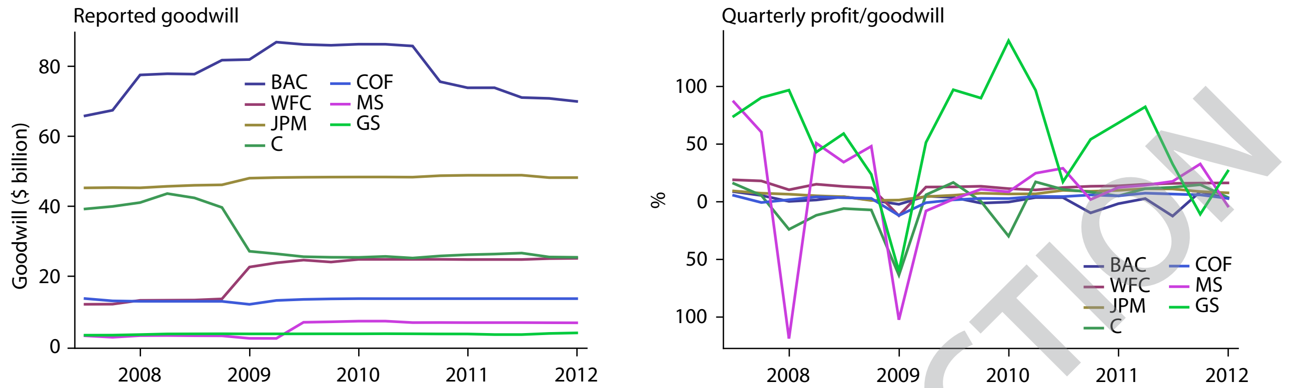
$$\begin{aligned} d\mathcal{G}_S &= dS + (\gamma - q)S\,dt \\ d\mathcal{G}_{P_b} &= r_b P_b\,dt - P_b\,dJ_b \\ d\mathcal{G}_\beta &= r\varepsilon^+ dt + r_F \varepsilon^- dt \end{aligned}$$

Note that all gain processes are functions of $t-$ not t. $\gamma_S(t)$ is the dividend yield on $S(t)$ and $q_S(t)$ is the financing cost. As in Burgard & Kjaer (2011), we assume we can put $S(t)$ into repo and we also assume it closes flat on default. Equally we assume zero recovery for the stock lender when we are short selling. If the cash position is positive, risk-free investment yields r, whereas negative cash costs the funding rate r_F. We can set the funding rate to the yield of an issued bond with recovery R_b, so $r_F = r + (1 - R_b)\lambda_b$. The price processes $\mathcal{P}_*$ are:

$$\mathcal{P}_S = 0; \quad \mathcal{P}_{P_b} = P_b; \quad \mathcal{P}_\beta = \varepsilon$$

The stock price process is zero except exactly at the instant of default but this portfolio cannot be bought, with no trading at

1 Goodwill



Left panel: reported goodwill for seven US banks (Bloomberg tickers: Bank of America, Wells Fargo, JP Morgan, Citigroup, Capital One, Morgan Stanley, Goldman Sachs) in \$ billion. Right panel: quarterly profits as a percentage of goodwill. For the non-pure investment banks this is a small percentage. For the two investment banks (GS, MS), goodwill is relatively small and profits are the same order of magnitude. Data from Bloomberg

the default time τ. Note that the dividend processes $\mathcal{D}_*$ are not individually zero:

$$d\mathcal{D}_S = d\mathcal{G}_S - d\mathcal{P}_S = dS + (\gamma - q) S dt$$
$$d\mathcal{D}_{P_b} = d\mathcal{G}_{P_b} - d\mathcal{P}_{P_b} = r_b P_b dt - dP_b$$
$$d\mathcal{D}_\beta = d\mathcal{G}_\beta - d\mathcal{P}_\beta = r\varepsilon^+ dt + r_F \varepsilon^- dt$$

Self-financing requires that $\mathcal{G}^\Pi = V^\Pi$ and replication requires that $V^\Pi = \hat{V}$, so $\mathcal{G}^\Pi = \hat{V}$. Considering V^Π we have:

$$-V^\Pi = \delta \times 0 + \alpha_b \times P_b + 1 \times \varepsilon \;\Rightarrow\; \varepsilon = -\hat{V} - \alpha_b P_b$$

