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Abstract

This paper examines how risk in trading activity can affect the volatility of asset prices. We look for this relationship in the behavior of interest rate swap spreads and in the volume and interest rates of repurchase contracts. Specifically, we focus on convergence trading, in which speculators take positions on a bet that asset prices will converge to normal levels. We investigate how the risks in convergence trading can affect price volatility in a form of positive feedback that can amplify shocks in asset prices. In our analysis, we see empirical evidence of both stabilizing and destabilizing forces in the behavior of interest rate swap spreads that can be attributed to speculative trading activity. We find that the swap spread tends to converge to a long-run level, although trading risk can sometimes cause the spread to diverge from that level.

Key words: convergence trading, interest rate swaps, swap spread, repurchase contracts, trading risk, volatility of asset prices

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Introduction

The empirical analysis in this paper examines how risk in trading activity can affect the volatility of asset prices. We look for evidence of this relationship in the behavior of interest rate swap spreads and in the volume and interest rate of repurchase contracts. The type of trading we consider is convergence trading in which speculators take positions on a bet that asset prices will converge to normal levels. We investigate how the risks in convergence trading can affect price volatility in a form of positive feedback in risk where trading risk can amplify shocks in asset prices. Normally, convergence trades would tend to move prices towards their long-run equilibrium levels and thereby would stabilize markets. If convergence trades were unwound prematurely, however, asset prices would tend to diverge further from their equilibrium values instead of converging. A premature unwinding of such trades can occur when trading counterparties refuse to rollover positions or internal risk managers instruct traders to close their positions in response to heightened concerns about trading risks.

The notion that markets are self-stabilizing is a fundamental precept in economics and finance. Research and policy decisions often are guided by the view that arbitrage and speculative activity move market prices towards fundamentally rational values. While most economists would accept this view as a general guide to the long run behavior of markets that holds true more often than not, a well established collection of research now exists on the ways in which markets outcomes can diverge from this scenario. For instance, Shleifer and Vishney (1997) argue that agency problems in the management of investment funds will constrain arbitrage activity by depriving arbitrageurs of capital when large shocks move asset prices away from fundamental values. Xiong (2001) shows that convergence traders with logarithmic utility functions will normally trade in ways that stabilize markets, but will amplify market shocks in a form of positive feedback if the shocks are large enough to severely deplete their capital. When such traders suffer severe capital losses they will hunker down and unwind their convergence trade positions, driving prices further in the same direction as the initial shock.

The subject of this paper is the effect of convergence trading on the spread between interest rate swap and Treasury interest rates (the swap spread). We find empirical evidence of both stabilizing and destabilizing forces in the behavior of interest rate swap spreads that can be attributed to speculative trading activity. The swap spread does tend to converge to a long run level, but trading risk can sometimes cause the spread to diverge from its long run level as well.

The interest rate swap market is one of the most important fixed-income markets in the trading and hedging of interest rate risk. It is used by non-financial firms in the management of the interest rate risk of their corporate debt. Financial firms use the swaps market intensively in hedging the mismatch in the interest rate risk of their assets and liabilities. The liquidity of the swaps market also underpins the residential mortgage market in the United States, providing real benefits to the household sector. If the swaps market were less liquid than it is, market mortgage lenders would find it more difficult and expensive to manage the interest rate risk of the prepayment option in fixed rate mortgages. The extensive use of interest rate swaps means that volatility of the swap spread can affect a large range of market participants, as they rely on a stable relationship between the interest rate swap rate and other interest rates in using swaps for their hedging objectives. For this reason, trading activity that would stabilize the swap spread performs a useful role in ensuring that market participants can rely on the market for their trading and hedging needs.

In research on the determinants of the swap spread, Duffie and Singleton (1997) show that variation in the swap spread can be attributable to both credit risk and liquidity risk. Liu, Longstaff and Mandell (2002) find a similar result and quantify the size of the two risk factors. They find that the spread depends on both the credit risk of banks quoting LIBOR in the Eurodollar market and on the liquidity of Treasury securities. Further, they find that much of the variability of the spread is attributable to changes in the liquidity premium in Treasury securities prices. In a complementary analysis, Lang, Litzenberger and Luchuan (1998) investigate how hedging demand for interest rate swaps influences the swap spread, and they show that the swap spread is determined by corporate bond spreads and the state of the business cycle. While these papers investigate the financial risk factors that determine the behavior of the swap spread, in this paper we look at how variables related to trading activity might influence the volatility of the swap spread.

Convergence trades on the interest rate swap spread

In our analysis, traders are assumed to undertake convergence trades when the swap spread deviates from its long run level. If the swap spread is above its long run level, a trader who expects the spread to fall would take a long position in an interest rate swap and a short position in a Treasury security.[1] Such a position is insulated from parallel changes in the level of interest rates, but would gain if swap and Treasury interest rates move relative to each other as expected – in this case, if the spread between the rates narrows.

The transactions in a convergence trade would normally cause the swap spread to converge to its long run level by exerting a counter force to shocks in the spread. In the case of an initial shock that drove the spread above its normal level, establishing the long position in the swap would put downwards pressure on the swap rate, while the sale of Treasuries to establish the short Treasury position would tend to cause Treasury yields to rise. Both transactions would exert downwards pressure on the spread, countering the effect of the initial shock. When the convergence trade is unwound, the reverse transactions would cause the swap rate to rise and the Treasury yield to fall; and the spread would widen, in the absence of other shocks. Normally, a convergence trader would wait until shocks in the opposite direction to the initial shock bring the spread down to a level that would allow the trade to be unwound at a profit. In this case,

[1] / Conversely, when the swap spread is below its long run level, a trader who expects the spread to rise would take a short position in an interest rate swap and a long position in a Treasury security.

convergence trading would stabilize the spread by exerting a countervailing force to shocks. However, if a convergence trade position is unwound prematurely before the spread has converged to its long run level, then the spread will diverge further from its normal level as a result of the unwound trade. The premature unwinding of the position thus causes volatility in the swap spread in the sense of the spread diverging from its long run level instead of converging.

