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Interest Rate Parity, Money Market Basis Swaps, and Cross-Currency Basis Swaps

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Because the classic interest rate parity condition requires default-free rates as input, the common practice of using rates derived from swap curves is not valid. This paper derives interest rate parity conditions that depend on basis swap spreads in addition to swap rates. The derivations reveal: i) the relatively well accepted proposition that money market basis swaps reflect the credit risk inherent in one floating rate versus another; and ii) the less known proposition that cross-currency basis swaps reflect the difference between the credit risk embedded in the short-term rates of one currency versus the other. Several empirical examples are given in support of this less known proposition. [1]

1. CLASSIC INTEREST RATE PARITY

Interest rate parity is an arbitrage argument used to derive forward foreign exchange rates. To describe the classic form of this argument, define the following variables:

S_0 : Spot exchange rate of dollars per unit of foreign currency.
y : T-year default-free dollar spot (ie, zero-coupon) rate of interest.
$\tilde{y}$: T-year default-free foreign spot (ie, zero-coupon) rate of interest.
F : Forward exchange rate of dollars per unit foreign currency for delivery in T years.

Now consider the following table of today's transactions (Figure 1). It is assumed throughout that there is no counterparty default risk in forward or swap contracts. [2]

Figure 1. The arbitrage argument for classic interest rate parity

Transaction	Today($)	Time *T* ($)	Today (Fgn)	Time *T* (Fgn)
Borrow S_0 dollars	$+S_0$	$-S_0\left(1+y\right)^T$		
Sell S_0 dollars, buy foreign	$-S_0$		+1	
Invest foreign			-1	$\left(1+\tilde{y}\right)^T$
Sell foreign forward		$+F\left(1+\tilde{y}\right)^T$		$-\left(1+\tilde{y}\right)^T$
Total	0		0	0

[1] *The authors thank Fredrik Akesson, Dev Joneja, Jean Paul Paradis, and Fei Zhou for helpful comments and suggestions. Pedro Porfirio works on the FX Trading Desk.*
[2] *Counterparty default risk is largely mitigated by the financial soundness of the entities involved, by requirements to post collateral based on changing market values, and by the imposition of credit lines.*

Because these transactions neither generate nor require cash today, ruling out arbitrage requires that they neither generate nor require cash at time *T* either. Mathematically,

$$-S_0\left(1+y\right)^T+F\left(1+\tilde{y}\right)^T=0 \tag{1}$$

Solving for the forward price,

$$F=S_0\frac{\left(1+y\right)^T}{\left(1+\tilde{y}\right)^T} \tag{2}$$

The problem with applying this classic argument in practice is that market participants observe spot rates implied from swap rates, not default-free spot rates. Because swap rates are fixed rates that are fair against 3-month LIBOR, which has a built-in credit premium, spot rates derived from swap rates are too high to be used in equation (2). The following section describes how money market basis swaps link rates containing different credit premiums.

2. MONEY MARKET BASIS SWAPS

A money market basis swap is an exchange of floating rate payments based on one index for floating rate payments based on another index. Liquid examples include: Fed Funds vs. 3-month LIBOR; T-Bills vs. 3-month LIBOR; 1-month vs. 3-month LIBOR; 1-month vs. 6-month LIBOR; and 3-month vs. 6-month LIBOR. Taking one example a bit further, on March 4, 2003, a trader might have agreed to exchange 1-month LIBOR plus 1.5 basis points monthly for 6-month LIBOR semiannually for three years.

Consider an imaginary basis swap to exchange the default-free rate of one term for the default-free rate of another term, eg, to exchange the default-free 1-month rate monthly for the default-free 3-month rate quarterly. Appendix 1 shows that this and all similar swaps should trade flat. Intuitively, the definition of the term structure of default-free rates is precisely that borrowers and lenders are indifferent between 1-month money rolled over a quarter and 3-month money.

Unlike these imaginary swaps of default-free rates, observed money market basis swaps exchange rates with a built-in credit premium. Furthermore, the credit premium built into a particular rate index differs from that built into another. For example, the credit risk of a 3-month loan is greater than that of rolling over 1-month loans for a quarter. Hence, to clear markets, 3-month LIBOR must be set such that its certain receipt, ie, its receipt with no possibility of default, has greater value than the certain receipt of 1-month LIBOR over the corresponding quarter. Hence, in a basis swap without any counterparty default risk, 1-month LIBOR plus a spread is fair against 3-month LIBOR.