Now the portfolio gain process $\mathcal{G}^\Pi$ is by definition the weighted sum of the individual gains, hence:

$$\begin{aligned} d\mathcal{G}^\Pi &= \delta\big(dS + (\gamma - q) S dt\big) + \alpha_b\big(r_b P_b dt - P_b dJ_b\big) \\ &\quad + \Big\{ r\big(-\hat{V} - \alpha_b P_b\big)^+ + r_F\big(-\hat{V} - \alpha_b P_b\big)^- \Big\} dt \end{aligned} \tag{2}$$

Applying Itô's lemma to $\hat{V}$, we have:

$$\begin{aligned} d\hat{V} &= \partial_t \hat{V} dt + \partial_S \hat{V} dS + \frac{1}{2}\sigma^2 S^2 \partial_{SS} \hat{V} dt \\ &\quad + \Big(\hat{V}(\tau) - \hat{V}(\tau-) - S(\tau-)\partial_S \hat{V}(\tau-)\Big) dJ_b \end{aligned} \tag{3}$$

Notice that the jump term in dS leads to one additional term within the last bracket. Positive $\hat{V}$ means long b-risk so α_b will be positive or zero.

Removing all risks by equating the dS and dJ_b coefficients within equations (2) and (3) (which are equal):

$$\delta(t) = \partial_S \hat{V}(t)$$
$$\alpha_b(t) = -\Big(\hat{V}(\tau) - \hat{V}(\tau-) - S(\tau-)\partial_S \hat{V}(\tau-)\Big) / P_b(\tau-)$$

If we now define a parabolic differential operator $\mathcal{A}_t$ as:

$$\mathcal{A}_t := \frac{1}{2}\sigma^2 S^2 \partial_{SS} + \big\{\lambda_b + (q_S - \gamma_S)\big\} S \partial_S \tag{4}$$

and:

$$\lambda_b := r_b - r$$
$$s_F := r_F - r$$

then $\hat{V}$ satisfies the partial differential equation (PDE):

$$\partial_t \hat{V} + \mathcal{A}_t \hat{V} - r\hat{V} = s_F\big(\hat{V} + \Delta\hat{V} + S\partial_S \hat{V}\big)^+ - \lambda_b\big(\Delta\hat{V} + S\partial_S\hat{V}\big) \tag{5}$$

$$\begin{aligned} &= \lambda_b \hat{V} + s_F\big(M^+ + R_b M^- + S\partial_S \hat{V}\big)^+ \\ &\quad -\lambda_b\big(R_b M^- + M^+ + S\partial_S \hat{V}\big) \end{aligned} \tag{6}$$

$$\begin{aligned} \partial_t \hat{V} + \widetilde{\mathcal{A}}_t \hat{V} - r\hat{V} &= \lambda_b \hat{V} + s_F\big(M^+ + R_b M^- + S\partial_S \hat{V}\big)^+ \\ &\quad -\lambda_b\big(R_b M^- + M^+\big) \end{aligned} \tag{7}$$

We move to equation (7) by absorbing the $\lambda_b S \partial_S \hat{V}$ term into $\mathcal{A}_t$, relabelling it $\widetilde{\mathcal{A}}_t$. Note that the terms inside the s_F-bracket are evaluated with the share price pre-default – funding occurs only while not defaulted, whereas the terms inside the λ_b-bracket are evaluated post-default.

We have been able to remove the jump risk from the PDE because the value of the stock is known pre-default and its jump size on default is also known. We needed to use both the stock itself and the own-bond to remove all the jump risk from the portfolio, that is, both δ and α_b were used.