Convergence trades and repo market variables

One leg of a convergence trade on the interest rate swap spread is a position in Treasury securities that would normally involve a transaction in the repo market. This use of repo contracts allows us to use repo market variables as a signal for convergence trading activity on the swap spread. Thus, while data on convergence trading positions do not exist, changes in these positions may be reflected in changes in repo market variables. Even though the behavior of aggregate repo positions is driven by multiple trading and financing motivations we might still expect that some of the variation in repo volume would be related to convergence trading activity. Thus, our analysis looks for a relationship between the behavior of the interest rate swap spread and the repo market variables that would be consistent with the effects of convergence trading activity.

An unwinding of a convergence trade would result in a fall in outstanding repo positions, in the absence of any other transactions, because one leg of the convergence trade involves a repo transaction. Since a convergence trade on the swap spread involves both an interest rate swap and a repo position in Treasury securities, the position could be unwound when either the swap counterparty or the repo counterparty call for a close-out of the position. This might occur when a position suffers losses and the counterparty makes a margin call for additional collateral, and the trader chooses to close the position rather than post more collateral or is unable to and the counterparty closes-out the position. Alternatively, a trading firm’s internal risk managers might also impose a disciplined trading strategy in which a losing position is closed out. In either case, an unwinding of the convergence trade would result in a fall in outstanding repo positions.

In the same way that repo balances might be affected by tightening of credit in trading activity, the tighter credit might also drive up the repo interest rate as supply is restricted. This would mean that an unwinding of convergence trades might also be accompanied by higher than normal repo interest rates. Alternatively, in another avenue of influence, abnormally high repo rates might discourage new convergence trades and leave repo balances lower than otherwise.

In the next section, we make use of these considerations regarding repo volume and repo interest rates to explore the empirical relationship between the volatility of the swap spread and the repo market variables.

Unwinding of convergence trades and change in swap spreads

The empirical analysis in this section rests on the combination of two relationships. First, a premature unwinding of convergence trades would cause the swap spread to diverge from its long run level. Second, as discussed above, a contraction of convergence trades would also be associated with a fall in repo positions. Together, these relationships means that falling aggregate repo positions would be associated with a swap spread diverging from its long run value.

In a similar relationship, also as discussed above, elevated repo interest rates could be associated with a lower level of convergence trading activity through tighter financing conditions in the repo market. This in turn would make the swap spread more vulnerable to shocks as convergence traders who would otherwise stabilize the spread stay out of the market. Thus, elevated repo rates could also be associated with the swap spread diverging from its long run value.

The relationship between changes in swap spreads and convergence trading activity as described above will be analyzed in the following regression equation,

(1) $\Delta S_{t+1} = C + \beta_1 W_t \bullet \Delta_2 RP_t + \beta_2 W_t \bullet \Delta_2 Dvt\_r_t + \alpha_1 Dvt\_S_t + \alpha_2 \Delta r_t + \alpha_3 \Delta S_t + \varepsilon_{t+1}$,

where W gives the sign of Dvt_S ($W_t = |Dvt\_S_t|/Dvt\_S_t$), Δ_2 denotes a two-period change ($\Delta_2 X_t = X_t - X_{t-2}$); and S is the swap spread, RP is the volume of repo contracts, Dvt_r is the deviation of the repo interest rate from its normal level, Dvt_S is the deviation of the swap spread from its long run level, and r is the repo interest rate. The variables and data are described in more detail in Table 1. The deviations of the swap spread and the repo rate from their long run or normal levels are defined more exactly in the subsections that follow.

In equation (1) the repo positions and the repo interest rate are weighted by the sign of the deviation of the swap spread from its long run value (W_t). The term W converts the effect of the repo variables into the appropriate direction change of the swap spread when the swap spread diverges (or converges) from its long run value. The term W is necessary because a swap spread diverging from its long run level could be associated with either a rising or falling swap spread depending on whether the spread is above or below its long run level. With this specification, the sign of the coefficient on weighted repo positions would be negative if a contraction in repo outstanding causes the swap spread to diverge from its long-run value.[2] Similarly, the sign of the coefficient on the weighted repo rate would be positive if an elevated repo rate is associated with the swap spread diverging from its long-run value.[3]

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[2] / *The negative relation between change in swap spread and the weighted change in RP volume:* Suppose that an unwinding of convergence trades causes the swap spread to diverge further from its long run value. The unwinding of trading positions means that the change in RP outstanding is negative, while the change in the spread is either positive or negative depending on the direction of the deviation of the spread from its long run value. In the case of the swap spread above it's long run value, the weight W is positive, and the diverging spread means that change in the spread is positive as well. Therefor, the change in swap spreads is positive and the weighted change in RP is negative. If the swap spread is below it's long run value, the weight W is negative, and the diverging spread means that the change in the spread is also negative. Thus, the change in spread is negative and the weighted change in RP is positive. Therefor, in all cases, we have a negative relationship between the change in the swap spread and the weighted change in RP outstanding.

[3] / *The positive relationship between change in swap spread and the weighted change in repo rates:* Suppose that a higher repo interest rate is associated with tighter credit conditions in the RP market and the tighter credit causes the volume of convergence trades to fall. Suppose also that a contraction of convergence trades causes the swap spread to diverge further from its long run value. In the case of the swap spread above it's long run value, the weight W is positive, and the diverging spread means that the

In the absence of premature unwinding of positions, convergence trading would cause the swap spread to move towards its long run level. The spread would tend to fall when it is above its long run level, and rise when it is below. Thus, the coefficient on the deviation of the swap spread from its long run level would be expected to have a negative sign.

In addition to the variables that are our primary interest, we include two other explanatory variables that might be necessary to fully account for the short run variability of swap spreads. First, since the major market participants are active in both the swaps market and repo market, some short run shocks in the two markets may be related through the influence of these participants. Thus, we might expect to find a short run relationship between changes in the swap spread and the repo interest rate.[4] Finally, as we might expect some serial correlation in the swap spread, the lagged change in the swap spread is also included as an explanatory variable.

A vector error correction (VEC) analogue of the structural model in this section could also be used to test our conjecture of the relationship between the repo market variables and changes in the swap spread. Annex 1 shows that such a VEC model produces similar results, though with somewhat lower levels of statistical significance than with the structural model.

