Levelling the playing field of the FRTB's forex rules

The Fundamental Review of the Trading Book's (FRTB's) standardised approach (SA) contains a strong asymmetry that may disadvantage banks, depending on their reporting currencies. Hany Farag recently published a comprehensive analysis of the mathematical properties of the SA's foreign exchange measures which showed that there is a way to fix the asymmetry while maintaining the FRTB framework. In this article, he presents a simple and detailed version of the solution and demonstrates how it can be applied to the delta and curvature measures individually or jointly

We refer the reader to Basel Committee on Banking Supervision (2012, 2013, 2014, 2015, 2016a,b, 2017, 2018a) and Farag (2017a) for the historical development, evolution and business impact of the Fundamental Review of the Trading Book (FRTB) framework. We also point the reader to Basel Committee on Banking Supervision (2019), which details the very recent response by the Basel Committee to the issues and proposals presented since the submission of this paper (see the last section, on recent developments, for more details). This framework has two major themes for calculating risk and capital requirements. The first is the standardised approach (SA), which is built around sensitivities (generally) produced by the front office, including a curvature calculation to capture nonlinear losses and a conservative correlation structure to capture correlation shifts during times of market stress. The SA attempts to calculate a standardised version of expected shortfall along with a default risk charge to account for the potential default of equities, debt instruments and their derivatives. The second is the internal model approach, which attempts to capture the same measures but using the bank's own internal models, with some constraints.

Here, we are only focused on the SA, and particularly on its foreign exchange capital measures: namely, delta and curvature. These capture the equivalent of a 97.5% expected shortfall for the linear and (purely) nonlinear parts of the forex risk of the trading book (respectively). The key principle of the Basel regulations is that forex risk is measured with respect to the reporting currency in which a bank will typically hold its assets. Alternatively, it can be the currency of the jurisdiction of the supervisor in which the relevant bank subsidiary is domiciled. In simple terms, it is a currency deemed risk-free by the local supervisor, and holding any amount of cash in such a currency is thought not to represent any forex risk to this entity as far as the supervisor is concerned. Naturally, the parent bank may have a different applicable jurisdiction in which a different currency is deemed to be the reporting currency at the aggregate level. We will not concern ourselves with such nuances and instead will mainly focus on the case of an already determined reporting currency for a given entity.

The SA rules were written in a rather symmetric way for any reporting currency. Indeed, the risk factors are defined as the exchange rates referencing the reporting currency: that is, they have the form $p(C_i, R)$, where R is the reporting currency and C_i is a foreign currency different from R. Here, $p(C_i, R)$ is the price of one unit of C_i in units of R. Now, if a bank with reporting currency R has an option on (say) EUR/USD, and R is neither EUR nor USD, one can still write:

$$p(\text{EUR, USD}) = p(\text{EUR}, R) \times \frac{1}{p(\text{USD}, R)} \tag{1}$$

It is then straightforward to express any portfolio of derivatives in terms of the prescribed risk factors. The SA has two types of charges relevant to forex that we will now study.

Forex delta

The delta capital charge is a risk measure for linear risk in the SA. The starting point is a risk factor sensitivity s_k (a Greek delta) with respect to a risk factor k. Each such risk factor in the SA is also assigned a risk weight RW_k. The weighted sensitivity WS_k due to this risk factor is then defined by:

$$\text{WS}_k = \text{RW}_k \times s_k \tag{2}$$

The framework has a hierarchy of buckets and intrabucket correlations ρ_{kl} between risk factors in the same bucket, leading to a bucket-level risk position K_b defined by:

$$K_b^2 = \sum \text{WS}_k^2 + \sum \sum_{k \neq l} \rho_{kl} \times \text{WS}_k \text{WS}_l \tag{3}$$