Below, we assume that we can put $\hat{V}$ into repo, so $s_F = 0$ hence:

$$\partial_t \hat{V} + \widetilde{\mathcal{A}}_t \hat{V} - r\hat{V} = \lambda_b\Big(\hat{V} - \big(R_b M^- + M^+\big)\Big) \tag{8}$$

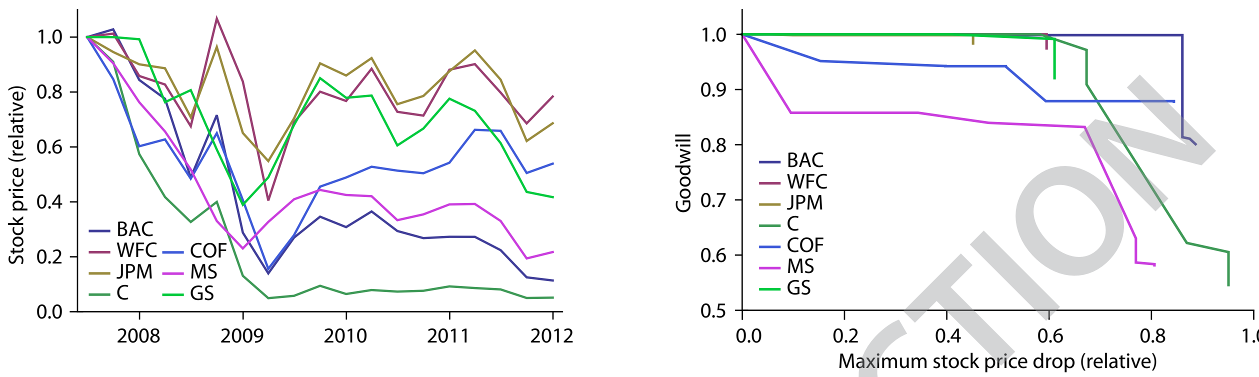
Example asset: goodwill

Introduction to the asset. Goodwill is an asset on the balance sheet that is reported quarterly. In our examples, we consider seven large US banks. Five are chosen for size and the other two as representative pure investment banks. These banks have significant levels of goodwill on their balance sheets as compared with quarterly profits (see figure 1).

Goodwill, as defined in FAS 350-20, is created when a company is bought for more than the book value of net assets acquired and liabilities assumed. The carrying value of goodwill must be regularly reviewed (at least annually, in a two-step procedure[1]), and can only stay at the same level or be impaired, that is, decrease

[1] *The first step is to see whether it is more likely than not (> 50% likely) that the carrying value exceeds the fair value (FASB updates 2011-08, 2012-02)*

2 Models for goodwill



Left panel: stock prices for seven US banks relative to their second-half 2007 values. Right panel: derived calibration curves for goodwill write-offs versus minimum stock price observed since mid-2007

(FAS 350-20-35-13). The basis for the carrying value is as though it were purchased anew (FAS 350-20-35-14). Thus we assume that the value of goodwill is capped on the balance sheet at its initial amount.

In regulatory terms, goodwill is not counted towards Basel III capital, effectively saying that it has zero recovery value. That is, it provides no buffer against default. IFRS 9 puts it into other comprehensive income, which feeds into equity, and it will remain on the balance sheet.

For tax purposes, some information (for example, USC Title 26 A.1.B.VI Section 197) suggests that goodwill must be amortised over 15 years. We use the word suggests to remind readers that this is an article exploring the application of DVA to assets, not a definitive tax or accounting opinion. This amortisation creates tax credits that can reduce tax payments on future profits. Tax treatments change present and future cashflows, whereas accounting treatments change reports and opinions.

Models for goodwill. We consider three models of goodwill value, two inspired by accounting and one from tax. First examine figure 2, where we show relative equity prices from mid-2007 on the left, and relative goodwill value (considering only write-downs) versus maximum stock price drop on the right. Despite significant stock price drops, three of the seven banks considered wrote down less than 10% of their goodwill. Thus we propose the following three models:

- Constant – the dollar value of goodwill never changes.
- Progressive – as the stock price drops, goodwill is gradually written off.
- Amortising – goodwill is amortised linearly over a fixed number of years.

The last model is inspired by USC Title 26 A.1.B.VI Section 197, mentioned above. In general, we would use a combination of constant and progressive since, for example, bank C did not write down 50% of goodwill despite a 90%-plus drop in stock price.

DVA on goodwill. We define DVA on goodwill as the expected loss from default or degradation of the company. Degradation is measured by decline in stock price. Our hedging methodology above includes both possibilities. Typically there is no recovery on goodwill as it represents part of going concern value.

