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Identifying, valuing and hedging of embedded options in non-maturity deposits ☆

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ABSTRACT

Non-maturity deposits like savings accounts or demand deposits contain significant option risks caused by the bank's discretionary pricing and the customers' withdrawal right. Option risks follow from inherent non-linear factor exposures. I propose an ordinal response model for deposit rate jumps to identify non-linear factor exposures and a discrete-time term structure model to value the resulting option risks and to derive hedge measures "outside the model". My delta profile resembles a constant maturity swap, but vega and gamma are more pronounced, which demonstrates that the widespread practice of static hedging with zero bonds is inadequate.

1. Introduction

Many banks trade options on a "stand-alone" basis. These explicit options have clearly defined payout characteristics like maturity and strike price. A bank does not have to trade with financial derivatives to incur option risk, however. Indeed, almost all banks incur option risk from options that are embedded in the banking book. These options are often hidden in seemingly humble core deposits, referred to herein as non-maturity deposits. Non-maturity deposits like savings accounts or demand deposits have no contractual maturity date and depositors can withdraw on very short notice or on demand.[1] The customer rates paid on non-maturity deposits are adjustable to market conditions as a matter of policy and rate changes usually apply to all account holders. I will show that non-maturity deposits contain significant option risk due to inherent non-linear factor exposures caused by the bank's discretionary pricing and depositors' withdrawal right. Non-linear factor exposures can be statistically identified by an ordinal response model and auto-regression, then I derive a term structure model in discrete time to value the resulting cash flows. Finally, I hedge "outside the model" to replicate risk measures such as gamma and vega to generate stable margin.

According to Payant (2004), the average U.S. bank was funded with 48% of non-maturity deposits. The drop in the Fed funds rate has contributed to an increase of this proportion to 58% in 2012, as reported by the FDIC. Non-maturity deposits are thus the banks' main funding source. New regulation on liquidity as outlined by Basel Committee on Banking Supervision (2010) and the sovereign debt crisis further intensified the banks' demand for deposits as the

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[1] Traditional examples include demand deposit accounts, negotiable order of withdrawal accounts, savings accounts, money market demand accounts. By contrast, time deposits or certificates of deposits have a fixed maturity, an explicit principal amount, and early withdrawal is only possible by paying a penalty fee.

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Table 1
Maximum likelihood estimates of pricing sensitivities in ordinal response model.

	Description	Model 1	Model 2	Model 3	Model 4
β_1	Customer rate before decision	−266.28	−260.04	-319.07	−319.67
	i_{t-1}	(38.02)	(37.97)	(46.43)	(46.93)
β_2	3-month LIBOR	64.53	50.88	93.91	101.62
	$L_{3,t}$	(28.31)	(29.15)	(33.54)	(34.35)
β_3	5-year swap rate	167.57	201.70	236.80	239.14
	$C_{60,t}$	(41.59)	(45.78)	(49.54)	(51.05)
β_4	Ind. customer rate below 0.5%		2.01	2.43	2.48
	$\mathbf{1}_{\{i_{t-1}<0.005\}}$		(0.83)	(0.81)	(0.81)
β_5	Ind. 3-month LIBOR greater 7%			−3.15	−3.49
	$\mathbf{1}_{\{L_{3,t}\geqslant 0.07\}}$			(1.16)	(1.18)
β_6	Absolute difference 3-month LIBOR				−112.25
	$\lvert L_{3,t}-L_{3,t-3}\rvert$				(65.13)
$\mathcal{L}$	Log likelihood	−126.00	−122.58	−118.76	−117.27
AIC	Akaike information criterion	148.00	146.58	144.76	145.27

The parameters, β_1, β_2, and β_3, measure the sensitivities of the ordinal response variable Y_t^* towards current customer rate, i_{t-1}, 3-month LIBOR, $L_{3,t}$, 5-year swap rate, $C_{60,t}$ and all three are statistically highly significant. The sensitivities, β_4, β_5, towards two indicators, $\mathbf{1}_{\{i_{t-1}<0.005\}}$ and $\mathbf{1}_{\{L_{3,t}\geqslant 0.07\}}$, capture an implicit rate floor and cap. Both parameters are statistically significant. That is, if a certain interest rate level is reached, the probability of further customer rate adjustments is reduced. The last sensitivity, β_6, towards the absolute change in the 3-month LIBOR within 3 months time models asymmetric adjustment speed. Asymmetric adjustment speed can be stipulated by setting β_6 unequal to zero. A negative value for β_6 implies a quicker response in a falling interest rate environment compared to a rising environment. The likelihood estimate of β_6 is significantly different from zero as can be seen from the standard error in brackets. Therefore, model 4 is the one I prefer.

