OpenRisk White Paper

Stress Testing Methodology for FX Lending

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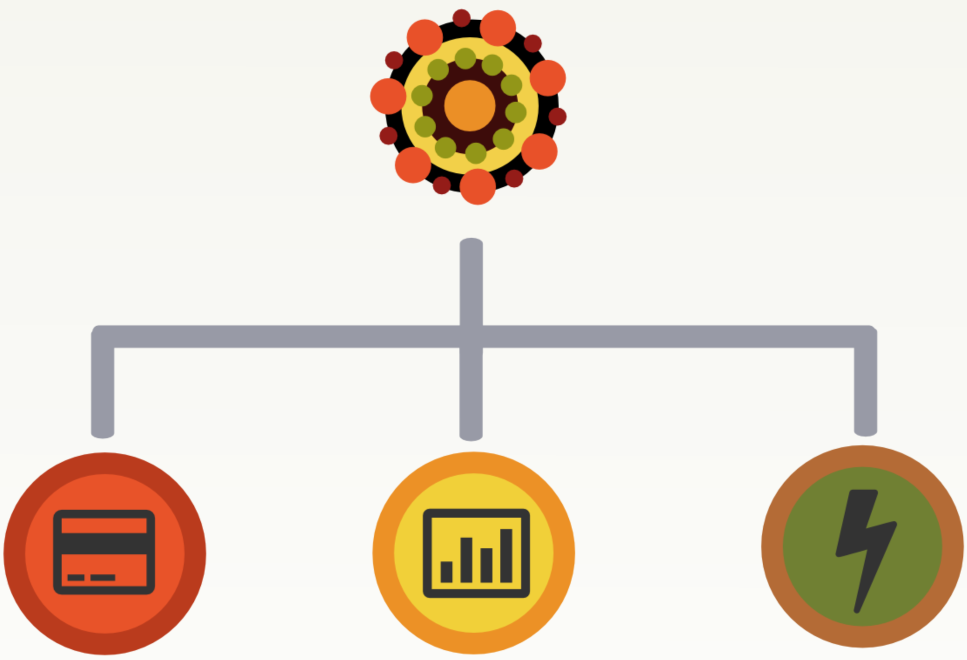

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SUMMARY

We develop a simple methodology for stress testing portfolios of credit instruments classified as foreign exchange lending. Loans whose repayment schedule is denominated in a currency other that that of the borrower's domestic currency are commonly seen in many jurisdictions and have a risk profile that is considerably more complicated than domestic currency loans. Yet the literature for credit risk assessment and stress testing of portfolios of such loans is very limited, which means that Stress Testing and Internal Capital Adequacy Assessment (ICAAP) requirements are harder to meet. Our methodology builds on existing standard tools used in portfolio credit risk modeling and enables obtaining insights into the additional risk factors embedded in foreign currency lending.

The white paper has two main sections:

- A *Review and Proposal* section discussing the motivation, concepts and previous research on stress testing FX lending portfolios along with a non-technical discussion of the proposed stress testing methodology
- The *Technical Documentation* section documenting an approach to stress testing FX lending and offering an initial exploration of impact.

Further Resources

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Review

Motivation

The vast majority of borrowers opt for lending products that require the contractual repayment of funds in the currency of their country of domicile (the so called *domestic* currency), which is typically also the currency in which their income or other repayment source is derived in. FX denominated Loans are also widely used, in particular by corporate borrowers that may be deriving income in different currencies. The impact of the financial crisis on corporate borrower's fx lending has been documented recently[1].

Yet the past decade saw also a significant rise, in diverse European jurisdictions, of large scale FX lending to *consumers*. During 2010, more than 70 per cent of all private sector loans in Estonia, Latvia and Serbia were denominated in (or linked to) a foreign currency. The share of FX loans also exceeded that of domestic currency loans in Bulgaria, Hungary and Romania[2]. A comprehensive survey of loan characteristics [3] is provided the OeNB Euro Survey covering nine CESEE countries (5 EU Member States Bulgaria, Croatia, Hungary, Poland and Romania and 4 (potential) EU candidate countries Albania, Bosnia and Herzegovina, FYR Macedonia and Serbia). Similar developments have also been observed in other countries (Argentina, Peru, Uruguay and Turkey). The motivations for the growth of this type of financial product may have been diverse, but the substantial interest differential of domestic versus FX loan rates prevailing in the last decade is almost certainly the underlying driver. As indicated in [4], the low interest of FX lending was raising creditworthiness of borrowers in foreign currencies against the domestic currency, as well as making such loans more accessible.