Goodwill is not a tradable asset in the normal sense used in mathematical finance. As a thought experiment, consider the simplified case that goodwill has a constant dollar value up to the default of the company. No self-financing portfolio could duplicate this value as it always decreases in a risk-neutral measure

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The maximum recommended length for articles is 3,500 words, with some allowance for charts and/or formulas. We expect all articles to contain references to previous literature. We reserve the right to cut accepted articles to satisfy production considerations.

A. Calibration for goodwill as sets of binary cash-or-nothing American options

BAC		WFC		JPM		C		COF		MS		GS	
b	loss	*b*	loss	*b*	loss	*b*	loss	*b*	loss	*b*	loss	*b*	loss
49	0.1	40	2.5	90	0.1	33	9.0	85	4.8	90	14.2	39	7.9
14	18.5			55	1.5	13	28.7	60	0.9	52	1.8		
13	0.3					5	7.6	41	6.3	33	0.8		
11	1.0									23	24.5		
										19	0.5		

Note: when the barrier *b*, as a percentage of mid-2007 stock price, is hit, the percentage goodwill loss occurs

(with positive interest rates) as we consider longer horizons. Furthermore, goodwill generates no cashflows, even when written down, but has a non-zero value today.

Although goodwill itself is not a tradable asset, DVA on goodwill is a tradable asset, at least in the sense that we can hedge it. We will be precise later, but for now we continue the thought experiment. Suppose we buy a zero-recovery credit default swap (CDS) on some company with notional equal to the goodwill, very long maturity (sufficiently high that the probability of default is close to unity), zero upfront cost and a given periodic premium payment. We can hedge this using a zero-recovery bond from the company, and a risk-free bank account (Carr, 2005). This CDS perfectly compensates us for the loss of value on default of the company (assuming no counterparty risk on the CDS itself). This works because unit notional CDSs hedge bond notionals not their coupons. This is the intuition behind the application of the hedging strategy in the previous section.

Constant model. To hedge the loss of goodwill value k on default the bank enters into a trade $\hat{V}$ that pays k on bank default, and zero otherwise. Note that the hedge will not require a position in S. For $\hat{V}$ to be risk-free, we assume that it is collateralised, and since the value will always be positive to the bank this means, effectively, that the derivative can be placed into repo and thus $s_F = 0$. Hence $M^+ = k$, $M^- = 0$ and equation (6) becomes:

$$\partial_t \hat{V} + \tilde{\mathcal{A}}_t \hat{V} - r\hat{V} = \lambda_b \hat{V} - \lambda_b k$$

Feynman-Kac transforms this to:

$$\begin{aligned} \hat{V} &= \mathbb{E}^{\mathbb{Q}}\left[\int_0^T e^{-(r+\lambda_b)s} \lambda_b k \, ds\right] \\ &= \frac{\lambda_b}{r+\lambda_b} k - \varepsilon(T) \end{aligned} \tag{9}$$

where $\varepsilon(T) \to 0$ as $T \to \infty$.

Equation (9) says that if the hazard rate is large relative to the risk-free rate then the DVA on goodwill will tend to the value of goodwill itself. This makes sense because goodwill is lost on default and a high hazard rate implies this happens soon.

Amortising model of goodwill. If goodwill is amortising in a straight line this means that, in tax terms, it creates a loss every year that can be offset against profits. These are called tax credits. We model the future value of the tax credits as:

$$G_{AM}(t) = \sum_{i=[t]}^{n_A} e^{-r(i-[t])} \frac{G(0)}{n_A}$$

where we have assumed that tax is paid once a year at the end of the year and amortisation is over n_A years (an integer). This is a simple extension of the constant model because the values are deterministic. Thus, as before the hedge will not require a position in S.

In this view of the value of goodwill, there is no link to the value of the company, or to any revaluation of goodwill after its creation. The value is set by law. Of course the DVA on goodwill is still set by the chance of default, and the relevant hedging strategy.

The value of a tax credit obviously depends on having profits. However, the profit does not always have to be in the same year as the tax credit. There is usually a limited ability to move these through time when a company does not have sufficient profits to use up tax credit, which then becomes a deferred tax credit. The formula above assumes that sufficient profits exist to use up all the tax credit as they appear. We show below that the DVA in this amortising model is relatively insensitive to the length of the amortisation. Thus whether the generated tax credits are used immediately or not is not highly significant.