It is important to distinguish between the pricing of loans made at the index rate and the pricing of basis swaps. The credit characteristics of Corporation A might be such that it fairly borrows at 1-month LIBOR. Similarly, the credit characteristics of Corporation B might be such that it fairly borrows at 3-month LIBOR. Nevertheless, as argued in the previous paragraph, parties to a swap with no counterparty default risk willingly exchange 1-month LIBOR plus a spread versus 3-month LIBOR. Because these swap parties do not bear any of the credit risk built into the loan rates, they look to the value of a certain flow of one rate against the value of a certain flow of the other rate.

3. CROSS-CURRENCY BASIS SWAPS

A cross-currency basis swap is essentially an exchange of a floating rate note in one currency for a floating rate note in another currency. For example, on March 4, 2003 the Canadian dollar (CAD) traded for .677 US dollars (USD) and a trader might have agreed to the following cross-currency basis swap:

- Pay 1 CAD and receive .677 USD at initiation
- Receive 3-month CDOR[3] plus 10 basis points on 1 CAD and pay 3-month USD LIBOR quarterly on .677 USD for three years
- Receive 1 CAD and pay .677 USD at expiration

To understand why 3-month CDOR plus 10 is fair against 3-month USD LIBOR, it is best to begin by considering an imaginary cross-currency basis swap exchanging a default-free, overnight CAD rate for a default-free, overnight USD rate. Under relatively mild assumptions, Appendix 2 proves that this cross-currency basis swap should trade flat. Intuitively, paying 1 CAD today, receiving the default-free CAD rate on 1 CAD, and receiving 1 CAD at expiration is worth 1 CAD today. Similarly, receiving .677 USD, paying the default-free USD rate on .677 dollars, and paying .677 USD at expiration is worth .677 dollars today. Therefore, because the exchange rate is .677 USD per CAD, the exchange of these floating rate notes is fair today.

Unlike this imaginary swap of default-free rates, observed cross-currency basis swaps exchange LIBOR rates. Therefore, one may think of a cross-currency basis swap of LIBOR rates as a portfolio of three imaginary swaps: a cross-currency basis swap of overnight, default-free rates; a money market basis swap of dollar LIBOR versus dollar, default-free, overnight rates; and a money market basis swap of foreign LIBOR versus foreign, default-free, overnight rates. Viewed this way, it becomes clear that observed cross-currency basis swap spreads arise from the difference between local basis spreads, that is, from the difference between the two term structures of credit spreads. In the example, if USD 3-month LIBOR has more credit risk than 3-month CDOR, then, in a swap with no default risk, a stream of USD LIBOR would be worth more than a stream of CDOR. Therefore, CDOR plus a spread would trade fair against USD LIBOR.

4. INTEREST RATE PARITY REVISITED

This section derives two interest rate parity relationships which depend on rates derived from the swap curve and on basis swap spread levels. For this purpose, define the following variables.

R : T-year dollar par swap rate with fixed flows paid quarterly.

$\tilde{R}$: T-year foreign par swap rate with fixed flows paid quarterly.

Y : T-year dollar zero-coupon swap rate.

$\tilde{Y}$: T-year foreign zero-coupon swap rate.

L_t : 3-month dollar LIBOR at time t.

$\tilde{L}_t$: 3-month foreign LIBOR at time t.

[3] *See section 5.2 for a description of Canadian short-term rates.*

b : A swap of the overnight dollar default-free rate is fair against 3-month dollar LIBOR minus b .

$\tilde{b}$: A swap of the overnight foreign default-free rate is fair against 3-month foreign LIBOR minus $\tilde{b}$.

X : A swap of 3-month dollar LIBOR plus X is fair against 3-month foreign LIBOR.

The derivation of the first parity relationship, using par swaps, zero-coupon swaps, and a 3-month cross-currency basis swap, is explained in Figure 2. Interim cash flows are annualized.