The risks embedded in consumer oriented FX loans became highly visible during and after the financial crisis, for example as the currencies of several countries substantially lost in value against the Swiss franc, which has been an important currency in FX lending. In the case of Austrian banks lending to Central, Eastern and Southeastern Europe the report of the OeNB [5] indicates very clear positive correlations between the increase in the exchange rate induced repayment burden and the loan loss provision ratio for a period between 2008-2009. Un-hedged foreign currency (FX) borrowing has come to be seen as a major threat to financial stability in eastern Europe [6]. Some countries have taken measures to reduce foreign currency lending and European regulatory authorities are intensifying their scrutiny of the applicable risk management policies and tools[7],[8].

Risk Profile of FX Loans

We focus here on the credit risk aspect of FX loans, while recognizing that a portfolio of such loans has also non-trivial Asset and Liability Management aspects (ALM). There is remarkably little literature focusing on the credit risk profile, see e.g. the report[9], which means that risk management activities such as stress testing and internal capital adequacy assessments (ICAAP) that require a degree of risk quantification are not supported as they should.

Yet while the risk profile of an FX denominated loan is more complex than a similarly structured domestic loan it would appear, a-priory, that standard tools can be *extended* to capture the essence of the new risk profile. The credit risks associated with FX lending derive from the fact that exchange rate movements influence a borrower's debt-servicing capacity, and potentially also the exposure at default and the value of the loan collateral (if applicable).

It is sometimes incorrectly stated in references that FX lending combines market risk with credit risk elements. This may indeed be true if a firm puts in place *FX hedges* in connection with an FX lending portfolio. The mark-to-market of that hedge will be indeed subject to market risk. Yet when focusing on a standalone FX lending portfolio, the essential risk is wholly captured under the credit risk category. The main difference with more conventional products (and maybe the source of confusion) is that the *credit behavior* of borrowers is correlated with *dynamic*, i.e. time varying, and possibly quite volatile market variables. Yet this correlation of creditworthiness with market variables is already the case for any domestic currency denominated *floating rate loan* and is thus not unique to FX loans. Clearly a firm's credit risk measurement framework must include all the risk drivers and attributes that are relevant, irrespective of if they are more or less static in nature.

Regulatory Framework

The Basel II Pillar I framework has hardly any provisions for capitalizing the additional risk inherent in FX lending. This means that even if the risk classification and risk parameters used for FX loans properly capture the full impact of FX risk in credit performance, it is very unlikely that use of such improved credit parameters with one of the capitalization options offered by Basel II will capture the *tail risk* inherent in an FX lending portfolio. This is explicitly not the case in the IRB context, where tail risk is solely driven by a *single* systemic factor and has been (roughly) calibrated to the volatility of generic portfolios.

Additional capital requirements for FX lending maybe required by local regulators as part of the ICAAP. As ICAAP methodologies are generally not public it is not possibly to list here any approaches followed. The EBA guidelines for the SREP process [8] specify the following:

EBA Guidelines (2013) on capital measures for foreign currency lending to unhedged borrowers under the supervisory review and evaluation process (SREP):

Additionally, competent authorities should ensure that institutions quantify the capital needed to cover FX lending risk, including the concentration risk aspect, in a prudent and forward-looking manner, in particular focusing on concentrations due to the dominance of one (or more) currency(ies) (as the movements in exchange rates are a common risk factor simultaneously driving defaults of many borrowers). Competent authorities should ensure that institutions provide a reasoned assessment of their internal capital level allocated to FX lending risk.