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change in the spread is positive. Therefor, both the change in the swap spread and the weighted change in the repo rate are positive. If, on the other hand, the swap spread is below it's long run value, the weight W is negative, and the diverging spread means that the change is the spread is negative as well. Thus, both the change in spread and the weighted change in the repo rate are negative. Therefor, in all cases, we have a positive relationship between the change in the swap spread and the weighted change in the repo interest rate.

[4] / When the repo rate is entered in the equation for the long-run behavior of the swap spread it is not significant, while as we shall see, it is significant in the equation for the short-run behavior of the spread. This confirms our conjecture that some short run shocks in the two markets are related.

The long run value of the swap spread

In equation (1), the deviation of the swap spread from its long run value will be defined using the following forecast model of its long run level.

$Dvt\_S = S_t - S_t^f$,

where,

$S_t^f = C + \lambda_1 Bond\_spr_t + \lambda_2 Tr^5_t + \lambda_3 UnEmp_{t-1}$,

and Bond_spr is the A-rated corporate bond spread over the ten-year Treasury rate, Tr^5 is the five-year Treasury rate, and UnEmp is the unemployment rate.[5]

The forecast uses concurrent values of the bond spread and the Treasury rate as traders will observe these rates within the observation month. The unemployment rate, however, appears with a lag as it is known to traders only with a lag. The estimation results for this equation are presented in Annex 2.[6]

The shock to the repo rate

The deviation of the repo rate from its normal level will be determined in two alternative models. In the first, the normal level of the repo rate is determined by the fed funds target rate and the change in the three-month Treasury interest rate. In the second model, the normal repo rate is assumed to be its centered five-month moving average.

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[5] / The model is adapted from Lang, Litzenberger and Luchuan (1998). In their model, more than one corporate bond spread is used. In the estimates for the sample period in our paper, however, only one bond spread at a time is statistically significant and other bond spreads do not add explanatory power. In any event, we find similar results in estimating equation (1) when the AAA bond spread is added to the forecast equation of the long run swap spread.

[6] / One potential problem with the use of this bond spread model of the swap spread in equation (1) is that convergence trading on corporate bond spreads could affect bond spreads in the same way that swap spreads might be affected. In this event, the forecast of the long run swap spread might not be independent of the short run changes that we are trying to isolate. To control for this possibility, a moving average of the swap spread could be used as an alternative model of its long run value. With this alternative specification we sill arrive at similar results as those reported in the paper.

Model 1. Deviation of the repo rate from model forecast.

$$Dvt\_r = r - r^f,$$

where,

$$r^f = C + \lambda_1 FF\_trg + \lambda_2 (\Delta Tr^{3m} - \Delta FF\_trg),$$

FF_trg is the fed funds target interest rate, and Tr^{3m} is the three-month Treasury interest rate.

Model 2. Deviation of the repo rate from centered five-month moving average.

$$Dvt\_r = r - r^a$$

where,

$$r_t^a = Avg(r_s \mid t+2 \geq s \geq t-2) .$$

In both models the intent is to capture shocks in the repo rate. In the first, the shocks are variations that are not predicted by benchmark short term interest rates. In the second model, the shocks are deviations from the smoothed path of the repo rate. The estimation results for the first model are presented in Annex 2.

Estimation results

From the preceding discussion we would expect the regression coefficients in equation (1) to have the following signs, $\beta_1<0$, $\beta_2>0$, and $\alpha_1<0$. The estimation results are shown in the first two columns of Table 2. The estimates are performed with monthly data (month-average), and with the two models of shocks to repo rates as described earlier. These specifications give us two sets of estimates, and in both the coefficients are statistically significant with the expected signs. The coefficients for the repo market variables show that a fall in repo balances leads to diverging swap spreads and likewise abnormally high repo rates also lead to diverging swap spreads. In addition, the coefficient for the deviation of the swap spread from its long run value has the expected negative sign. These results show that normally the swap spread tends to converge to its long run value, but it can deviate from its long run value in a way that is consistent with the premature unwinding or contraction of convergence trades.

In an alternative to equation (1), we can apply the weight W to the dependent variable instead of the repo market variables. Doing so gives us the regression in equation (2). In this specification, the weighted change in the swap spread on the left hand side has the convenient property that it takes positive values when the change in the swap spread causes the spread to diverge further from its long-run value, while a negative value corresponds to the swap spread converging to its long-run value.

$$(2) \qquad \Delta S_{t+1} \bullet W_t = C + \beta_1 \Delta_2 RP_t + \beta_2 \Delta_2 Dvt\_r_t + \alpha_1 Dvt\_S_t \bullet W_t + \alpha_2 \Delta r \bullet W_t + \alpha_3 \Delta S_t \bullet W_t + \varepsilon_{t+1}$$

In equation (2), all terms are as defined earlier and the coefficients have the same expected signs as the corresponding terms in equation (1). The estimation results for this equation are shown in the first two columns of Table 3, where we find results similar to those with the initial regression equation.

Repo market tightening

In the preceding discussion the relationship between the repo variables and the deviation of the swap spread from its long run level was discussed in terms of tighter financing conditions in the repo market. The relationship found in Tables 2 and 3, however, could be consistent with both a tighter and expanding repo market. To confirm that the relationship actually exists with a contraction in repo volume or tightening of repo financing conditions, we estimate equation (1) with sub-samples restricted to uni-directional changes in the repo variables. The estimates for these restricted regressions are reported in Table 4, where the regressions for tighter financing conditions are in the first two columns. In column (1) and (3), we find that the relationship between the change in repo volume and change in the swap spread holds for both rising and falling repo volume. In column (2) and (4), however, we see that the relationship between repo rates and the swap spread is found only when financing conditions tighten. Thus, the estimates in Table 4 confirm that the relationship between the repo variables and shocks to the swap spread is indeed found in tight financing conditions in the repo market.

How well do the repo variables explain short run variations in the swap spread?