Then, we also have an inter-bucket correlation γ_{bc} leading to a delta charge:

$$\text{delta charge} = \sqrt{\sum \left(K_b^2 + \sum \sum_{b \neq c} \gamma_{bc} \times S_b S_c \right)} \tag{4}$$

where:

$$S_b = \sum_k \text{WS}_k \tag{5}$$

which is the sum over the risk factors k in bucket b. This structure is used in both delta and vega (for volatility risk factors) in all asset classes. In forex, each exchange rate $p(C_i, R)$ is a risk factor that has its own bucket, and the above structure is simplified a bit. In Farag (2017b) it is shown that, for a portfolio of derivatives on EUR/USD, if we consider the delta charge for a USD bank and a CAD reporting bank, the ratio of the charge for the latter to that of the former is:

$$\sqrt{2(1-\gamma)} \tag{6}$$

where γ is 0.6 times a multiplier that can take one of three values (1, 1.25 or 0.75) depending on the so-called correlation scenarios (see Basel Committee on Banking Supervision 2016a). These ratios are then 0.89, 0.7 and 1.05, respectively. Here, one can already see asymmetries with respect to reporting currency, though we have not yet shown whether or not this is a natural situation or an anomaly. We address this question fully in a later section.

Forex curvature

For the nonlinear or curvature capital charge for forex, we start by defining a curvature risk position for each risk factor, namely:

$$\mathrm{CVR}_k = -\min\left\{\begin{array}{l}\sum_\alpha V(x_{\alpha,k} + \mathrm{RW}_k \times x_{\alpha,k}) - V(x_{\alpha,k}) - \mathrm{RW}_k \times s_k \\ \sum_\alpha V(x_{\alpha,k} - \mathrm{RW}_k \times x_{\alpha,k}) - V(x_{\alpha,k}) + \mathrm{RW}_k \times s_k\end{array}\right\} \tag{7}$$

where $x_{\alpha,k}$ is the original value of the risk factor (often called the base value by practitioners), $V(\cdot)$ is the value of the instrument in a given position α as a function of the risk factors, and the sum is over all instruments in the portfolio. From this point on, we will drop the sum over the instruments and just think of $V(\cdot)$ as the value of the entire portfolio (that is, the sum over positions is implicit). Observe that the curvature risk position in risk factor k is the risk of a profit-and-loss change of the portfolio in excess of the linear (delta) part. So, it is intended to isolate the nonlinearities and, hence, it is mainly relevant for options rather than linear positions such as spot positions or forwards. Now, the curvature capital charge has more pronounced nonlinearities in its aggregation than the delta charge, but it essentially follows a similar scheme:

$$K_b'^2 = \left[\max\left(0, \sum_k (\max(0, \mathrm{CVR}_k))^2 + \sum_{i \neq k} \rho'_{i,k} \times \mathrm{CVR}_k \mathrm{CVR}_l \psi(\mathrm{CVR}_k, \mathrm{CVR}_l)\right)\right]^{1/2} \tag{8}$$

where the sum is over all risk factors in bucket b, ρ' is an intrabucket correlation matrix and $\psi(x, y)$ is a function that takes the value 0 if both its arguments are negative, and 1 otherwise. Again, to aggregate, we start with:

$$S_b' = \sum_k \mathrm{CVR}_k$$

where the sum is over the risk factors in bucket b. Then, we have:

$$\text{curvature charge} = \sqrt{\max\left(0, \sum_b K_b'^2 + \sum_{a \neq b} \gamma' \times S_b' S_a' \psi(S_a, S_b)\right)} \tag{9}$$

where the sum is now over the buckets and γ' is an interbucket correlation matrix. In forex, there is only one risk factor per bucket, and γ' is simply a constant.

In Farag (2017b), it is shown that, for a portfolio that behaves quadratically on EUR/USD with positive curvature, the ratio of the charge for a CAD reporting bank to that for a USD reporting bank has the form:

$$\sqrt{1 + 2\frac{1}{(1 - \mathrm{RW})}\gamma' + \frac{1}{(1 - \mathrm{RW})^2}} \tag{10}$$

where RW is the uniform risk weight, and γ' takes a value of 0.36 times a multiplier that takes one of the abovementioned three values, ie, 1, 1.25 or 0.75, depending on the relevant correlation scenario. For RW $\approx$ 21%, this leads to ratios of 1.874, 1.93 and 1.81, respectively. For portfolios more complicated than quadratic, there is no known bound for this anomaly. We will show in the next section that this anomaly is not justifiable.