market for unsecured wholesale funding dried up. Thus, the FDIC concludes that "non-maturity deposit assumptions are critical" since "interest rate risk [IRR] measurement relies heavily on deposit assumptions." Thanks to regulatory efforts to introduce a mandatory capital charge for IRR in the banking book, the modeling of non-maturity deposits remains in the spotlight as noted by Byres (2013). Despite its tremendous practical and regulatory importance and the fact that "the treatment of non-maturity deposits will be, for many banks, the single most important assumption in measuring their IRR exposures," (FDIC), valuation and hedging of non-maturity deposits is an understudied issue.[2]

Many banks replicate non-maturity deposits with a static portfolio of straight bonds by minimizing the tracking error between the cash flows of the hedge portfolio and those of the account during a sample period as noted by Kalkbrener and Willing (2004). The crucial assumption is that "the duration of these accounts is relatively constant" as stated by Wilson (1994, p. 14). To validate the portfolio composition, banks can resort to the guidelines proposed in Section 305 of the FDIC Improvement Act (FDICIA 305). These guidelines provide for a proportion of the volume in different non-maturity accounts to be treated as rate sensitive across a range of maturity buckets.

I will demonstrate that the so called gamma risk is significant. That is, in a low interest rate regime, the duration of $1 in a non-maturity deposit account is considerably longer than in normal times. As a consequence, I clearly reject the "constant duration assumption" of Wilson (1994). Since a portfolio of straight bonds has no vega risk, it cannot replicate the non-linear risks generated by embedded options.[3] I will therefore dismiss both the proposal of Kalkbrener and Willing (2004) to replicate with a "bond portfolio [that] is derived from the delta profile of the non-maturing liabilities" (p. 1559) and the equivalent proposal of Elkenbracht and Nauta (2006) to "determine the amount of zero-coupon bonds required in each bucket to hedge the value" (p. 83). In Jarrow and van Deventer (1998), the deposit rate is just a continuous function of the short rate. As a consequence, they miss important non-linearities such as truncation to the next integer. I will also present empirical evidence that both depositors' supply function and a bank's pricing behavior can be more sensitive towards swap rates than money market rates. As a result, unlike Jarrow and van Deventer (1998) and Kalkbrener and Willing (2004), and unlike all profiles listed in Table 1 of the bank survey carried out by Poorman (1999), my delta profile bears some resemblance to a constant maturity swap, but vega and gamma risks are more pronounced. Furthermore, existing valuation models for non-maturity deposits such as Jarrow and van Deventer (1998), O'Brien (2000) and Kalkbrener and Willing (2004) are in continuous time, I will derive a valuation and hedging framework in a discrete-time economy.

Deposit rates tend to be lower and adjust only partially to increasing wholesale rates.[4] To boot, the adjustment speed is often asymmetric, rising wholesale rates are only slowly passed on to depositors whereas the adjustment speed is higher when interest rates fall.[5] A bank has also the option to quote deposit rates in fractions of a percentage point instead of continuously.[6] Furthermore, banks sometimes market non-maturity deposits with implicit rate ceiling and rate floor. The model of Jarrow and van Deventer (1998) captures partial adjustment but does not replicate asymmetric adjustment speed, discrete price steps, floor or cap. Asymmetric adjustment speed is important to valuation and hedging as reported by O'Brien et al. (1994). The more advanced asymmetric partial adjustment models of Neumark and Stephen (1992) and Moore et al. (1990) would offer a way to include asymmetric adjustment speed. Unfortunately, "individual bank deposit rate adjustments are more discrete in size and less regular in frequency," as noted by O'Brien (2000). In other words, existing models neglect the non-linearity to change deposit rates in discrete steps and having some leeway how much to adjust if at all. Further, the option to quote rates on a discretionary basis requires a specification that can respond not only to the short rate as in Jarrow and van Deventer (1998), Kalkbrener and Willing (2004), or Nyström (2008) but to other changes of the yield curve as well, e.g., a curve flattening or steepening.

I propose an econometric specification that can adequately cover non-linearities such as discrete price steps, asymmetric adjustment speed, partial adjustment, floors and caps, term spread

[2] A few examples are the papers of O'Brien et al. (1994), Hutchison and Pennacchi (1996), Jarrow and van Deventer (1998), Janosi et al. (1998), O'Brien (2000), Kalkbrener and Willing (2004), Elkenbracht and Nauta (2006) and Nyström (2008).

[3] Vega risk is normally defined as the change in prices if implied volatilities change whilst zero rates remain fixed and I will also apply this definition. Hence, vega will be zero for a portfolio of zero bonds.

[4] see, e.g., Hutchison and Pennacchi (1996).

[5] see, e.g., Diebold and Sharpe (1990), Moore et al. (1990), Hannan and Berger (1991), Neumark and Stephen (1992) and O'Brien (2000).

[6] see, e.g., Kahn et al. (1999).