The indicative schedule for additional own funds requirements is given by:

- FX lending risk is assessed as 'Low' would attract additional own funds requirements of between 0 and 25%
- FX lending risk is assessed as 'Medium-Low' would attract additional own funds requirements of between 25.1% and 50%
- FX lending risk is assessed as 'Medium-High' would attract additional own funds requirements of between 50.1% and 75%
- FX lending risk is assessed as 'High') would attract additional own funds requirements of over 75.1% (this figure can be over 100%)

Requirements for stress testing relevant FX lending portfolios have been published by the European Banking Authority[7]. In brief, when FX lending exposures are significant, PD and LGD measures for FX lending for currencies must be computed. These risk metrics must take into account the altered creditworthiness of obligors, given the FX evolution under the baseline and adverse scenario specified for the stress testing exercise. The marginal impact from the risk emanating from FX lending exposure has to cover both PDs and LGDs. For PDs, the impact should be based on satellite models that link the macro scenario to the PD. For LGDs, the impact should be based on an addon for the LTV ratio.

Non-technical Description of Methodology

Our proposed methodology aims to provide a *relative* measure of credit risk for FX lending which utilizes an existing reference (or baseline) credit risk assessment. That baseline assessment captures the credit risk of a comparison pool of borrowers and lending products that are in all other respects identical but do not have an FX denomination clause.

As an aside, it possible to develop a fully standalone credit assessment framework that produces *absolute* risk measures without reference to a comparison credit rating. Yet the data requirements for calibration and containing the model risk associated with such a more complicated approach are significantly higher. Roughly speaking for an acceptable model one would need to have for *each* cohort of homogeneous credits, sufficiently long observations periods that cover *the entire FX volatility range*, in order to sample all levels of repayment burden. The currently available historical data cover only one significant FX realization (scenario) per cohort. While this single data point is invaluable for benchmarking and validation, it is not sufficient for building a standalone framework. For example there is a risk that the weight of more static characteristics of the borrower (such as their financial profile) will be conflated with the impact of a disproportionate repayment burden. Hence, as a first step, there much to be gained by a simpler approach that focuses on capturing the non-linear dependence of credit risk on FX rate development.

To develop the methodology we adopt the more or less "standard" credit risk modeling toolkit that involves interpreting the default of a borrower as an event triggered by their ability to repay dropping below a certain threshold level. This line of reasoning goes back to the so-called structural models for evaluating corporate liabilities[10] but it should be made clear that the precise economic meaning of the variables do depend on how the model is calibrated (i.e., whether using market prices or historical default histories etc.).

The starting point is the probability of default of the non-FX denominated loan (for any given scenario). We assume that this probability is obtained by stressing an existing one-year PD that is in turn obtained by an internal credit rating model. The corresponding FX-loan PD is calculated by evaluating the impact of the FX scenario on the ability of the borrowers to repay.

To obtain the stressed FX default rate we need to specify in detail the *dependency structure* of FX rates and credit performance and the precise quantification of correlation structures involved. We opt to keep these choices as simple as possible to provide an entry point for meaningful calculations. In this spirit, the distribution of macro factors and FX rates is taken to be normal (Gaussian) and the factor structure is kept to the simplest possible number of factors (in this case two).

We focus here on stressed PD's only. The EBA proposed approach of stressing LGD's is to use a stressed LTV estimate (taking into account the FX denominated loan value). This is certainly a good and easy to implement approximation.

Technical Documentation

Model Setup

Model for Asset and FX uncertainty

We use a one period risk framework (conventionally taken to be an annual period). The i-th borrower's ability to repay is determined by the comparison of the evolution of their effective "asset base" A_1^i at the end of the observation period (by convention set at $t = 1$) to a specified default threshold K.

In the case of FX lending, while the assets and ability to pay of the borrower are denominated in *local currency*, the default threshold will instead be varying in accordance with the exchange rate f_t of local versus foreign currency prevailing at a given time t.

A useful representation of future uncertainty around asset and FX realizations is offered by a log-normal continuous time specification:

$$\frac{dA_t^i}{A_t^i} = \sigma^i dW_t^i \quad (1)$$

$$\frac{df_t}{f_t} = \sigma_f d\tilde{W}_t \quad (2)$$

where we have ignored possible drift components, introduced (σ_i, σ_f) as the instantaneous asset and FX volatilities respectively and used $(W_t^i, \tilde{W}_t)$ as (possibly correlated) Brownian motions that drive the uncertainties.