Forex capital measures and reporting currencies

In this section, we prove our key result, which offers a solution to the problem. Before we proceed, however, we need to make one point clear. Suppose a bank holds a very large amount (X) of cash in its reporting currency. This, seen as a portfolio, has zero forex risk with respect to the bank's reporting currency; however, it cannot possibly have zero risk for a bank that has a different reporting currency. Our derivation below is 'aware' of this issue. Only for zero mark-to-market (MtM) portfolios is it meaningful to ask for symmetry with respect to reporting currencies. This was observed in Farag (2017b) and will be highlighted below as well.

We now present two different proofs, from first principles, that forex risk in FRTB with respect to a reporting currency can be theoretically calculated by measuring forex risk via another currency, according to FRTB rules for the latter, without loss of generality or accuracy. Furthermore, this is true for curvature and delta, separately or jointly. This proof is an extension of the arguments in Farag (2017b).

For concreteness, we assume CAD is the reporting currency of the bank and that USD is simply some major currency for which we have approved FRTB rules, representing the potential forex risk (ie, loss) for a portfolio P (valued in USD), with risk measured with respect to USD. Our argument will show a tight mathematical connection between the two. We start by making various observations to be used later.

■ **Observation 1.** In FRTB rules, the spot rate f (for USD/CAD) for the CAD reporting bank is shocked by $(1 \pm \mathrm{RW})$. That is, under FRTB shocks:

$$f \to f \times (1 \pm \mathrm{RW}) \tag{11}$$

■ **Observation 2.** Suppose a portfolio P has a spot MtM value X in USD and is held by a CAD reporting bank. Suppose also the value of this portfolio in general has no dependency on any exchange rate (eg, pure USD cash). Then, under all forex shocks for the FRTB, the potential loss to the CAD reporting bank can be expressed as:

$$\begin{aligned}\text{CAD loss} &= X \times f \times (1 - (1 \pm \mathrm{RW})) \\ &= \mathrm{RW} \times \text{CAD notional}\end{aligned} \tag{12}$$

Here, we use the sign that maximises the loss and express $|X| \times f$ as CAD notional. The absolute value allows us to consider negative MtM portfolios, but the reader can consider $X > 0$ for simplicity. This is exactly the same loss we would have encountered had we performed straightforward delta calculations in CAD reporting for a linear position with sensitivity (to USD/CAD) equal to CAD notional. This result holds for any USD denominated position that does not depend on forex rates (eg, USD cash or bonds, equity or a simple non-quanto equity option).

■ **Observation 3.** Suppose now the CAD bank holds a more general portfolio (which can depend on all forex rates without restriction). Say that portfolio is P, with a spot MtM value of X in USD. We also have a way (already approved) to calculate the potential loss, $L > 0$, of this portfolio in USD.

L is the potential loss under forex shocks, as per FRTB rules, for USD. The value of this portfolio in USD under such shocks is then $X - L$. To a CAD reporting bank holding this same portfolio, the loss can be more than L converted by the spot rate, as CAD can also move against USD simultaneously when these shocks occur. This is much more conservative than the correlation assumptions of the FRTB rules, and it is a very conservative estimate. The CAD loss to the CAD bank can then be estimated as:

$$\text{CAD loss} \leqslant \max(X-(X-L)(1+RW), X-(X-L)(1-\text{RW}))\times f \quad (13)$$

Here, the maximum is taken over the different sign choices. The maximisation depends on the various signs of the quantities involved, but all we need to know for now is that it can be related to the loss L in this way. This is an important connection between the USD loss and the CAD loss. Our next observation will simplify this expression in a natural way.

■ **Observation 4.** A CAD reporting bank holding an arbitrary portfolio P can have arbitrarily large amounts of CAD cash without any forex risk in CAD. Observation 3 still holds even if we ignore this fact, although the maximisation in (13) would ultimately produce a large double-count of risk that way (so the upper bound would be unnecessarily large). To simplify the following calculations and the expression for the CAD loss in (13), we express the portfolio as:

$$P = P - P_0 + P_0 \quad (14)$$

Here, P_0 is the spot MtM value of the portfolio P in CAD, expressed as a cash position. This cash position has zero risk to a CAD bank in FRTB regulations or any other risk measurement framework. Therefore, it represents no loss of information or generality. It is, therefore, sufficient to restrict our considerations to the 'dynamic' portfolio $P - P_0$ when calculating forex risk, or capital charges, for the CAD bank. This dynamic portfolio has zero, spot and MtM values in all currencies. Immediately, we have made progress, because (13) can now be expressed ($X = 0$) as:

$$\text{CAD loss} \leqslant L \times f \times (1 + \text{RW}) \quad (15)$$

This is the result we wanted to prove. It shows that the intended capital charge for a CAD bank, which is presumed to be necessary to cover the losses in CAD, can be connected to the loss in USD via the FRTB rules for USD and the risk weight. This completes the first proof of our claim. We mention in passing that the dynamic portfolio we have considered is commonly encountered in the trading book. Essentially, traders borrow or lend cash to finance their trades, and the above dynamic portfolio is typical of a 'CAD-funded' desk or trading book. To apply our technique, however, no special structure for desks or funding is required. One just has to apply the rules to the dynamic portfolio, nothing more.

Before we move on to the next proof, it should be noted that our consideration of the dynamic portfolio leads to another helpful simplification. Whereas the RW term in (12) and (13) was critical to capture even the first-order risk, the explicit RW term in (15) leads to a higher-order term only. This is because the loss captured in L by the construction of the dynamic portfolio itself (using FRTB rules) has at least an order of one in RW (or higher). This deserves an example. Again, consider the case of a portfolio of (say) USD cash or bonds. Assume that, in USD, the spot MtM is X. The dynamic portfolio is then expressed as:

$$X \text{ USD cash} - X \times f \text{ CAD cash} \quad (16)$$

Let us now calculate the loss L in USD. According to FRTB-prescribed rules in Basel Committee on Banking Supervision (2016a), in USD, this portfolio has a sensitivity of X with respect to CAD/USD, and therefore it has a potential loss of:

$$L = X \times \text{RW}$$

This represents the delta charge in USD and there is no curvature. Using (15), we obtain:

$$\text{CAD loss} \leqslant X \times \text{RW} \times f \times (1 + \text{RW}) \quad (17)$$

As can be seen if we compare the above with the exact answer in (12), which is only $X \times \text{RW} \times f$, (17) is overly conservative, and the additional RW term in the factor $(1 + \text{RW})$ is in fact overkill here. What matters is the upper bound in (15) works, regardless of the form of the regulation by which we calculate L. This is a general principle and is not specific to the FRTB.

Next, we approach the same problem using capital considerations. P is an arbitrary portfolio. P_0 is a CAD cash position equal to the spot MtM of P, in CAD. Here, again, we use the dynamic portfolio $P - P_0$ without loss of generality. The CAD bank now holds the portfolio $P - P_0$. Under FRTB calibration for delta and curvature, it has the potential to lose $L > 0$, in USD (which can be calculated as if it is a USD bank). If the CAD reporting bank actually held its capital for this risk in USD, it would suffice to hold the amount L. No further capital is required to cover the potential losses for this forex risk (according to FRTB principles in USD).

Suppose, however, this CAD bank holds the equivalent of L in CAD (ie, L converted to CAD by the spot rate) or $L \times f$ as trading capital for this risk. This bank is now exposed to forex risk due to its capital potentially sliding in value against the USD. This sort of situation (although not precisely in this context) is typically referred to as 'structural forex' and is typically exempted from market risk capital requirements (see, for example, Basel Committee on Banking Supervision 2018b). In principle, this CAD bank is essentially only exposed to a linear position in USD/CAD on USD notional multiplied by L due to the potential move of the value of the capital itself. According to FRTB calibrations for this CAD bank, it now requires additional capital of:

$$L \times f \times \text{RW} \quad (18)$$

Therefore, in total, the capital estimate for the CAD bank is estimated as:

$$L \times f \times (1 + \text{RW}) \quad (19)$$

which is identical to (15) but with the additional insight that banks' exemption from needing the extra factor $1 + \text{RW}$ is akin to the exemptions for structural forex: these exempt forex risk capital when a bank is hedging its capital ratios against forex risk. We return to this point below using symmetry arguments. We conclude that the FRTB framework, if self-consistent, should respect the theoretical result that:

$$\text{FRTB CAD capital} \leqslant \text{FRTB USD capital} \times f \times (1 + \text{RW}) \quad (20)$$

This is the main result that we set out to prove.