Ruling out arbitrage opportunities implies that the time-T dollar payoff is zero, ie:

$$-S_0\left[(1+X/R)(1+Y)^T - X/R\right] + F\left(1+\tilde{Y}\right)^T = 0 \tag{3}$$

Solving for the forward rate,

$$F = S_0\frac{(1+Y)^T}{\left(1+\tilde{Y}\right)^T}\left[1 + X\frac{(1+Y)^T - 1}{R(1+Y)^T}\right] \tag{4}$$

The obvious advantage of equation (4) over the classic parity condition (2) is that (4) depends on swap rates and on the cross-currency market basis swap spread. By contrast, the classic condition depends on the generally unobservable default-free rates of interest.

According to the definitions of R and Y, the term multiplying X in (4) is the present value factor for a stream of quarterly payments at the annual rate of X. Hence this parity relationship may be rewritten as:

$$F = S_0\frac{(1+Y)^T}{\left(1+\tilde{Y}\right)^T}\left[1+\text{PV}[X]\right] \tag{5}$$

where $\text{PV}[X]$ gives the present value just described.

Figure 2. The interest rate parity argument with a cross-currency basis swap

Transaction	Today ($)	Interim ($)	Time *T* ($)	Today (Fgn)	Interim (Fgn)	Time *T* (Fgn)
Spot FX	$-S_0$			+1		
Cross-currency swap	$+S_0$	$-S_0(L_t+X)$	$-S_0$	-1	$\tilde{L}_t$	+1
Par swap: rec fixed/ pay floating on S_0X/R		$S_0X-[S_0X/R]L_t$				
Zero-coupon swap: rec floating on $S_0(1+X/R)$		$S_0(1+X/R)L_t$	$-S_0(1+X/R)\left[(1+Y)^T-1\right]$			
Zero-coupon swap: pay floating					$-\tilde{L}_t$	$\left(1+\tilde{Y}\right)^T-1$
Sell foreign forward			$+F\left(1+\tilde{Y}\right)^T$			$-\left(1+\tilde{Y}\right)^T$
Total	0	0		0	0	0

The second parity relationship uses a cross-currency swap of overnight, default-free rates and an overnight versus 3-month basis swap in each currency instead of a cross-currency swap of 3-month LIBOR rates. Because cross-currency swaps of overnight, default-free rates do not trade, this second relationship is of less practical use than (4) or (5). However, this second result is useful for understanding the determination of the 3-month LIBOR cross-currency basis swap spread.

Define r_t and $\tilde{r}_t$ to be the overnight, dollar and foreign default-free rates and consider the set of transactions described in Figure 3. Ruling out arbitrage opportunities requires that

$$-S_0 - S_0\left(1-b/R\right)\left[\left(1+Y\right)^T - 1\right] + F\left[\left(1+\tilde{Y}\right)^T - \left(\tilde{b}/\tilde{R}\right)\left[\left(1+\tilde{Y}\right)^T - 1\right]\right] = 0 \qquad (6)$$

Solving for the forward rate,

$$F = S_0 \frac{\left(1+Y\right)^T \left[1 - b\dfrac{\left(1+Y\right)^T - 1}{R\left(1+Y\right)^T}\right]}{\left(1+\tilde{Y}\right)^T \left[1 - \tilde{b}\dfrac{\left(1+\tilde{Y}\right)^T - 1}{\tilde{R}\left(1+\tilde{Y}\right)^T}\right]} \qquad (7)$$

Comparing (7) with (4) reveals that the cross-currency basis swap spread depends on the relative magnitudes of the money market basis spreads in their own currencies. If the credit risk embedded in the dollar curve is relatively large, so that b is large relative to $\tilde{b}$, then X tends to be negative and dollar LIBOR minus a spread tends to be fair against foreign LIBOR. Conversely, if the credit risk embedded in the foreign curve is greater, so that $\tilde{b}$ is large relative to b, X tends to be positive and dollar LIBOR plus a spread tends to be fair against foreign LIBOR.