A time series graph of the fitted values from equation (2) compared with a graph of the fitted values from a regression without the repo market variables shows the explanatory power of these variables. The graphs are displayed in Figure 1 , where we see that the fitted values from our model track the actual values episodically. While they do not track all the changes in the swap spread, the fitted values track the actual values rather well in periods of large changes in swap spreads. In contrast, the fitted values from regressions without the repo variables barely track the change in swap spreads.

Comparison of the adjusted R^2 from the regressions with and without the repo market variables also confirms the explanatory power of the repo variables. The adjusted R^2 for equations (1) and (2) are more than twice as large as the corresponding R^2 in the benchmark equations without the repo variables (see Tables 2 and 3).

As might be expected, the LTCM liquidity crisis in the fall of 1998 shows up prominently in Figure 1.[7] Notably, however, other episodes of swap spread volatility also are accounted for by the repo variables. To see whether the repo variables can explain short-run variability in swap spreads in periods other than 1998, we estimate equation (1) in a sub-sample that excludes the year 1998.[8] The estimates are shown in Table 5 with results similar to those described earlier for the full sample, though with somewhat lower levels of statistical significance. We find that the relationship between the repo market

[7] / Long Term Capital Management (LTCM) was a hedge fund that conducted convergence trades on a large scale. The firm suffered a severe loss of capital in the Fall of 1998 when spreads moved against its positions. LTCM at that point did not have the liquidity to meet margin and collateral calls and was taken over by its counterparties in an informal bankruptcy procedure and ultimately was closed down (see U.S. Treasury, 1999). During this episode, market liquidity was severely strained in many important fixed income markets and spreads diverged sharply from normal levels for a prolonged period of time. For a discussion of market conditions around this event, see BIS (1999).

[8] / Similar results are also found with equation (2) in the restricted sub sample.

variables and volatility of the swap spread while episodic is present throughout the recent past.

Convergence trading losses

The preceding results show the existence of a relationship between the short run variability of the swap spread and changes in repo market variables. We have conjectured that the relationship arises out of the risk in trading activity, but have not directly examined the effect of trading risk on the repo market variables themselves. To address this omission, in this section we look for signs of a response to heightened trading risk in the variation of the repo market variables.

The starting point for our analysis is the observation that a convergence trade position put in place on a bet that the swap spread will converge to its long run level will suffer a loss when the spread diverges instead. A trading counterparty that monitors its exposure to the trader may respond by refusing to roll over its trading position with the trader or call for higher collateral levels when the trader's loss reaches some threshold level. If the trader does not transfer the additional collateral then the position would be closed out. In this case, we would expect to see a negative relationship between repo balances and trading losses from widening deviations of the swap spread from its long run level.

In addition to its impact on repo volume, heightened concerns about counterparty credit risk might also affect repo interest rates by limiting the supply of financing. Tighter financing supply might be expected to drive up repo rates, not through any credit premium in creditors' reservation prices but through the effect of a quantity restriction on market clearing prices.[9] Thus in addition to looking for a quantity relationship we also look at whether losses in convergence trades cause a spike upwards in repo interest rates.

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[9] / The repo interest rate can be thought of as a risk-less financing rate because repo transactions are essentially collateralized loans. See Liu, Longstaff, and Mandell (2002) for discussion of this issue and supporting evidence. Nevertheless, repo transactions are not entirely free of credit risk because of the risk that the collateral value might fall below the amount of the loan. The failure of LTCM is a dramatic

To account for the possibility of a simultaneous relationship between repo volume and repo rates, we use two-stage least squares estimation of the following equations,

$$(3) \quad \Delta RP_{t+1} = C + \alpha_1 \Delta r_{t+1} + \beta_1 \Delta S_t \bullet W_{t-1} + \beta_2 \Delta_2 S_t \bullet W_{t-2} + \lambda_1 |Dvt\_S_t| + \lambda_2 Trm\_spr_t + \varepsilon_{t+1}$$

$$(4) \quad \Delta r_{t+1} = C + \alpha_2 \Delta RP_{t+1} + \beta_3 \Delta S_t \bullet W_{t-1} + \beta_4 \Delta_2 S_t \bullet W_{t-2} + \lambda_3 \Delta FF\_trg_{t+1} + \lambda_4 (\Delta Tr^{3m}_{t+1} - \Delta FF\_trg_{t+1}) + \lambda_5 \Delta r_t + \mu_{t+1}$$

with the instruments, $\Delta S_t \bullet W_{t-1}$, $\Delta_2 S_t \bullet W_{t-2}$, $|Dvt\_S_t|$, Trm_spr_t, ΔFF_trg_{t+1}, $\Delta Tr^{3m}_{t+1} - \Delta FF\_trg_{t+1}$, and Δr_t; where $\Delta_2 S_t = S_t - S_{t-2}$, Trm_spr is the spread between the ten-year and three-month Treasury rates, and all other terms are as defined earlier.

In these equations, the term $\Delta S \bullet W$ is a proxy for the trading losses of convergence traders. This term is positive when the swap spread diverges further from its long run value, and negative otherwise. When this term is positive, convergence trades will suffer losses, creating a larger credit risk for the trader's counterparty. In this case, we would expect the volume of repo contracts to fall as the counterparties limit their exposure. Thus, we would expect the coefficients β_1 and β_2 to be negative. If credit risk concerns about the trading losses cause a rise in repo rates, say through tighter financing conditions, the coefficients β_3 and β_4 would be positive.

In addition to the trading loss term, the other independent variables in this model are the absolute value of the deviation of the swap spread from its long-run value, the Treasury yield curve term spread, and the interest rates that were used to forecast the normal level of repo rates in the analysis in the preceding section. The deviation of the

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illustration of the credit risk in collateralized financing. Even though LTCM's credit exposures to its trading counterparties were collateralized, the large price shocks in the Autumn of 1998 caused the credit exposures to rise relative to collateral values. When LTCM was unable to post additional collateral to cover the fall in value of its initial positions, the counterparties found themselves exposed to significant credit risk.

swap spread from its long run value and the Treasury term spread appear as explanatory variables in the repo volume equation because they drive trading strategies that involve repo contracts (convergence trades and carry trades). In the repo rate equation, the fed funds target rate and the deviation of the three-month Treasury rate from the fed funds target are used as explanatory variables because they forecast the normal level of repo rates (see earlier discussion and Annex 2).

