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ADVERSE INTER-RISK DIVERSIFICATION EFFECTS FOR FX FORWARDS1

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Adverse Inter-Risk Diversification Effects for FX Forwards[1]

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Abstract

We describe the phenomenon of negative inter-risk diversification effects between credit and market risk. For portfolios of FX forwards, integrated market and credit risk may be *larger than the sum* of both by a factor of 200–400. This phenomenon occurs for portfolios hedged against market risk. The result implies that measuring market and credit risk in an integrated way spots risks of adverse interaction between credit and market events that are hidden to a simple addition of pure market and credit risk numbers.

1 Introduction

Interactions of market and credit risk may give rise to risks above and beyond the sum of market plus credit risk, as the following case indicates. During the Russian rouble (RUR) crisis of August 1998 some Western banks incurred severe losses when Russian banks defaulted on their FX forward contracts.[2] On August 17, 1998, Russia announced a devaluation of the RUR and a moratorium on servicing official short-term debt. Subsequently, the RUR depreciated more than 70 percent against the US dollar (USD), the government imposed conditions on most of its foreign and domestic debt, and several Russian financial institutions became insolvent.

Some Western banks had USD/RUR forwards with Russian banks and matching RUR/USD forwards with mostly Western companies and banks hedging their exchange rate risk. These positions were fully hedged against moves in the USD/RUR exchange rate. Furthermore, default risk was irrelevant to the banks as long as the exchange rate did not move: If a counter-party defaulted, it was always possible to get the currency deliverable to the other counter-party on the market at no loss if the exchange rate did not move. And a move of exchange

[2] Bank Austria, for example, suffered a loss of ATS 4.7bn, which amounts to EUR 341m, according to its official Annual Report for 1998 [2, p.63].

rates was very improbable in those times of the managed RUR exchange rate regime. So from both a pure market risk and a pure credit risk point of view the risk of the portfolio was close to zero.

For this reason banks considered the narrow spread between the matching forwards as an almost riskless profit.[3] However, during the crisis adverse credit events and market moves occured *simultaneously*. The Russian counterparties defaulted and at the same time the value of the RUR dropped dramatically. The USD deliverable to the Western companies and banks had to be purchased on the market and the RUR they got in return were not much worth. This led to enormous losses for the banks involved.[4] How could it happen that banks suffered so heavy losses on portfolios which were almost perfectly hedged against both credit risk and market risk? This paper suggests that one answer to this question might be due to adverse interactions between market and credit risk.

The rest of the paper is structured as follows. The relevant literature on the size of the inter-risk diversification between market and credit risk is reviewed in Section 2. Sections 3 and 4 describe the portfolio, the valuation model, and the data. In Section 5 we give the main results. Section 6 concludes.

2 Related Research

The integration of market and credit risk has been subject of intense research over the past decade. Some of the most important topics are the introduction of market risk factors in credit risk models, in particular the development of credit risk models with stochastic interest rates; the dependence between default frequencies, macroeconomic variables, and recovery rates; and modelling the joint distribution of market and credit risk factors at a common time horizon.

But there are relatively few papers quantifying the risk effects of simultaneous moves of market and credit risk factors. Duffie and Singleton [6, chp. 13], reporting on Duffie and Pan [5], compare VaR numbers in the absence of credit risk to VaR numbers when default intensities are correlated lowly or highly to

[3] Alejandro Eduardoff, in charge of the Moscow dependency of Bank Austria was quoted by the Austrian weekly *Profil* [11, p. 40] on September 28, 1999: *"Why call this 'betting', why call this 'speculation'? These terms do no apply here. After all, one could assume justifiedly even the day before the RUR devaluation of August 17th that the RUR exchange rate would remain in its narrow corridor. And under this assumption our derivative was a quite acceptable product."* [my translation]