Progressive model. Goodwill is written off progressively as the equity price declines, considering the minimum stock price reached. We want to hedge these losses, that is, this DVA on Goodwill.

Calibration. In general, the precise relationship between equity price declines and goodwill write-off is one for internal analysts to answer as they are the ones calculating the value of goodwill. However, looking back historically we can recover the calibration curves that internal analysts would have calculated.

Figure 2 shows the monotonic decline in goodwill with the minimum stock price reached at the end of the quarter. Note that this model leaves open the possibility that the writedown occurs with a delay after the barrier is reached when the stock price hits its minimum. This can occur, but there is typically just one big drop in the period, so we leave this detail out of the modelling, as a straightforward extension to a delayed cashflow. The calibration set of barriers and losses is shown in table A.

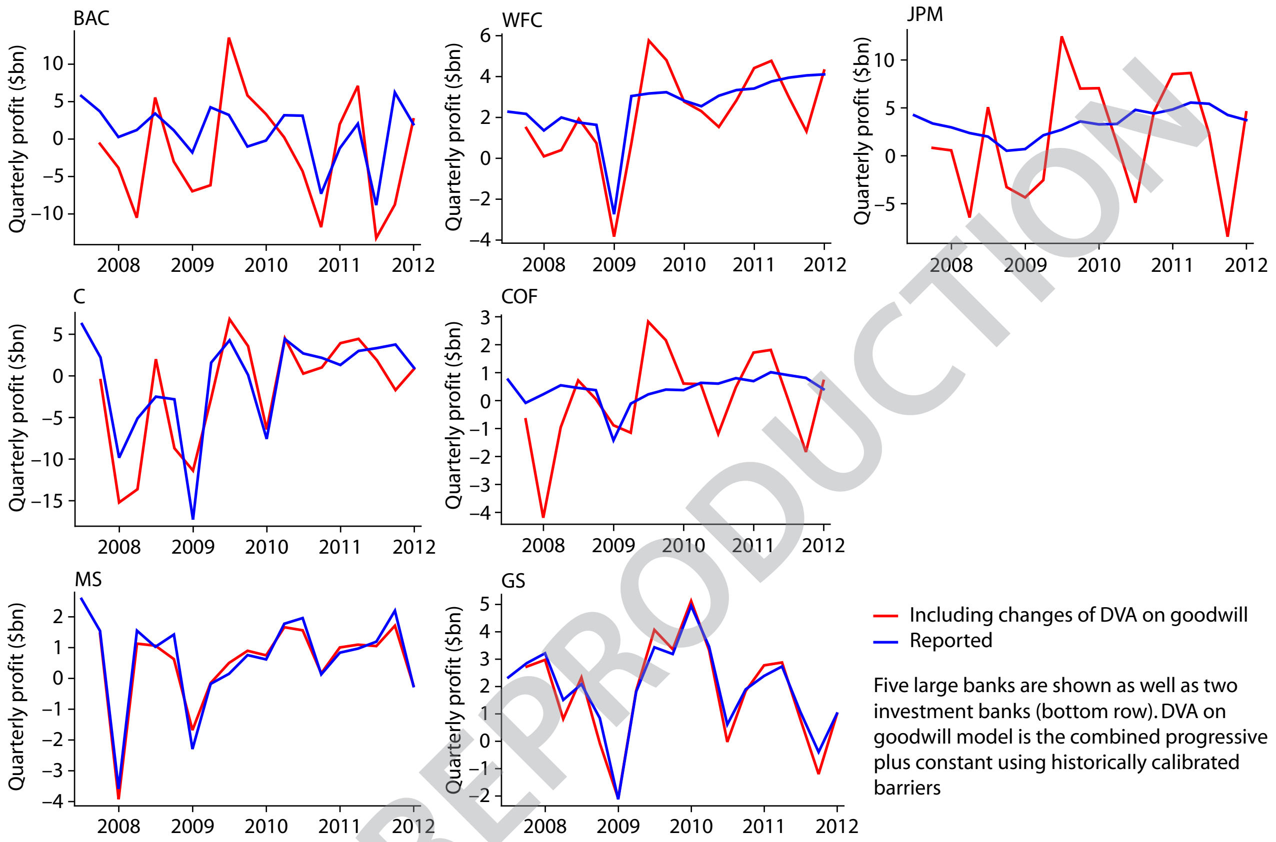
Hedging. This consists of instruments that give positive cashflows when the stock price reaches successive barriers, so we can write DVA on goodwill in terms of a series of American-style binary cash-or-nothing options $\hat{V}_i$. Practically, we have captured aspects of a structural model of approach-to-default with these barriers as opposed to reduced form.