The estimation results are shown in Table 6 for equations (3) and (4) and also for a smaller model in which independent variables that are not statistically significant are omitted. In both models, the β coefficients are statistically significant with the expected signs. This result is consistent with the conjecture that losses in convergence trading positions lead to tighter credit standards in trading activity as reflected in a shrinkage of repo balances and a rise in repo interest rates.

The significance level of trading losses in the quantity equation is far stronger than in the price equation. In fact, the level of statistical significance of trading losses in the repo rate equation is relatively low (almost 10%). This finding of a strong quantity effect but a weak price effect is consistent with analyses such as Stiglitz and Weiss (1981) where credit risk in the presence of asymmetric information leads to quantity rationing rather than to adjustments to the price of credit.

In the case of repo volume, an alternative to the credit risk explanation exists in the effect of trading firms' internal risk management discipline. In this conjecture, a trading loss that exceeds a loss limit would trigger a risk management instruction to close-out the losing position, with the same observed relationship between trading losses and repo balances as in the counterparty credit risk explanation. We cannot distinguish between these conjectures with equation (3). While the result for equation (4) is consistent with the credit hypothesis, it does not rule out the internal risk management interpretation either. Thus, we might conclude that trading losses affect repo balances through both counterparty credit risk concerns and internal risk management controls.

Conclusion

In this paper, we examined how risk in trading activity can affect the volatility of asset prices. We found evidence of this relationship in the behavior of interest rate swap spreads and in the volume and interest rate of repurchase contracts. We investigated how the risks in convergence trading could affect price volatility in a form of positive feedback in risk where trading risk might amplify shocks in asset prices. We reported empirical evidence of both stabilizing and destabilizing forces in the behavior of interest rate swap spreads that can be attributed to speculative trading activity. The swap spread does tend to converge to a long run level, but trading risk can sometimes cause the spread to diverge from its long run level as well.

Annex 1

Vector Error Correction Model

In the vector error (VEC) correction model, the repo market variables are included as endogenous variables, and the exogenous variables are the repo market variables weighted by the sign of the deviation of the swap spread from its long run value, and the gain/loss on convergence trades. In this VEC model, the deviation of the swap spread from its long run value is estimated as the cointegrating equation.

The equation for the change in the swap spread in the first column of the VEC estimates is the analogue of the structural equation (1). As can be seen from the estimated coefficients for the cointegrating equation and the repo market variables weighted by the term W, the estimated VEC results are similar to those reported in Table 2, but with lower significance levels for the exogenous variables.

The equations for the change in the repo market variables in the right most two columns of the VEC estimates are the analogue of the structural equations for the effects of trading losses on the repo market variables. The estimated VEC results for the trading loss term are similar to those in the structural equations reported in Table 6, but with lower significance levels.[10]

Vector Error Correction Estimates

Cointegrating Equation						
S(-1)	Bond_Spr(-1)	Tr^5(-1)	UnEmp(-1)	RP(-1)	DVT_r(-1)	Const.
1.000000	-0.437720 (0.03209)	-0.133081 (0.01876)	0.182517 (0.01654)	-0.250862 (0.08917)	-0.065377 (0.12692)	0.366330

VEC Equations						
	ΔS	ΔBond_Spr	ΔTR^5	ΔUnEmp	ΔRP	ΔDvt_r
Coint_Eq	-0.595369 (0.15550)	-0.477164 (0.28996)	1.589184 (0.55752)	-0.893315 (0.33028)	-0.193298 (0.09626)	-0.053069 (0.30914)
ΔS(-1)	0.462697 (0.15959)	0.702668 (0.29759)	-1.685364 (0.57220)	0.183303 (0.33898)	0.041175 (0.09880)	0.251569 (0.31729)
ΔS(-2)	0.241781 (0.15114)	0.457492 (0.28182)	-0.840207 (0.54188)	0.144748 (0.32102)	0.064364 (0.09356)	-0.083491 (0.30047)
ΔS(-3)	0.006262 (0.13897)	0.354795 (0.25913)	-0.486976 (0.49825)	0.298633 (0.29517)	-0.033393 (0.08603)	0.232075 (0.27628)
ΔBond_Spr (-1)	-0.070746 (0.10135)	0.108703 (0.18900)	0.131573 (0.36339)	-0.157293 (0.21528)	-0.012153 (0.06274)	0.053794 (0.20150)
ΔBond_Spr (-2)	0.037912 (0.10016)	-0.331399 (0.18677)	0.697364 (0.35912)	0.062312 (0.21275)	-0.054148 (0.06201)	-0.419768 (0.19913)
ΔBond_Spr (-3)	0.164290 (0.10087)	-0.375905 (0.18810)	0.521529 (0.36167)	-0.034556 (0.21426)	-0.097923 (0.06245)	-0.292773 (0.20055)

[10] / In the last two columns of the VEC table, see the row for the term $\Delta_2 S(-1) \bullet W(-3)$ near the bottom of the table. The results reported in this table are with trading losses over a two-month period only; a specification using both one- and two-month trading losses as in Table 6 has similar results.