[4] Losses would have been much higher had the RUR exchange rate not peaked around September 15. On September 17th, 1998, *The Economist* [13] wrote: *"And the banks have been helped by some extraordinary manipulation of the RUR exchange rate. Having fallen by more than two-thirds in the first three weeks after mid-August, from six to 22 RURs to the USD, it rocketed to 7.5 on September 15th only to crash to 13.5 the next day. The explanation for this lies in $2 billion or so outstanding in non-deliverable forward contracts, taken out by investors in short-term RUR debt in order to hedge their currency risk, which came due on no prizes for guessing September 15th. Although no RURs actually change hands (hence the tag non-deliverable), the value of these contracts depends on the exchange rate. Russian banks would have been faced with huge losses at a rate of 22 RURs to the USD. They suffered almost none at the more favourable exchange rate which was so mysteriously but conveniently reached on Tuesday of this week."*

some market event. This comparison is done for a loan portfolio and an option portfolio. For the loan portfolio they find that VaR numbers in the case of high correlation are roughly five times higher than in case of low correlation, which in turn are 12 times higher than risk numbers if no credit risk at all is present. For the option portfolio VaR numbers in case of high and low correlation are very similar to numbers if no credit risk is present. Duffie and Pan compare pure market risk (in the absence of credit risk) to integrated risk and find—for the loan portfolio—that integrated risk is higher. In contrast this paper compares integrated risk to the *sum* of pure market risk and pure credit risk.

Dimakos and Aas [4] decompose the joint distribution of market, credit, and operational risk factors into a set of conditional probabilities and require conditional independence in order to write total risk as a sum of conditional marginals plus unconditional credit risk. They find that integrated risk is 10–20% smaller than the sum of individual risks, depending on the quantile.

Kuritzkes, Schuermann, and Weiner [8] assume joint normality of risks and arrive at closed form solutions. According to their results, the integrated risk is about 15% smaller than the sum of individual risks of typical banks .

Walder [14] uses a framework based on the Mark-to-Future approach [7] of Algorithmics to analyse the contribution of market and credit risk to portfolio risk. He finds that the integration of market and credit risk makes inter-risk diversification benefits possible. Walder says his result is valid for every portfolio type analyzed, but portfolios with an equilibrated exposure to market and credit risk have the highest potential for integration benefits. Consequently, according to Walder [14, p. 33], the determination of capital requirements by adding market and credit risk overestimates true integrated risk.

Rosenberg and Schuermann [12] model the joint risk distribution of market, credit, and operational risk factors using the method of copulas. On the basis of regulatory reports they design their portfolio to resemble large, internationally active banks. For these banks they explore the impact of business mix and inter-risk correlations on total risk, whether measured by value-at-risk or expected shortfall. For the portfolios and models Rosenberg and Schuermann consider, total integrated risk is 40–60% smaller than the sum of market and credit risk (see Section 6 in [12]) .

All the studies mentioned above find integrated risk to be *smaller* than the sum of credit and market risk. While these results are highly plausible, they are not universally valid. In particular, all the above references [6, 8, 5, 12, 14, 4] restrict attention to portfolios without short positions. Short positions are essential for the hedged portfolios we consider in this paper. We point to a portfolio where integrated risk is much *larger* than the sum of credit and market risk. This negative inter-risk diversification effect seems to occur only for portfolios well hedged against market risk.

3 The model

We will analyse integrated market and credit risk of a FX forward portfolio. For this we start from a valuation function specifying the value of the portfolio as a function of various market and credit risk factors. As credit risk factors we take default probabilities (PDs). Alternatively, any specific credit risk model could be used to determine the PDs from other risk factors. In order to arrive at a parsimoneous model we do not model recovery rates stochastically but assume them to be constant.

The next step is to model the joint distribution of market risk factors and PD by determining by the marginals and the copula. The marginal distributions are modelled with an AR(1) term, a GARCH (1,1) term, and a residual distribution with historic returns as 80% body and Pareto fitted tails, as in McNeil *et al.* [10]. The details of the model for the marginals are described in [3]. The model was chosen on the basis of out-of-sample density forecast tests, which are also described in [3]. For the copula we chose the Student copula.

We measure risk by Expected Shortfall (ES) rather than by Value at Risk (VaR). The main reason for this is that VaR is not subadditive. Therefore it might occur that VaR for some portfolio is larger than the sum of VaR numbers of its subportfolios. This can happen if either the risk factor changes are not distributed elliptically or if the portfolio value is not a linear function of the risk factors. In order to exclude non-subadditivity of the risk measure as a possible explanation for the negative inter-risk diversification effect we use ES as a risk measure. In the literature there are several definitions of ES, or of related concepts such as worst conditional expectation, tail conditional expectation, conditional value-at-risk (CVaR), tail mean. We use the definition in Acerbi and Tasche [1, Def. 2.6]:

$$ES_\alpha := -\alpha^{-1}\left(E[X\mathbf{1}_{\{X<x_\alpha\}}] + x_\alpha\left(\alpha - P[X \leq x_\alpha]\right)\right), \qquad (1)$$

where x_α is the α-quantile of the distribution X. Expected Shortfall is a coherent risk measure [1, Prop. 3.1].

