Dynamic Profits Sharing Mechanism for a High-tech Virtual Enterprise

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Abstract

To establish a High-tech Virtual Enterprise (HTVE) is an effective method for a High-tech enterprise to quickly respond to market opportunity and disperse risks. However, most partners readily incline to reduce their innovation efforts for worrying about lose resulted from unpredictable risks. Thus, it is imperative to design a practical profits sharing mechanism to stimulate partners' effort by timely compensating their potential loss. A quantitative model was firstly established to examine how some factors such as risk preference, core competency and cost etc. can comprehensively affect the effort degree of a partner. Based on this analysis, a formula to calculate the desired profits sharing proportion of each partner are provided. Considering the changes of uncertainties will make the original profits sharing tactics unreasonable, the paper subsequently provides a method to monitor the conflict degree of profits sharing and tactics to modify profits sharing tactics dynamically according to the actual cost and risks assumed by partners in different stage. The dynamic profits sharing mechanism can motivate partners' efforts more effectively than traditional mechanism can.

Keywords: Virtual enterprise, High-tech enterprise, profits sharing, Corporation governance, Contribution evaluation, Cost management

1. Introduction

A virtual enterprise is a system of autonomous firms that collaborate to achieve common business objectives. It gives participants a competitive edge in markets demanding agility and rapid response (Reorganizes, 2001, P. 172). Nowadays, drastic market fluctuation and high innovation risks have made it difficult for high-tech enterprises to obtain competitiveness. The reason is that sole high-tech enterprise ordinarily does not possess the necessary competencies for satisfying the demands timely. In this situation, to establish a High-tech Virtual Enterprise (HTVE) is an effective method to cultivate sustainable competitive advantages for High-tech enterprises (Liu, 2006, P. 2). HTVE, here, is defined as a temporary organization, which is constructed by many entities with different core competencies surpassing their own organization boundaries under a consistent net-based coordination mechanism, aims at providing high-tech products and services to quickly respond to demands of market. HTVE differs substantially from markets and hierarchical organization. It provides new challenges for the conception and practice of corporation governance because of expanded management scope, multilateral transaction processes and uncompleted constraints of cooperation contract (Cachon, 2005, P. 30), and of the characteristics relative with high-tech, such as market uncertainty, product complexity, and shared knowledge. Furthermore, most partners readily incline to reduce their efforts during cooperation for worrying about irrevocable loses resulted from unpredictable risks. Thus in this situation, in order to stimulate the partners, it is imperative for a HTVE to design a serial of tactics to tackle profits sharing among the partners. Obviously, the precondition is to precisely evaluate the contribution of each partner to the HTVE and then to calculate the desired sharing proportion of each partner according to his contribution. In section 2, this paper will provide a comprehensive model to analyze how some major factors quantitatively affect the effort of each partner. Further, in next section indicators to express the contribution of each partner are presented as well as a formula to calculate the desired sharing proportion of each partner. Because the changes of some uncertainties will make some factors changed, and then affect the reasonability of the desired profits sharing proportion, the paper in section 4 provides a dynamic tactics by which profit sharing proportions can be adjusted dynamically corresponding to the factual cost and risks assumed by partners in different cooperation stage. Section 5 is the summaries.

2. Relationship of major factors with a partner's contribution

Generally speaking, the more efforts a partner makes, the more contribution he makes to a HTVE. Thus at first we should examine how some factors affect the effort degree of a partner. These factors involve the partner's total cost, core competency, marginal ratio and risk preference and so on. Where total cost sometimes are called Collaboration cost which is considered to be one of the most important indicators that influence the efficiency of virtual enterprise (Wang, 2009, P.860). But the Collaboration cost is just one indicator to reflect a partner's effort. Other factors such as risk, core competency, opportunity cost etc. also play great role of affecting a partner's effort decision and then its final contribution to HTVE. Therefore, we have to comprehensively examine to what degree these factors affect a partner's contribution for the sake of accuracy and fairness.

2.1 Effects of some factors to a partner's contribution

Assume that the HTVE herein consists of supplier S, manufacturer M and seller R. The partners will recognize that a mistake or inactive actions of anyone may result in no chance to develop new products successfully, let alone gaining profits. Thus they tend to form a closer relationship which will readily induce a more comparatively centralized cooperation pattern (Gao, 2006, P.1934). The next discussions are based on this situation and firstly give the following premises.