$\Delta Tr^5(-1)$	0.047446 (0.05599)	0.001245 (0.10441)	0.131495 (0.20075)	-0.116692 (0.11893)	0.018306 (0.03466)	0.045662 (0.11131)
$\Delta Tr^5(-2)$	0.018671 (0.05518)	-0.036153 (0.10289)	0.093616 (0.19783)	-0.122135 (0.11720)	-0.035539 (0.03416)	-0.267667 (0.10970)
$\Delta Tr^5(-3)$	0.092403 (0.05177)	-0.191675 (0.09653)	0.442153 (0.18560)	0.028918 (0.10995)	-0.066466 (0.03205)	-0.202809 (0.10292)
ΔUnEmp(-1)	0.069746 (0.06079)	0.252750 (0.11336)	-0.497347 (0.21797)	-0.296195 (0.12913)	0.006123 (0.03763)	0.088454 (0.12086)
ΔUnEmp(-2)	0.035640 (0.05860)	0.019615 (0.10927)	0.075780 (0.21010)	0.091929 (0.12447)	0.005493 (0.03628)	0.226948 (0.11650)
ΔUnEmp(-3)	-0.087418 (0.05744)	-0.092707 (0.10712)	0.174489 (0.20596)	0.097860 (0.12202)	-0.012979 (0.03556)	0.043051 (0.11421)
ΔRP(-1)	-0.207402 (0.21498)	-0.291752 (0.40088)	1.631386 (0.77080)	-0.333860 (0.45663)	-0.107716 (0.13309)	0.300673 (0.42741)
ΔRP(-2)	-0.731603 (0.24342)	-0.723228 (0.45391)	1.452294 (0.87275)	-0.167284 (0.51704)	-0.255034 (0.15069)	-0.041744 (0.48394)
ΔRP(-3)	-0.414878 (0.22420)	-0.709845 (0.41807)	1.017612 (0.80384)	-0.857807 (0.47621)	-0.169542 (0.13879)	-0.317669 (0.44573)
ΔDvt_r(-1)	0.021946 (0.08335)	0.081835 (0.15542)	-0.120187 (0.29883)	-0.110658 (0.17703)	-0.007989 (0.05160)	-0.843759 (0.16570)
ΔDvt_r(-2)	0.157272 (0.08378)	0.458302 (0.15622)	-0.880769 (0.30038)	-0.370094 (0.17795)	0.041827 (0.05186)	-0.443396 (0.16656)
ΔDvt_r(-3)	0.192982 (0.06413)	0.318628 (0.11958)	-0.421091 (0.22993)	-0.210878 (0.13621)	-0.031312 (0.03970)	-0.163139 (0.12749)
Const.	0.016197 (0.00951)	0.039900 (0.01772)	-0.096841 (0.03408)	0.016138 (0.02019)	0.016391 (0.00588)	0.026693 (0.01890)
Δr(-1)	0.139762 (0.05745)	0.234884 (0.10713)	-0.481769 (0.20600)	-0.159014 (0.12204)	0.045330 (0.03557)	0.266677 (0.11422)
Δ_2S(-1)•W(-3)	-0.074379 (0.08951)	-0.055281 (0.16690)	0.035570 (0.32092)	0.013410 (0.19012)	-0.117519 (0.05541)	0.239102 (0.17795)
Δ_2RP(-1)•W(-1)	-0.215399 (0.18546)	-0.271738 (0.34583)	0.181213 (0.66494)	0.544714 (0.39393)	0.045123 (0.11481)	0.567947 (0.36871)
Δ_2Dvt_r(-1) •W(-1)	0.101575 (0.05169)	0.008675 (0.09638)	0.166765 (0.18532)	0.032905 (0.10978)	-0.013830 (0.03200)	-0.282236 (0.10276)
R-squared	0.414586	0.451608	0.415279	0.430564	0.333267	0.540284
Adj. R-squared	0.174148	0.226375	0.175126	0.196688	0.059431	0.351471

Dvt_r is defined using Model 1, the deviation of the repo rate from its model forecast. W represents the sign of the cointegration term (W(-1)=|Coint_Eq|/Coint_Eq), and Δ_2 denotes a two-period change. The sample period is 1996-2002. The standard errors are in parentheses.

Annex 2

Estimate of Long Run Swap Spread and Normal Repo Rate

(a) Estimation of long run swap spread.

$$S_t^f = -0.389 + 0.432\ Bond\_spr_t + 0.136\ Tr^5_t - 0.122\ UnEmp_{t-1}$$
$$\quad (0.112) \quad (0.000) \qquad (0.000) \qquad (0.000)$$

Adjusted $R^2 = 0.887$.

Sample period is 1993-2002. P-values in parentheses.
Bond_spr is the A-rated corporate bond spread over the ten-year Treasury rate, Tr^5 is the five-year Treasury rate and UnEmp is the monthly unemployment rate.

(b) Estimation of the normal repo rate in Model 1.

$$r^f = 0.048 + 0.989\ FF\_trg + 0.317\ (\Delta Tr^{3m} - \Delta FF\_trg)$$
$$\quad (0.358) \quad (0.000) \qquad (0.003)$$

Adjusted $R^2 = 0.990$.

Sample period is 1996-2002. P-values in parentheses.
FF_trg is the Fed funds target rate, and Tr^{3m} is the three-month Treasury rate.

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Table 1
Variable Definitions

S	Spread of five-year swap rate over five-year Treasury rate.[a]
S^f	Forecast of long run value of swap spread.
Dvt_S	Deviation of swap spread from its long run forecast value. $Dvt\_S = S - S^f$
RP	Overnight and continuing gross repo positions at primary dealers (the sum of their repo and reverse repo positions).[b]
r	Repo interest rate
Dvt_r	Deviation of repo rate from its forecast value. $Dvt\_r = r - r^f$, where r^f is the forecast of the normal value of the repo rate.

(a) Five-year rates are used instead of ten-year rates because of the higher frequency of specialness of the ten-year Treasury security in the repo market.[11] The periods in which the ten-year Treasury is on special may make arbitrage activity involving the ten-year security more difficult and risky. Thus, more general results might be found in analysis of the five-year swap spread. Out of curiosity we estimated the model with ten-year rates and found similar results but with lower levels of statistical significance – an outcome consistent with our expectation of greater noise in the ten-year Treasury rate.

(b) The data consists of all overnight and continuing repurchase contracts at primary dealers. Ideally, we would use data on repo positions in Treasury securities only, but such data does not exist for a sufficiently long sample period. We only have a long time series for aggregate repo positions. (In any event, the predominant repo contract is a repo on Treasury securities.)

The analysis is conducted with gross positions (the sum of dealers' repo and reverse repo positions), and we can only ask whether the spread converges or diverges from its long run level because convergence trades are generally conducted by both dealers and their customers. Convergence trades are conducted by both customers such as hedge funds that transact with dealers and by dealers' own proprietary trading desks, and a short Treasury position could appear as either a repo or a reverse repo in the data depending on whether the short position is established by a customer or a dealer. This fact prevents us from associating disaggregated repo and reverse repo positions with the direction of an arbitrage trade. Thus, we must use gross repo positions and can only ask whether

[11] / A security is "on special" in the repo market when it is scarce and can be financed at advantageous rates.

the spread converges or diverges without regard to whether it is falling or rising to its long run level.