Our goal is to analyse the difference between summing up separate risk numbers for market and credit risk as opposed to the risk number for integrated market and credit risk. Summing up separate risk numbers for credit and for market risk will be done in a bank with independent credit and market risk management units, each modelling the distributions of their respective risk factors, generating scenarios, and calculating risk measures independently. We calculated expected shortfall of the portfolio from three profit-loss distributions. Distribution (0) reflects the portfolio value changes due pure to market risk, assuming default probabilities to be zero. Since the benchmark portfolio is perfectly hedged to market risk, ES is equal to zero. Distribution (1) reflects the profit and losses due to pure credit risk with market risk factors assumed constant. Distribution (2) reflects the profits and losses from joint moves in the market risk factor and in the default frequency.

The results will display the ES numbers for the distributions (0), (1), and (2), along with the 95% confidence intervals for the ES numbers. Confidence intervals were calculated using the method of Manistre and Hancock [9]. The last column gives the inter-risk diversification effect indicator

$$I = \frac{ES(\text{integrated})}{ES(\text{market}) + ES(\text{credit})}.$$

If I is greater than 1, integrated risk is higher than the sum of pure market and pure credit risk, which amounts to the negative inter-risk diversification effect. If it is smaller than 1, integrated risk is smaller than the sum of separate risks.

We use the term "negative inter-risk diversification" between credit risk and market risk to denote the fact that integrated risk is greater than the sum of credit risk and market risk. This use of the term "diversification" is non-standard because the effect is not about adding up risks of different portfolios but about "adding" up different kinds of risk for the same portfolio.

4 Portfolio and Data

In order to understand the effect hitting banks during the Russian crisis, we consider a similar portfolio of FX Forwards today. Instead of RUR/USD forwards we look at EUR/USD forwards. Although the moves in the USD/EUR exchange rate are much less dramatic than the 70% plunge in the USD/RUR rate of August 1998, the effects of the interaction of market and credit risk will still be astonishing.

The portfolio consists of one thousand long and one thousand short USD/EUR Forwards, each with a different counterparty. So the holder agrees with long counterparties to buy one dollar for K euros in three months. And he agrees with the short counterparties to sell one dollar for K euros at the same date. (Actually there is a small spread between the buy and sell prices. It is this spread which makes the portfolio profitable, independent of the future exchange rate, as long as no counterparty defaults. But we do not model this spread here because it is irrelevant for risk management purposes.) At the time of the agreement, the strike K is set to

$$K = S_0[(100 + r_{\text{USD}})/(100 + r_{\text{EUR}})]^{1/4},$$

where S_0 is the USD/EUR spot rate, r_{USD} is the USD 3m interest rate, and r_{USD} is the EUR 3m interest rate, all at the time of the agreement. With this strike K the value of all the forwards is zero at the time of the agreement.

At maturity, after three months, the USD/EUR spot rate will have moved to a new value S, a certain number d_1 of counterparties of long contracts will have defaulted, and a number d_2 of short counterparties will have defaulted. Then the value of the 1000 - d_1 long contracts with non-defaulted counterparties will be $(1000 - d_1)(S - K)$. The value of the 1000 - d_2 short contracts with non-defaulted counterparties will be $-(1000 - d_2)(S - K)$. We assume that the value of long contracts with defaulted counterparties is zero if $S > K$ since the counterparty cannot pay, and that it is K-S when $S < K$ since we have to pay our dues to the counterparty even if it defaulted. So the contracts with the d_1 defaulted long counterparties are worth $d_1 \min(S-K,0)$. Similarly, the value of the contracts with the d_2 defaulted counterparties of the short contracts is $d_2 \min(K-S,0)$, which equals $-d_2 \max(S-K,0)$. In total, the value of the portfolio at maturity is

$$(d_2 - d_1)(S-K) + d_1 \min(S-K,0) - d_2 \max(S-K,0).$$

We make the calculation as of December 31, 2004. Contracts are due end of December 2004. Market data for the exchange rate and the interest rates in the period 1987–2004 were taken from Datastream. The PD data were computed from quarterly transition matrices provided by Standard & Poor's Credit-Pro Corporate Ratings (`http://creditpro.sandp.com`), starting Q1/1987 and ending Q4/2004.