Figure 3. The interest rate parity argument with money market basis swaps

Transaction	Today ($)	Interim ($)	Time *T* ($)	Today (Fgn)	Interim (Fgn)	Time *T* (Fgn)
Spot FX	$-S_0$			+1		
Cross-currency swap	$+S_0$	$-r_t S_0$	$-S_0$	-1	$\tilde{r}_t$	+1
O/N vs. 3-month swaps		$+r_t S_0 - (L_t - b) S_0$			$-\tilde{r}_t + \tilde{L}_t - \tilde{b}$	
Par swaps on $S_0 b/R$ and $\tilde{b}/\tilde{R}$		$-bS_0 + [bS_0/R] L_t$			$\tilde{b} - (\tilde{b}/\tilde{R}) \tilde{L}_t$	
Zero-coupon swaps on $S_0(1-b/R)$ and $1-\tilde{b}/\tilde{R}$		$S_0(1-b/R) L_t$	$-S_0(1-b/R)\left[(1+Y)^T - 1\right]$		$-(1-\tilde{b}/\tilde{R}) \tilde{L}_t$	$(1-\tilde{b}/\tilde{R})\left[(1+\tilde{Y})^T - 1\right]$
Sell foreign forward			$+F\left[(1+\tilde{Y})^T - (\tilde{b}/\tilde{R})\left[(1+\tilde{Y})^T - 1\right]\right]$			$-(1+\tilde{Y})^T + (\tilde{b}/\tilde{R})\left[(1+\tilde{Y})^T - 1\right]$
Total	0	0		0	0	0

5. EMPIRICAL EVIDENCE

Cross-currency basis swaps spreads are normally quoted as USD LIBOR versus the foreign currency plus or minus a spread. The theory presented in the previous sections predicts that when the credit risk embedded in foreign LIBOR rates is greater than the credit risk embedded in USD LIBOR rates, the cross-currency basis swap spread should be negative, ie, certain payments of USD LIBOR are fair against foreign LIBOR minus a spread. Similarly, when the credit risk embedded in foreign LIBOR rates is less than that in USD LIBOR rates, the spread should be positive. This section presents some empirical evidence supporting these implications.

5.1 Cable versus USD

Both US and UK markets trade 1-month versus 3-month money market basis swaps. Quoted versus local 3-month rates, representative levels in April 2003 were 1-month USD LIBOR plus .75 basis points and 1-month GBP LIBOR plus 2 basis points. These levels strongly imply that more credit risk is built into GBP LIBOR than into USD LIBOR. Therefore, theory predicts that the cross-currency basis swap spread should be negative. This was in fact the case: a representative level in April 2003 was -1.5 basis points.

In May 2003, the money market basis swaps moved to 1-month USD LIBOR plus 1.5 basis points and 1-month GBP LIBOR plus 1.75 basis points. The widening of the US spread and tightening of the UK spread can be at least partially explained by a substantial weakening of the US dollar, 45-year lows in 10-year US yields, and a strong risk in the Lehman Risk Premium Index. In any case, as predicted by theory, the narrowing of the difference between the money market basis swap spreads coincided with the cross-currency basis swap spread falling from -1.5 in April to -.75 in May.

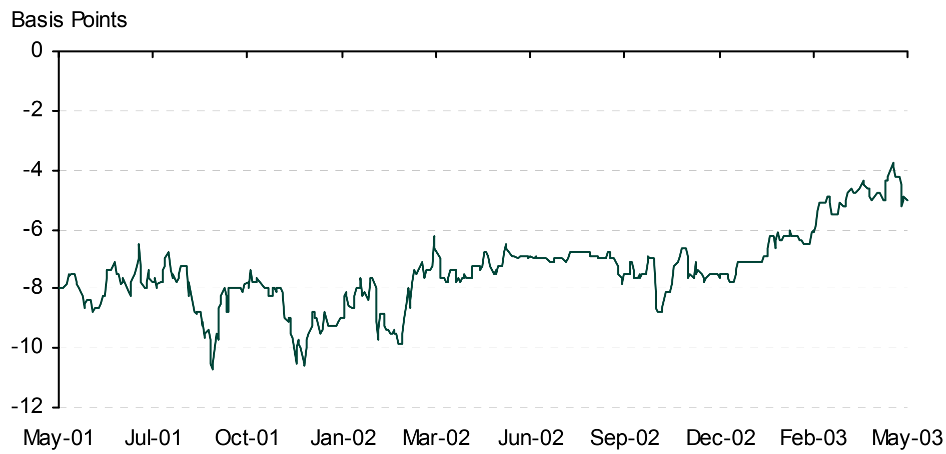
5.2 CAD versus USD

The floating rate of CAD swaps are called CDOR rates (pronounced see-dor), which are keyed off Canadian BAs (Bankers' Acceptances). Since BAs are collateralized by receivables whereas LIBOR rates are unsecured bank loans, CDOR rates should reflect lower credit risk than LIBOR rates. In that case, theory implies that USD versus CAD cross-currency basis swap spreads should be positive. As of May 2003, the 1-year swap traded at 8 basis points, the 2-year at 9 basis points, and the 5- and 10-year at 10 basis points.