Table 2
Regression Results for Change in the Swap Spread

	With Repo Market Variables		Without Repo Variables
	Model 1	Model 2	
C	-0.002 (0.747)	-0.004 (0.515)	0.004 (0.647)
$W \bullet \Delta_2 RP$	**-0.270** **(0.026)**	**-0.324** **(0.013)**	
$W \bullet \Delta_2 Dvt\_r$	**0.099** **(0.015)**	**0.116** **(0.005)**	
Dvt_S	**-0.241** **(0.006)**	**-0.248** **(0.005)**	**-0.239** **(0.007)**
Δr	0.086 (0.022)	0.120 (0.000)	0.065 (0.065)
ΔS	0.229 (0.053)	0.246 (0.040)	0.222 (0.078)
Adj R^2	0.145	0.205	0.074

Regression results for the equation

(1) $\Delta S_{t+1} = C + \beta_1 W_t \bullet \Delta_2 RP_t + \beta_2 W_t \bullet \Delta_2 Dvt\_r_t + \alpha_1 Dvt\_S_t + \alpha_2 \Delta r_t + \alpha_3 \Delta S_t + \varepsilon_{t+1}$,

where $W_t = |Dvt\_S_t|/Dvt\_S_t$, and $\Delta_2 X_t = X_t - X_{t-2}$.

Model 1: Dvt_r is the deviation of the repo rate from model forecast.

Model 2: Dvt_r is the deviation of repo rate from centered five-month moving average.

Regression results with Newey-West HAC standard errors and covariance. Sample period is 1996-2002. P-values are in parentheses. Bold: the coefficient of interest has the expected sign and is statistically significant at a better than five percent level.

Table 3
Regression Results for Positive Feedback in the Swap Spread

	With Repo Market Variables		Without Repo Variables
	Model 1	Model 2	
C	0.0168 (0.067)	0.015 (0.136)	0.005 (0.489)
Δ_2RP	**-0.330** **(0.010)**	**-0.363** **(0.006)**	
Δ_2Dvt_r	**0.104** **(0.017)**	**0.111** **(0.010)**	
Dvt_S•W	**-0.385** **(0.000)**	**-0.375** **(0.001)**	**-0.287** **(0.003)**
Δr•W	0.089 (0.011)	0.124 (0.000)	0.060 (0.064)
ΔS•W	0.234 (0.041)	0.250 (0.031)	0.227 (0.079(
Adj R^2	0.165	0.217	0.070

Regression results for the equation

(2) $\Delta S_{t+1} \bullet W_t = C + \beta_1\, \Delta_2 RP_t + \beta_2\, \Delta_2 Dvt\_r_t + \alpha_1\, Dvt\_S_t \bullet W_t + \alpha_2\, \Delta r \bullet W_t + \alpha_3\, \Delta S_t \bullet W_t + \varepsilon_{t+1}$,

where $W_t = |Dvt\_S_t| / Dvt\_S_t$, and $\Delta_2 X_t = X_t - X_{t-2}$.
Model 1: Dvt_r is the deviation of the repo rate from model forecast.
Model 2: Dvt_r is the deviation of repo rate from centered five-month moving average.
Regression results with Newey-West HAC standard errors and covariance. Sample period is 1996-2002. P-values are in parentheses. Bold: coefficient of interest has the expected sign and is statistically significant at a better than two percent level.

Table 4
Regression Results Conditional on Direction of Δ_2RP and Δ_2Dvt_r

	(1) $\Delta_2RP<0$	(2) $\Delta_2Dvt\_r>0$	(3) $\Delta_2RP>0$	(4) $\Delta_2Dvt\_r<0$
C	0.001	-0.000	-0.005	-0.002
	(0.943)	(0.946)	(0.486)	(0.884)
W•Δ_2RP	**-0.720**	**-0.502**	**-0.218**	-0.064
	(0.023)	**(0.008)**	**(0.040)**	(0.583)
W•Δ_2Dvt_r	0.158	**0.243**	0.076	0.000
	(0.150)	**(0.000)**	(0.117)	(0.997)
Dvt_S	**-0.494**	**-0.426**	-0.151	**-0.232**
	(0.077)	**(0.000)**	(0.150)	**(0.076)**
Δr	0.161	0.136	0.006	0.001
	(0.007)	(0.003)	(0.876)	(0.970)
ΔS	0.135	0.393	0.408	-0.093
	(0.586)	(0.009)	(0.005)	(0.615)
Adj R^2	0.316	0.377	0.123	0.010
N	23	47	60	36

Regression results for the equation
(1) $\Delta S_{t+1} = C + \beta_1 W_t \bullet \Delta_2 RP_t + \beta_2 W_t \bullet \Delta_2 Dvt\_r_t + \alpha_1 Dvt\_S_t + \alpha_2 \Delta r_t + \alpha_3 \Delta S_t + \varepsilon_{t+1}$,
where all terms are as defined earlier, and with Dvt_r as defined in model 1 (see Table2). Regression results with Newey-West HAC standard errors and covariance. Sample period is 1996-2002. P-values are in parentheses. Bold: the coefficient of interest has the expected sign and is statistically significant at a ten percent level.