The hedges are bought options and hence always positive-valued. Since we do not want counterparty risk on the options, we assume that they are collateralised and hence $s_F = 0$. Unlike the constant case, on default these options pay the loss amounts l_i since the stock price will have breached the respective barrier. Thus we have a similar PDE but with different boundary conditions:

$$\partial_t \hat{V}_i + \tilde{\mathcal{A}}_t \hat{V}_i - r\hat{V}_i = \lambda_b \hat{V}_i - \lambda_b l_i \tag{10}$$

provided $S \geq b_i$, where (b_i, l_i) is the (barrier, loss) pair.

We can evaluate equation (10) as an integral over standard one-touch options with rebates for not touching with different maturities, since default is independent of stock price. A one-touch option is not a free boundary problem, so the PDE we have can be used with suitable boundary conditions (see Wilmott, 2006, 9.7 for details). We choose the rebates to be $l_i \lambda_b e^{-(r+\lambda_b)T}$ for maturity T, 3 Effect on reported quarterly profits of including changes in DVA on goodwill



Five large banks are shown as well as two investment banks (bottom row). DVA on goodwill model is the combined progressive plus constant using historically calibrated barriers

thus capturing the payout at default when the stock price goes to zero, provided the barrier has not previously been reached.

The no-hit rebate at T of R option price $RnoH(T, R)$ is known:

$$RnoH(T,R) = \mathrm{R}e^{-rT} - R\left(\left(S/b_i\right)^{2\zeta} P_d\left(b_i^2/S;b_i\right) + C_d\left(S;b_i\right)\right)$$

where C_d, P_d are digital call and put options and $\zeta = 1/2 - (r - \gamma)/\sigma^2$. Hence the DVA on goodwill under the progressive model is:

$$\sum_i \hat{V}_i = \sum_i \int_0^T l_i\left(OneTouch\left(b_i,s\right) + RnoH\left(s,1\right)\right)\lambda_b e^{-\lambda_b s} ds$$

It is beyond the scope of this article to – from the outside – estimate future calibrations for goodwill. However, making the assumption that internal teams could create a good calibration, we can use the historical data to reproduce it after the fact (see figure 2 and table A). Thus we can calculate their DVA on goodwill throughout the crisis period, as would have been reported.

Results

Constant and progressive models. We calibrate the progressive model using historical data from mid-2007 to end-2011 on seven US banks (see table A and the right panel of figure 2). Stock implied volatility is from Bloomberg using at-the-money volatility at the longest consistently available quote, 18 months. We use the five-year CDS spread as representative together with the five-year swap rate for discounting. The goodwill that was not lost over this period we assign to the constant model.

Figure 3 shows the effect on reported quarterly profits of including changes in DVA on goodwill. The two investment banks (GS and MS) see little effect on their reported profits. This is because they have little goodwill relative to their profits and it was little affected by writedowns over the crisis period. One major bank (C) showed initially large effects, which were later much reduced. This is because it wrote off a significant fraction of goodwill over the crisis and subsequently was only affected by CDS changes. The remaining four major banks show volatile effects over the crisis period. This reflects their large amounts of goodwill, the crisis and in some cases changes resulting from acquisitions.