5.3 Yen versus USD

Given the difficulties of the Japanese economy and banking system over the past several years, it is reasonable to conclude that short-term Japanese rates reflect much higher credit risk than equivalent maturity US rates. Furthermore, under this supposition, theory predicts that the cross-currency basis swap spread should be substantially negative. Figure 4, plotting this spread since January 2001, supports this contention. The declining magnitude of the spread since the end of 2002 may reflect optimism surrounding recent changes at the Bank of Japan.

Figure 4. Recent History of the USD/JPY Cross-Currency Basis Swap Spread



6. CONCLUSION

This paper derives interest rate parity formulas that include the effects of non-zero cross-currency basis swap spreads. The proposition that these spreads reflect credit differences across short-term rates in various currencies is supported by some evidence from recent levels of GBP/USD, CAD/USD, and Yen/USD cross-currency basis swaps.

APPENDIX 1: MONEY MARKET SWAPS OF DEFAULT-FREE RATES TRADE FLAT

The default-free term structure of rates is defined such that for the risk-neutral process of the instantaneous, continuously compounded rate $r(t)$, the price of a zero coupon bond maturing at time T is:

$$E\left[e^{-\int_0^T r(s)ds}\right] \tag{8}$$

It follows that a floating rate note paying the instantaneous rate is worth

$$E\left[\int_0^T r(s)e^{-\int_0^s r(t)dt}ds\right]+E\left[e^{-\int_0^T r(s)ds}\right] \tag{9}$$

Evaluating the integral in the first expectation term,

$$E\left[-e^{-\int_0^s r(t)dt} \Big|_{s=0}^{T} \right] + E\left[-e^{-\int_0^T r(s)ds} \right]$$

$$= -E\left[-e^{-\int_0^T r(s)ds} \right] + 1 + E\left[-e^{-\int_0^T r(s)ds} \right] \tag{10}$$

$$= 1$$

Hence, this floating rate note is worth par.

If payments are based on rates of a particular term, the floating rate note is still worth par. Let $y_{i\tau}$ be the rate of term τ years at time $i\tau$. Then, the value of the note is:

$$E_0\left[\sum_i y_{i\tau}\tau e^{-\int_0^{(i+1)\tau} r(s)ds} \right] + E_0\left[e^{-\int_0^T r(s)ds} \right] \tag{11}$$

Where, by definition,

$$\frac{1}{1+y_{i\tau}\tau} = E_i\left[e^{-\int_{i\tau}^{(i+1)\tau} r(s)ds} \right] \tag{12}$$

Using the law of iterated expectations, (11) may be rewritten as:

$$E_0\left[\sum_i y_{i\tau}\tau e^{-\int_0^{i\tau} r(s)ds} E_i\left\{ e^{-\int_{i\tau}^{(i+1)\tau} r(s)ds} \right\} \right] + E_0\left[e^{-\int_0^T r(s)ds} \right] \tag{13}$$

Substituting (12) into (13) and using the law of iterated expectations again,

$$E_0\left[\sum_i e^{-\int_0^{i\tau} r(s)ds} \left\{ 1 - e^{-\int_{i\tau}^{(i+1)\tau} r(s)ds} \right\} \right] + E_0\left[e^{-\int_0^T r(s)ds} \right]$$

$$= E_0\left[\sum_i e^{-\int_0^{i\tau} r(s)ds} - e^{-\int_0^{(i+1)\tau} r(s)ds} \right] + E_0\left[e^{-\int_0^T r(s)ds} \right] \tag{14}$$

$$= 1 - E_0\left[e^{-\int_0^T r(s)ds} \right] + E_0\left[e^{-\int_0^T r(s)ds} \right] = 1$$

Hence, a floating rate note paying the default-free rate of any term is also worth par.