5 Results

Table 1 shows the ES numbers for market risk, credit risk, and integrated risk of the FX forward portfolio. Column (0) represents the pure market risk perspective. The ES numbers arise from moves in the market risk factor only, which in this case is the USD/EUR exchange rate. Default probabilities are assumed to be zero. Since the portfolio is perfectly hedged against exchange rate moves, ES numbers in the pure market risk perspective are equal to zero. Column (1) shows the pure credit risk perspective. The exchange rate S is assumed to be constant at the level S_0 at which it was at the time of the agreement of contracts. The default probabilities are stochastic, and the default numbers d_1, d_2 are Bernoulli distributed from 1000 draws with success rate equal to the default probabilities. Pure credit risk numbers are small but not zero, although the contracts have value zero at the time of agreement. This is because the strike K is not equal to S_0 due to the interest rates differential between the USD and the EUR. Therefore the contracts will have a small non-zero value if the exchange rate at maturity is S_0.

The main result of Table 1 is in the last column. Integrated risk is greater than the sum of separate risks by a factor of 209 to 385, depending on the quantile α. The dramatic negative inter-risk diversification effect of the Table 1 cannot be due to a failure of subadditivity of our risk measure, since ES is subadditive. In this example the sum of market and credit risk gives no indication at all about the size of integrated risk. It was integrated risk that hit banks in the Russian crisis.

Table 1: ES numbers for market risk, credit risk, and integrated risk of the FX Forward portfolio. Recovery rates constant at 60%. 95% Confidence intervals for ES numbers in brackets. We observe that integrated risk exceeds the sum of credit and market risk by a factor of 209–385. The effect is larger for more extreme quantiles α.

ES α	(0) MR no CR		(1) CR no MR		(2) Integrated MR&CR		(2)/((0)+(1)) diversification effect I	
0.1%	0	(0, 0)	18.72	(18.32, 19.12)	7 222.21	(6 939.90, 7 504.52)	385.73	(363.0, 409.6)
0.25%	0	(0, 0)	15.20	(14.98, 15.42)	5 286.60	(5 152.21, 5 421.00)	347.71	(334.1, 361.9)
0.5%	0	(0, 0)	12.93	(12.79, 13.07)	4 152.38	(4 075.40, 4 229.35)	321.17	(311.8, 330.7)
1%	0	(0, 0)	10.97	(10.88, 11.05)	3 233.04	(3 189.05, 3 277.03)	294.82	(288.6, 301.2)
2.50%	0	(0, 0)	8.75	(8.71, 8.80)	2 288.00	(2 267.09, 2 308.91)	261.36	(257.6, 265.1)
5 %	0	(0, 0)	7.34	(7.31, 7.37)	1 730.18	(1 718.27, 1 742.10)	235.71	(233.1, 238.3)
10%	0	(0, 0)	6.09	(6.08, 6.11)	1 274.27	(1 267.45, 1 281.08)	209.08	(207.4. 210.7)

6 Conclusions

The key contribution of this paper is a description of negative inter-risk diversification effects between credit and market risk: Integrated market and credit risk may be *larger* than the sum of market risk and credit risk. This phenomenon occurs for portfolios hedged almost perfectly against market risk. The result implies that measuring market and credit risk in an integrated way spots risks that are hidden to a simple addition of pure market and credit risk numbers.

In at least two ways our integrated market and credit risk model is strongly simplified. First, defaults of different counterparties are assumed to be independent, although probabilities of default vary stochastically, of which default correlation dyamics may be one cause. A more sophisticated model of dependent defaults is desirable. Second, recovery rates are assumed to be constant. This neglects the dependence between recovery rates and default probabilities. It remains to be seen, whether the negative inter-risk diversification effect persists also for such a more sophisticated integrated model of market and credit risk.

Also, it remains to be seen whether similar negative inter-risk diversification effects occur for not only for derivatives portfolios but also for plain bond portfolios.

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