The astute reader will notice that, so far, we have treated capital (or risk) as a total quantity in our exact results, and we did not attempt to split it into linear (delta) and nonlinear (curvature). We address this issue in the appendix by decomposing our portfolio into two subportfolios: one purely linear and the other purely nonlinear (second order or higher). There it will be shown that inequality (20) should be respected by both curvature and delta individually.

While mathematically we cannot dismiss the factor $(1+\text{RW})$ in connecting the losses in one currency to those in another, there are other reasons why this factor is best dropped. Indeed, symmetry arguments also suggest that (20), (21) and (26) should hold if USD and CAD are swapped. Therefore, assigning this additional factor to the calculation in one currency but not the other would seem arbitrary. So, from the perspective of having a level playing field for the industry, there is no *a priori* reason to prescribe the $(1+\text{RW})$ factor to either reporting currency to avoid any potential bias. We also point out that the risk weight RW has now come down to approximately 10% for most currency pairs, and so the impact of dropping this factor is relatively small anyway.

In summary, it is very reasonable to argue that a level playing field and a self-consistent framework are best achieved when either delta or curvature, or both, are calculated in any appropriate currency and converted by the spot forex rate. Note that for curvature this requires no extra work from the bank other than performing the calculation in a different currency, since the subtraction of the cash position P_0 has no impact on curvature. For delta, however, this is a critical step; although it is quite simple to perform from an operational point of view.

Finally, we remark that Farag (2017b) offers more solutions than the one presented here. Indeed, in that paper a variety of 'invariants' are discussed to produce a level playing field. Our present results can also be extended to these cases. The economic impact or meaning of these mathematical invariants, however, differs and depends on the objective of the regulation. In this paper, we focused on what is perhaps the most natural and simplest choice, but by no means is it unique. We refer any reader interested in pursuing other variants to the above work.

Conclusion

We have provided arguments to motivate a simple solution for the forex asymmetry in the FRTB, and we have given general mathematical constraints that any regulation (not just the FRTB) should observe in order to maintain a level playing field in forex trading. The solution proposed is easy to state and implement.

Allow a bank to calculate its forex capital in another 'base' currency in the SA, using the FRTB rules for that currency, as if it were its reporting currency, and convert that capital to the reporting currency using the spot rate. In order to ensure all forex risk is captured in this manner, one should replace the original portfolio P with $P - P_0$, where P_0 is a cash position equal to the MtM of P, valued in the bank's reporting currency. The latter step is only needed in the delta calculation as it does not affect curvature.

Recent developments

Since the submission of this paper, the FRTB text has been revised (see Basel Committee on Banking Supervision 2019). It is stated in paragraph 21.14 of that document that, subject to supervisory approval, a bank may use this 'base currency' approach provided it accounts for all of its forex risk, including translation risk. While no clear guidance is provided on how to do this exactly, our approach provides a simple and complete solution to this treatment. We note that, while we have made an effort to justify the separate treatment of curvature and delta using the base currency approach, the Basel Committee on Banking Supervision appears to require that should a bank opt for this treatment for delta, it must do the same for curvature as well, and (presumably) vice versa.

Then, in paragraph 21.98 of Basel Committee on Banking Supervision (2019), we find that for curvature one can apply another allowance (subject to supervisory approval). In this treatment, the bank calculates curvature not only by shocking one currency at a time against the reporting currency, as in the standard FRTB rules, but also by adding a scenario in which the reporting currency itself is shocked against all others. This is essentially a treatment equivalent to applying the original FRTB rules with respect to a universal currency (eg, gold). Indeed, a shock of one currency at a time (including the reporting currency) against such a universal currency is equivalent to the treatment suggested by paragraph 21.98 and was studied in Farag (2017b) as one way to restore the symmetry. There, the author's view was that this would increase the capital requirements unnecessarily. This issue is addressed in paragraph 21.98, which advocates dividing the total curvature calculated in this way by a scalar multiplier of 1.5. While mathematically appealing (it gives the same answer for all reporting currencies), this solution is a bit less natural from an economic point of view, as it solves the problem by adding a less meaningful capital term to the original formula (representing loss due to movement of the reporting currency against such a universal currency). Alternatively, one can also see this as a redundancy, since accounting for all individual currencies moving against the reporting currency with various correlations already includes scenarios in probability space with the reporting currency moving against all others. This treatment, then, seems to artificially add this redundancy before recalibrating the output. Nonetheless, it is perhaps better to restore the level playing field.