Because all floating rate notes keyed off default-free rates are worth par, a swap of any default-free rate for another is worth zero.

APPENDIX 2: CROSS-CURRENCY BASIS SWAPS OF DEFAULT-FREE RATES TRADE FLAT

As in Appendix 1, let $r(t)$ denote the risk-neutral process for the valuation of dollar claims. Let $S(t)$ be the exchange rate process of dollars per unit of foreign currency which is risk-neutral with respect to the valuation of dollar claims. By these definitions, the mean of $S(t)$ is constrained by an instantaneous form of interest rate parity. To wit, consider using 1 dollar to buy $1/S$ units of foreign currency, investing those proceeds at the foreign rate and, after time Δt, converting back to dollars. Because the processes are risk-neutral with respect to pricing dollar claims, the present value of this strategy must be 1 dollar. Mathematically, letting the foreign currency interest rate be $\tilde{r}$,

$$\begin{aligned} &E\left[\frac{S+\Delta S}{S} e^{\tilde{r}\Delta t} e^{-r\Delta t}\right] = 1 \\ &E\left[\frac{\Delta S}{S}\right] = e^{(r-\tilde{r})\Delta t} - 1 \end{aligned} \tag{15}$$

Letting Δt approach zero,

$$E\left[\frac{dS}{S}\right] = (r - \tilde{r})\,dt \tag{16}$$

The dollar value of a claim in the foreign currency may be computed by converting the foreign currency cash flows to dollars, discounting at dollar interest rates, and taking expectations using the risk-neutral process for valuing dollar claims. In the case of a floating rate note in the foreign currency, the value is:

$$E\left[\int_0^T S(t)\tilde{r}(t) e^{-\int_0^t r(u)du} dt\right] + E\left[S_T e^{-\int_0^T r(t)dt}\right] \tag{17}$$

For concreteness, let the risk-neutral exchange rate follow the stochastic process

$$\frac{dS}{S} = (r - \tilde{r})\,dt + \sigma dw(t) \tag{18}$$

which implies that

$$S(t) = S_0 e^{\int_0^t (r(s) - \tilde{r}(s))ds - \frac{1}{2}\sigma^2 t + \sigma W(t)} \tag{19}$$

Using (19), the first term of (17) may be simplified as follows:

$$
\begin{aligned}
E\left[\int_0^T S(t)\tilde{r}(t)e^{-\int_0^t r(u)du}dt\right] &= S_0E\left[\int_0^T \tilde{r}(t)e^{-\int_0^t \tilde{r}(s)ds-\frac{1}{2}\sigma^2 t+\sigma W(t)}dt\right] \\
&= S_0E\left[\int_0^T \frac{d}{dt}\left\{-e^{-\int_0^t \tilde{r}(s)ds}\right\}e^{-\frac{1}{2}\sigma^2 t+\sigma W(t)}dt\right] \\
&= S_0E\left[-e^{-\int_0^t \tilde{r}(s)ds}e^{-\frac{1}{2}\sigma^2 t+\sigma W(t)}\Bigg|_{t=0}^{T} + \int_0^T -e^{-\int_0^t \tilde{r}(s)ds}d\left\{e^{-\frac{1}{2}\sigma^2 t+\sigma W(t)}\right\}\right] \\
&= S_0 - S_0E\left[-e^{-\int_0^T \tilde{r}(s)ds}e^{-\frac{1}{2}\sigma^2 T+\sigma W(T)}\right]
\end{aligned}
\tag{20}
$$

The last equality holds because the last term in the brackets of the penultimate equality is a martingale and, therefore, zero in expectation.

Using (19), the second term of (17) is:

$$
S_0Ee^{\int_0^T -\tilde{r}(s)ds-\frac{1}{2}\sigma^2 T+\sigma W(T)} \tag{21}
$$

Combining the last equality of (20) with (21) to add the two terms of (17), the value of the foreign floating rate note is S_0 dollars or 1 unit of foreign currency.

From Appendix 1, the dollar floater is worth its notional amount; from this appendix, the foreign floater is worth its notional amount. Hence, a cross-currency basis swap, ie, an exchange of S_0 notional amount of dollar floating rate swaps for 1 notional amount of foreign floating rate swaps, is worth zero. In other words, the cross-currency basis swap trades flat.

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