The final values of asset and FX rate at the end of period are obtained directly as the integrals

$$A_1^i = A_0^i e^{\sigma^i W_1^i - \frac{1}{2}\sigma_i^2} \quad (3)$$

$$f_1 = f_0 e^{\sigma^f \tilde{W}_1 - \frac{1}{2}\sigma_f^2} \quad (4)$$

where (f_0, A_0^i) are the initial values (at the start of the period).

Thus, the asset based repayment ability denominated in local and foreign currency is respectively

$$A_1^i = A_0^i e^{\sigma^i W_1^i - \frac{1}{2}\sigma_i^2} \quad (5)$$

$$\tilde{A}_1^i = f_0 A_0^i e^{\sigma^i W_1^i - \frac{1}{2}\sigma_i^2 + \sigma^f \tilde{W}_1 - \frac{1}{2}\sigma_f^2}. \quad (6)$$

The expression for $\tilde{A}_1^i$ captures the key risk driver in the model. It depends on both the volatility of domestic asset values and exchange rate variables and the correlation between these.

From the above we derive and approximate the FX denominated *asset return* $\tilde{r}_1^i = \frac{\tilde{A}_1^i - \tilde{A}_0^i}{\tilde{A}_0^i}$ as

$$\tilde{r}_1^i = e^{\sigma^i W_1^i - \frac{1}{2}\sigma_i^2 + \sigma^f \tilde{W}_1 - \frac{1}{2}\sigma_f^2} - 1 \quad (7)$$

$$\approx \sigma^i W_1^i + \sigma^f \tilde{W}_1 \quad (8)$$

where we kept only leading terms in the exponential expansion and ignored the drift due to the volatility. This expression can be compared with the corresponding formula for the domestic asset return:

$$r^i_1 \approx \sigma^i W^i_1 \tag{9}$$

Credit Defaults in Threshold Model

First a brief reminder: The default flag D^i is - in the standard, non-FX loan case - determined as the indicator function:

$$D^i = \mathbb{1}_{\{r^i_1 < K\}} \tag{10}$$

and takes value 1 when in default, or zero when not. Ex-ante, the probability of borrower default is

$$PD^i = P(r^i_1 < K) \tag{11}$$

Correspondingly, for an FX denominated loan:

$$\tilde{PD^i} = P(r^i_1 < \tilde{K}) \tag{12}$$

where $\tilde{PD^i}$ is the default probability of the FX denominated loan. For computational purposes is will be convenient to work with assets expressed in foreign currency instead of the threshold $\tilde{K}$.

$$\tilde{PD^i} = P(\tilde{r}^i_1 < K) \tag{13}$$

Credit Portfolio Correlations

We now turn to considering a pool of homogeneous borrowers. To capture the credit volatility of a portfolio of standard loans we use the single factor model e.g., similar to what is embedded in the IRB framework. We expand this model by utilizing one more factor (to capture a possibly independent FX rate evolution) and impose the following correlation structure between the exchange rate and different obligors in that credit pool (we now work exclusively with the marginal distributions at the final period and drop the time indicator):

$$W^i = \sqrt{\rho} Z + \sqrt{1-\rho}\epsilon^i \tag{14}$$

$$\tilde{W} = \sqrt{\alpha} Z + \sqrt{1-\alpha}\xi \tag{15}$$

$$\tag{16}$$

where Z denotes a systemic factor (commonly associated with GDP), ϵ^i is an idiosyncratic factor associated with each obligor and ξ is any idiosyncratic component driving currency returns. The set of (Z, ϵ^i, ξ) variables are taken to follow a zero mean and unit variance distribution and have zero correlation. The correlation of asset returns of different obligors is thus ρ, whereas the correlation between individual asset returns and the FX rate is $\sqrt{\rho\alpha}$.

Conditional Default Probability for FX Loans

For a given macro scenario, the conditional default probability Q for non-FX loans , is the well known expression:

$$\begin{aligned}
Q(Z) &= P(r_i < K|Z) && (17)\\
&= P(\sigma^i W^i < K|Z) && (18)\\
&= P(\sqrt{\rho}Z + \sqrt{1-\rho}\epsilon^i < \frac{K}{\sigma^i}|Z) && (19)\\
&= N(\frac{\bar{K} - \sqrt{\rho}Z}{\sqrt{1-\rho}}) && (20)
\end{aligned}$$

where $\bar{K}$ is the volatility scaled threshold value ($\frac{K}{\sigma^i}$). For a large pool the above conditional probability expression captures the fraction of obligors in default for a given realization of the systemic factor Z.