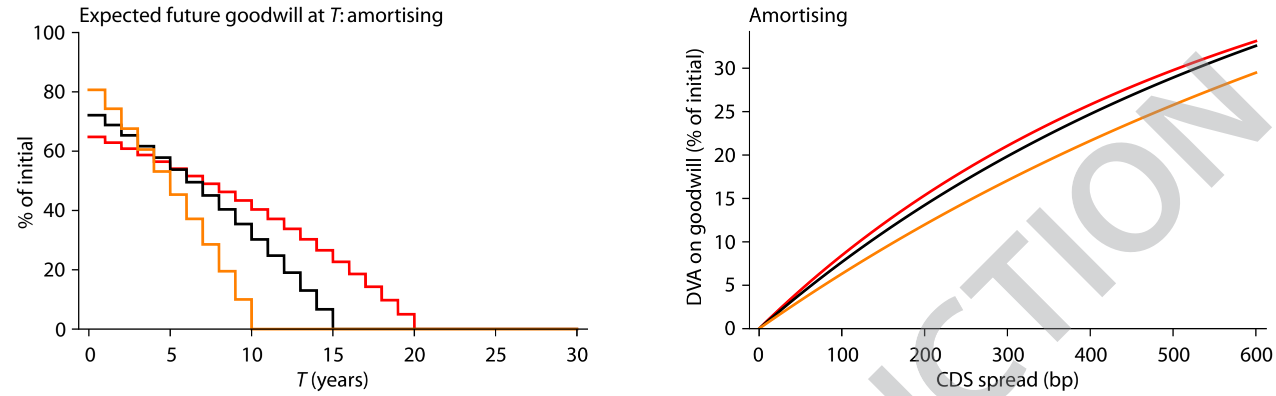
Amortising model. The left panel of figure 4 shows the value of future goodwill for the amortising model, which is inspired by tax considerations. The staircase effect from paying tax yearly is evident. There is a strong dependence on the length of the amortisation period, which can be set by law.

The DVA on tax credits from goodwill amortisation is shown in the right panel of figure 4. There is a relatively small range of values for a wide range of amortising lengths, 10–20 years. The amortisation range is important in that it shows that the results are robust against deferment of the use of the tax credits. This potentially captures the case where the credits can only be used one-third to half the time. If there are no net profits over a long continuous period, then the tax credits may not be used. However, such cases are probably already captured by the default probability.

Conclusion

DVA on liabilities and derivatives is well established (Burgard & Kjaer, 2011, Brigo, 2011, Cesari *et al*, 2010), even to the extent of

4 DVA on expected future goodwill



Left panel: expected future values of potential tax credits from goodwill as percentage of initial value under amortising model. Straight line amortisation over $n_A = 10, 15, 20$ years is displayed. Right panel: the DVA on these expected future tax credits from goodwill amortisation for a range of CDS spreads, with hazard rates calculated assuming 40% recovery, and flat 5% discount curve

proscriptive accounting rules in some jurisdictions, for example, FAS 157. DVA on assets, as far as we are aware, has had only limited attention (Kenyon & Stamm, 2012). We have presented a concrete example of an asset whose value is dependent on the default of its owner, namely goodwill, and shown how the potential value lost on default can be hedged using an extension of Burgard & Kjaer (2011). Calibrating our models to seven US banks over the crisis, we have shown that the effect of changes in DVA on assets can have significant effects on reported profits.

This work complements existing studies on valuation adjustments to do with creditworthiness, collateral and funding (Burgard & Kjaer, 2011, Brigo, 2011, Cesari *et al*, 2010, Brigo *et al*, 2011, Pallavicini, Perini & Brigo, 2011, Crépey, 2012, and Brigo *et al*, 2012). We note that DVA is specifically excluded from regulatory capital (Basel Committee on Banking Supervision, 2012) but is no less a trading reality. DVA hedging by proxy has been suggested in the *Wall Street Journal*. This works for spread changes, but not default events. For example, imagine if Morgan Stanley had used CDSs on Lehman.

Technically, as in Burgard & Kjaer (2011) and pointed out by Kenyon & Stamm (2012, sections 8.3.2 and 8.3.3), the key to analytic tractability is the use of repo accounts for financing. Without this, analytic tractability is limited.

As well as the accounting point of view of our constant and progressive models, we consider potential losses, and their hedging, relating to a tax point of view with our amortising model. We hope this will widen the debate over the scope and application of DVA.

Banks have reported large changes in profits from the effects of their own creditworthiness on liabilities. Our investigation suggests that including creditworthiness on assets can make the picture even more volatile. In balance sheet – and hedging – terms, this volatility is real. ■

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