Finally, paragraph 21.98 has yet another allowance (subject to supervisory approval). This allows a bank to assign a scalar multiplier to the individual curvature exposure, depending on whether or not the option referenced the reporting currency itself. As discussed in Farag (2018), we remain concerned about this approach as it may lead to potential (material) distortions and instability of the measures.

Appendix

Here, we demonstrate that (20) should also be respected by curvature and delta individually. First, we observe that all linear positions for a CAD bank, when expressed in USD, will also remain linear (with possibly constant terms). This can be seen from the linear part of a Taylor series or simply by representing the linear positions by cash positions denominated in different foreign currencies. Since the linear portfolio's total capital in the FRTB is purely delta, and since the delta of the original portfolio is the delta of the linear part, we conclude – using (20) applied to these linear portfolios – that a self-consistent FRTB framework should respect the theoretical result that:

$$\text{FRTB CAD delta capital} \leqslant \text{FRTB USD delta capital} \times f \times (1+\text{RW}) \quad (21)$$

To do the same for curvature, we observe that the higher-order terms for a CAD portfolio (which we denote by P_2) can be represented as:

$$\begin{aligned} P_2(p(\text{GBP},\text{CAD}),\dots,p(\text{USD},\text{CAD})) &= A(p(\text{GBP},\text{CAD}) - p_0(\text{GBP},\text{CAD}))^2 \\ &\quad + B(p(\text{USD},\text{CAD}) - p_0(\text{USD},\text{CAD}))^2 \end{aligned}$$

$$
\begin{aligned}
&+ C\,(p(\mathrm{USD},\mathrm{CAD}) - p_0(\mathrm{USD},\mathrm{CAD}))\\
&\qquad \times (p(\mathrm{GBP},\mathrm{CAD}) - p_0(\mathrm{GBP},\mathrm{CAD}))\\
&+ D\,(p(\mathrm{JPY},\mathrm{CAD}) - p_0(\mathrm{JPY},\mathrm{CAD}))\\
&\qquad \times (p(\mathrm{GBP},\mathrm{CAD}) - p_0(\mathrm{GBP},\mathrm{CAD}))\\
&+ \cdots + \text{h.o.t.}
\end{aligned} \tag{22}
$$

where the subscript 0 indicates spot values, the ellipses indicate terms of similar structures, and 'h.o.t.' stands for higher-order terms. When expressed in USD, P_2 is dynamically (ie, under any shocks) expressed as:

$$P_2(p(\mathrm{GBP},\mathrm{CAD}), \ldots, p(\mathrm{USD},\mathrm{CAD})) \times p(\mathrm{CAD},\mathrm{USD}) \tag{23}$$

Now, we write:

$$p(\mathrm{GBP},\mathrm{CAD}) = \frac{p(\mathrm{GBP},\mathrm{USD})}{p(\mathrm{CAD},\mathrm{USD})} \tag{24}$$

and:

$$p(\mathrm{USD},\mathrm{CAD}) = \frac{1}{p(\mathrm{CAD},\mathrm{USD})} \tag{25}$$

It is then straightforward, using (22), (24) and (25), to check that all first derivatives with respect to exchange rates such as $p(\mathrm{CAD},\mathrm{USD})$, $p(\mathrm{GBP},\mathrm{USD}), \ldots$ evaluated at the spot rates (with zero subscripts) of the expression in (23) vanish. This implies that all second-order (and higher) terms of this portfolio when expressed in CAD also produce second-order (and higher) terms when expressed in USD. Since for purely nonlinear portfolios (ie, second order or higher) the total FRTB capital is that of the curvature charge only, we then have, using (20):

$$
\begin{aligned}
\text{FRTB CAD curvature capital} \leqslant \text{FRTB USD curvature capital}\\
\times f \times (1 + \mathrm{RW})
\end{aligned} \tag{26}
$$

Again, this is the theoretical result the FRTB framework should respect, if it is self-consistent. This completes our proof for delta and curvature separately. ■

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