For an FX loan, the conditional default probability $\tilde{Q}$, calculated on the basis of given systemic factor and currency realizations at the end of the period is given by:

$$\begin{aligned}
\tilde{Q}(Z,\xi) &= P(\tilde{r}_i < K|Z,\xi) && (21)\\
&= P(\sigma^i W^i + \sigma^f \tilde{W} < K|Z,\xi) && (22)\\
&= P(\sigma^i(\sqrt{\rho}Z + \sqrt{1-\rho}\epsilon^i) + \sigma^f(\sqrt{\alpha}Z + \sqrt{1-\alpha}\xi) < K|Z,\xi) && (23)\\
&= P(\epsilon_i < \frac{K - \sigma^i\sqrt{\rho}Z - \sigma^f(\sqrt{\alpha}Z + \sqrt{1-\alpha}\xi)}{\sigma^i\sqrt{(1-\rho)}}|Z,\xi) && (24)\\
&= N(\frac{\bar{K} - \sqrt{\rho}Z - \frac{\sigma^f}{\sigma^i}(\sqrt{\alpha}Z + \sqrt{1-\alpha}\xi)}{\sqrt{(1-\rho)}}) && (25)
\end{aligned}$$

This is the key result of our setup. It is a minimal extension of the classic formula (20) to incorporate FX rate volatility and correlation. We observe that we use the same $\bar{K}$ threshold for defaults, but modify the risk factors by introducing the additional degree of freedom expressed by ξ and we have three more model parameters ($\sigma^i, \sigma^f, \alpha$) to content with.

Stressed FX default rate versus standard stressed default rate

For a given macro stress level (e.g., in our context captured by the negative return in Z in terms of standard deviations) the two conditional probabilities (25,20) are related by the following formula:

$$\tilde{Q}(Z,\xi) = N(N^{-1}(Q(Z)) - \frac{\sigma^f}{\sigma^i\sqrt{(1-\rho)}}(\sqrt{\alpha}Z + \sqrt{1-\alpha}\xi)) . \quad (26)$$

This formula provides the basic mechanism for stress testing an FX loan pool. Given a macro stress scenario (and translating it into relalizations for the factors (Z,ξ) we obtain first the stressed default rate $Q(Z)$ for a standard loan portfolio. Using the formula we obtain directly the stressed FX default rate.

Some observations might help elucidate the meaning of the expression:

- The expression becomes an identity when setting the FX volatility to zero ($\sigma^f = 0$). This expresses the obvious fact that if the exchange rate is fixed, then the risk profile of FX denominated loans is not different from standard loans.

- Assuming zero correlation ($\alpha = 0$) between the FX rate and the systemic factor does not imply that the risk profile of an FX loan is the same as a local currency loan. In other words the fact that the FX rate has its own intrinsic volatility increases the FX loan's credit risk irrespective of whether there are adverse correlations between economic factors and the FX rate.
- The relative importance (impact) of the currency effect on creditworthiness depends on the ratio of the currency volatility to the obligor asset base volatility.

Model Calibration

The calibration approach for the model is not unique and depends significantly on the availability and quality of datasets, so we will not provide a definitive procedure. Instead we sketch the main steps that are likely to be involved:

Standard Default Threshold and Asset Volatility

The standard default threshold is calibrated with reference to the historical default rate of similar borrowers *not* exposed to FX risk. Assuming we have a pool of credit performance data of such credits which produce a period default rate of DR, we make the identification:

$$DR = E[D_i] = P(r^i < K) = P(W^i < \bar{K}) \tag{27}$$

which leads to

$$\bar{K} = N^{-1}(DR) \tag{28}$$

It is notable that using only the default history data does not allow us to estimate the asset volatility parameter σ^i. We can only do this separately by estimating e.g., the asset volatility from house price histories or household wealth indicators etc.

Standard Credit Volatility

Once the default threshold has been established it is straightforward to also calibrate the obligor correlation parameter ρ with reference to the observed loan pool default rate volatility using, e.g., the result of[11].

$$Var(DR) = N_2(\bar{K}, \bar{K}; \rho) - DR^2 \tag{29}$$

FX Volatility and Correlation with Systemic Factor

The volatility σ^f of the FX rate can be established with standard tools using historical data.