Table 5
Regression Results with and without 1998

	Including 1998		After 1998	
	Model 1	Model 2	Model 1	Model 2
C	-0.002 (0.747)	-0.004 (0.515)	0.002 (0.835)	0.001 (0.916)
$W \bullet \Delta_2 RP$	**-0.270** **(0.026)****	**-0.324** **(0.013)****	-0.203 (0.180)	**-0.257** **(0.109)***
$W \bullet \Delta_2 Dvt\_r$	**0.099** **(0.015)****	**0.116** **(0.005)****	**0.146** **(0.018)****	**0.132** **(0.006)****
Dvt_S	**-0.241** **(0.006)****	**-0.248** **(0.005)****	**-0.536** **(0.001)****	**-0.598** **(0.000)****
Δr	0.086 (0.022)	0.120 (0.000)	0.143 (0.017)	0.196 (0.000)
ΔS	0.229 (0.053)	0.246 (0.040)	0.363 (0.006)	0.356 (0.002)
Adj R^2	0.145	0.205	0.253	0.277

Regression results for the equation

(1) $\Delta S_{t+1} = C + \beta_1 W_t \bullet \Delta_2 RP_t + \beta_2 W_t \bullet \Delta_2 Dvt\_r_t + \alpha_1 Dvt\_S_t + \alpha_2 \Delta r_t + \alpha_3 \Delta S_t + \varepsilon_{t+1}$,

where all terms area as defined earlier and Models 1 and 2 are as defined in Table 2.
The results for the sample including 1998 are from Table 2 and repeated here for ease of comparison.
Regression results with Newey-West HAC standard errors and covariance. The full sample period is 1996-2002. P-values are in parentheses. Bold: the coefficient of interest has the expected sign and is statistically significant -- at five percent (**), and at ten percent (*) levels.

Table 6
Regression Results for Effects of Trading Losses

	Model A		Model B	
	Equation 3	Equation 4	Equation 3'	Equation 4'
Dependent Variable	ΔRP	Δr		
C	0.004 (0.648)	0.000 (0.996)	0.006 (0.142)	-0.025 (0.306)
ΔRP		-1.480 (0.705)		1.671 (0.364)
Δr	-0.027 (0.343)		-0.025 (0.346)	
$\Delta S \bullet W(-1)$	0.048 (0.540)	**0.620** **(0.081)**		**0.514** **(0.099)**
$\Delta_2 S \bullet W(-2)$	**-0.131** **(0.007)**	-0.407 (0.452)	**-0.125** **(0.004)**	
Dvt_S	-0.026 (0.786)			
Trm_Spr	0.004 (0.369)			
ΔFF_trg		0.735 (0.000)		0.850 (0.000)
$\Delta Tr^{3m} - \Delta FF\_trg$		0.354 (0.113)		0.490 (0.004)
$\Delta r(-1)$		0.114 (0.407)		
Adj R^2	0.024	0.365	0.051	0.426

Regression results for two-stage least squares estimates.
Model A:

(3) $\Delta RP_{t+1} = C + \alpha_1 \Delta r_{t+1} + \beta_1 \Delta S_t \bullet W_{t-1} + \beta_2 \Delta_2 S_t \bullet W_{t-2} + \lambda_1 |Dvt\_S_t| + \lambda_2 Trm\_spr_t + \varepsilon_{t+1}$

(4) $\Delta r_{t+1} = C + \alpha_2 \Delta RP_{t+1} + \beta_3 \Delta S_t \bullet W_{t-1} + \beta_4 \Delta_2 S_t \bullet W_{t-2} + \lambda_3 \Delta FF\_trg_{t+1} + \lambda_4 (\Delta Tr^{3m}{}_{t+1} - \Delta FF\_trg_{t+1}) + \lambda_5 \Delta r_t + \mu_{t+1}$

with the instruments, $\Delta S \bullet W_{t-1}$, $\Delta_2 S \bullet W_{t-2}$, $|Dvt\_S_t|$, Trm_spr_t, ΔFF_trg_{t+1}, $\Delta Tr^{3m}{}_{t+1} - \Delta FF\_trg_{t+1}$, Δr_t.

Model B (omitting insignificant independent variables in Model A):

(3') $\Delta RP_{t+1} = C + \alpha_1 \Delta r_{t+1} + \beta_1 \Delta_2 S_t \bullet W_{t-2} + \varepsilon_{t+1}$

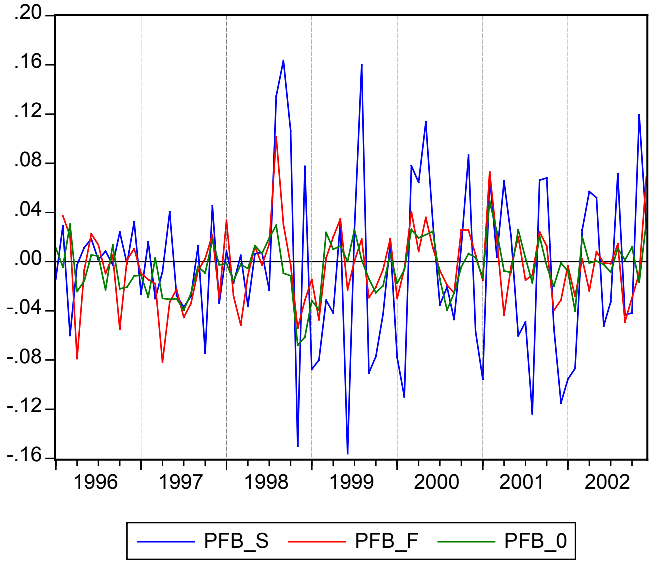
(4') $\Delta r_{t+1} = C + \alpha_2 \Delta RP_{t+1} + \beta_2 \Delta S_t \bullet W_{t-1} + \lambda_1 \Delta FF\_trg_{t+1} + \lambda_2 (\Delta Tr^{3m}{}_{t+1} - \Delta FF\_trg_{t+1}) + \mu_{t+1}$

with the instruments, $\Delta S \bullet W_{t-1}$, $\Delta_2 S \bullet W_{t-2}$, ΔFF_trg_{t+1}, $\Delta Tr^{3m}{}_{t+1} - \Delta FF\_trg_{t+1}$.

In both sets of equations, $\Delta_2 S_t = S_t - S_{t-2}$.

The sample period is 1996-2002. P-values are in parentheses. Bold: coefficient of interest has the expected sign and is statistically significant at the ten percent level.

Figure 1
Divergence and Convergence of Swap Spreads



Actual and fitted values for equation (2), and fitted values of a benchmark equation without the repo market variables.
PFB_S is the actual value, PFB_F is the fitted value in the full model, and PFB_0 is the fitted value from the benchmark model.