The correlation α of FX rate with the systemic factor can be estimated either from historical default rate data, i.e., using the inverse expression to reconstruct implicit systemic factor return realizations:

$$Z_t = \frac{\sqrt{1-\rho}\bar{K} - N^{-1}(DR_t)}{\sqrt{\rho}} \tag{30}$$

or, in case there are data issues with historical default data, on the basis of a suitable GDP timeseries that can be used as a proxy for the systemic factor.

Parametric Dependence

We explore the basic quantitative signals embedded in equation (25) using parametric plots.

Dependence on FX volatility

We focus first on what is intuitively the most important risk factor. We establish a base scenario with the following parameters:

Parameter	Value	Comment
PD	0.1	Emulating a vulnerable set of retail borrowers
ρ	0.1	Using a value on the upper end of Basel retail correlation parameters
σ^i	0.1	A conservative value of real estate index volatility
σ^f	0.02	Indicative value for FX rate volatility
α	0.20	Indicative value for FX / GDP correlation

Table 1: Base parameters (all annualized) for exploring the impact of different stress scenarios

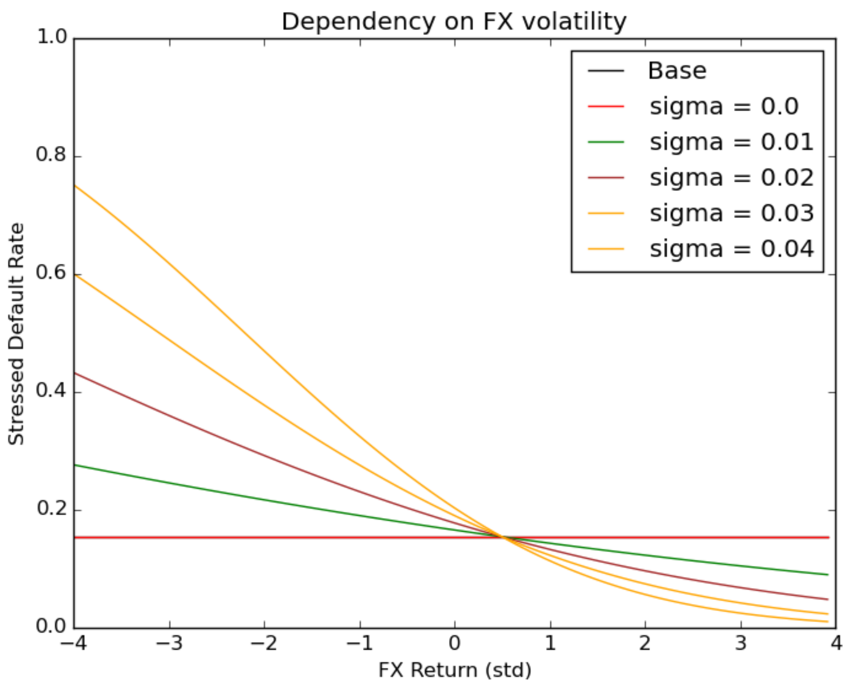

Figure 1: Besides the base parameters we specify a stress scenario where the systemic factor is one standard deviation below the mean. This produces a stress default rate for non-FX loans slightly less than 20% (versus the orininal 10%). This is captured by the horizontal red line. This line overlaps also with the FX-stressed default rate in the case where the FX volatility is zero. For non zero FX volatility we see a rapid deterioration of the default rate as a function of volatility. For example in the one standard deviation scenario for the FX rate, with a volatility of 2% the default rate almost doubles.

Dependence on correlations

First we look at the influence of α, the correlation of the FX rate with the systematic factor. To bring out the effect more clearly we consider a neutral $Z = 0$ GDP scenario and increase the FX volatility to 4%.

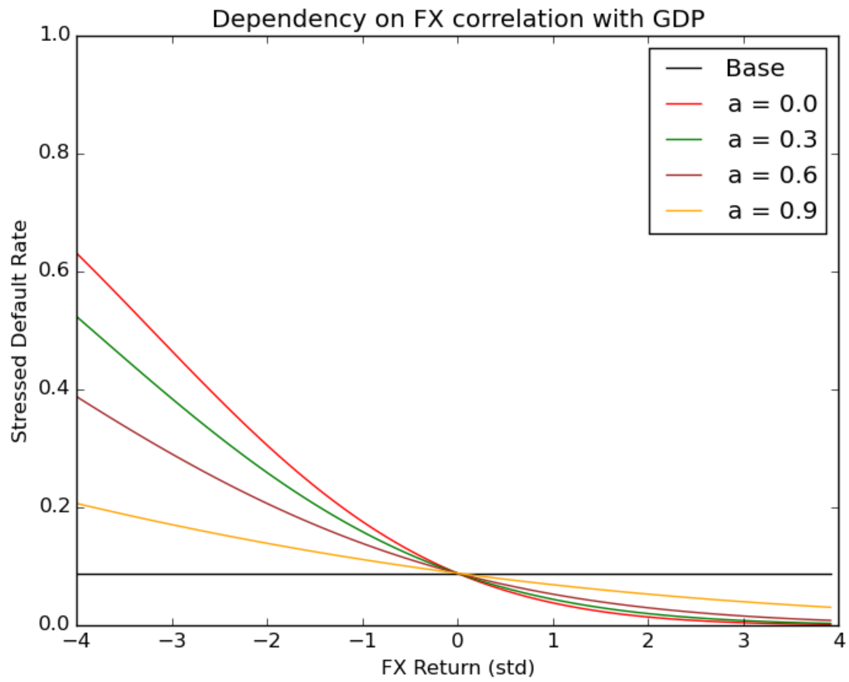

Figure 2: We see that the higher the correlation between FX rate and systemic factor returns, the *less* the impact on the stressed default rate. This is because the higher that correlation the more the specification of the macro scenario determines also what the realization of the FX rate is.

Next we look at the influence of ρ, the usual credit correlation within the pool of borrowers. Again we consider a neutral $Z = 0$ GDP scenario and increase the FX volatility to 4% to bring out the effects more clearly.

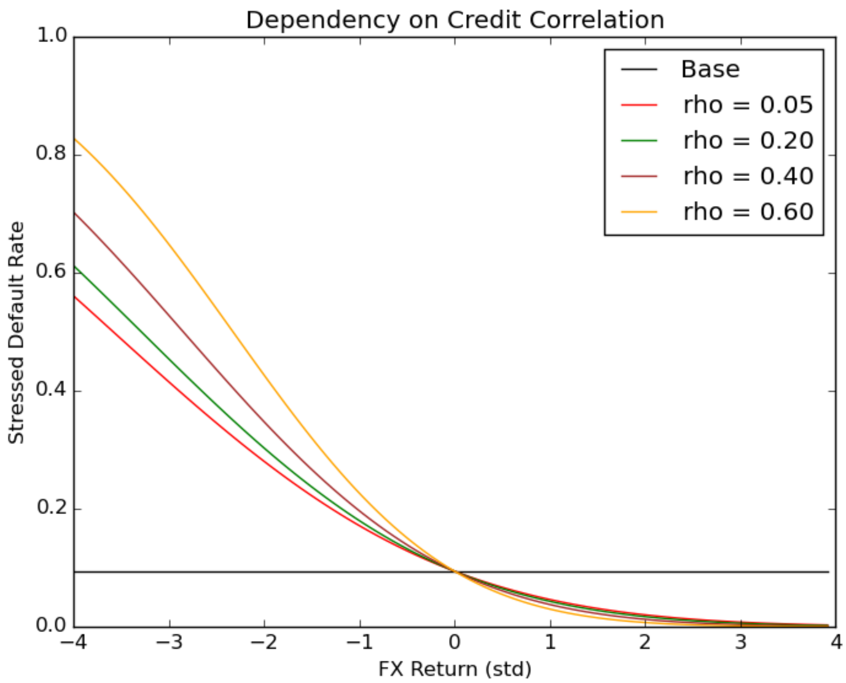

Figure 3: We see that the higher the credit correlation the higher the stressed default rate, but it requires correlation values significantly higher than those associated with retail pools before a significant quantitative impact is registered

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