(1) The levels of effort of supplier S, manufacturer M and seller R are X_s, X_m, X_r respectively; $\alpha_s, \alpha_m, \alpha_r$ are the partners' contribution coefficients for depicting the contribution of partners' effort to the total profit of HTVE, which have relationship with the partners' core competencies.

(2) Let $\beta_s, \beta_m, \beta_r$ respectively represent the unit effort cost of the partners, and C_{s0}, C_{m0}, C_{r0} are their Fixed Operational Costs, then we can give the total cost of each partner (Lu, 2003, P. 61). The total cost of supplier S is $C_s(X_s)=C_{s0}+\frac{1}{2}(\beta_s X_s)^2$; the total cost of manufacture M is $C_m(X_m)=C_{m0}+\frac{1}{2}(\beta_m X_m)^2$ and the one of seller R is $C_r(X_r)=C_{r0}+\frac{1}{2}(\beta_r X_r)^2$. Obviously $C_s'(X_s)>0$ and $C_s''(X_s)>0$ mean that, there is an increasing in the Innovation Cost, and it grows faster and faster.

(3) Suppose that the total profit of the HTVE in a certain stage is $R'(X_s, X_m, X_r)=R(X_s, X_m, X_r)+\xi$ and $R'(X_s, X_m, X_r)>0$, $R''(X_s, X_m, X_r)<0$, where ξ is a stochastic disturbing factor followed normal distribution $N(0,\sigma^2)$.

(4) Suppose that the profit sharing tactics among the partners is a linear proportion based on the total profit $R'(X_s, X_m, X_r)$, then we can get the profit of supplier S is $\pi_s = T_s + d_s(R'-T_s-T_r)-C_s$; the total profit of manufacturer M is $\pi_m = d_m(R'-T_s-T_r)-C_m$, and seller R can gain $\pi_r = T_r + d_r(R'-T_s-T_r)-C_r$, where d_s, d_m, d_r are respectively the Profit Sharing Proportion (PSP) and obviously $d_s+d_m+d_r=1$.

(5) Assume that all partners have unchangeable absolute risk-elusion characteristic, that is to say, they match this utility function $u_x=\frac{1-e^{-\rho_x\pi_x}}{\rho_x}$, where u_x represents the utility which partner x has when gaining the actual income π_x of capital or assets, and the parameter ρ_x describes the degree of risk-elusion of partner x, the greater ρ_x is, the more readily partner x trends to elude risk. Suppose that the manufacturer is a risk-neutral partner, so the parameter $\rho_m=0$. But as for supplier and seller, they are risk-elusion partners, so the parameters $\rho_s, \rho_r>0$, which means they have to pay additional Risk Premium (Espen, 2008, p.2007). Herein the risk cost of supplier S is supposed to be $C_{sr}=\frac{1}{2}\rho_s d_s^{\,2}\sigma^2$, and the seller's is $C_{rr}=\frac{1}{2}\rho_r d_r^{\,2}\sigma^2$.

Let i_s, i_m and i_r denote respectively the marginal ratio of the supplier, manufacturer and seller, then we can formulate a mathematic model as follows.

$$\max d_m\left(R\left(X_s, X_m, X_r\right)-T_s-T_r\right)-\left(1+i_m\right)\left(C_{m0}+\tfrac{1}{2}\left(\beta_m X_m\right)^2\right) \tag{1}$$

Subject To

$$T_s+d_s\left(R\left(X_s, X_m, X_r\right)-T_s-T_r\right)-\tfrac{1}{2}\rho_s d_s{}^2\sigma^2 \geq\left(1+i_s\right)\left(C_{s0}+\tfrac{1}{2}\left(\beta_s X_s\right)^2\right) \tag{2}$$

$$T_r+d_r\left(R\left(X_s, X_m, X_r\right)-T_s-T_r\right)-\tfrac{1}{2}\rho_r d_r{}^2\sigma^2 \geq\left(1+i_r\right)\left(C_{r0}+\tfrac{1}{2}\left(\beta_r X_r\right)^2\right) \tag{3}$$

For $\forall X_s' \in\left[0, \bar{X}_s\right]$

$$\begin{aligned} & T_s+d_s\left(R\left(X_s, X_m, X_r\right)-T_s-T_r\right)-C_{s0}-\tfrac{1}{2}\left(\beta_s X_s\right)^2-\tfrac{1}{2}\rho_s d_s{}^2\sigma^2 \\ & \geq T_s+d_s\left(R\left(X_s', X_m, X_r\right)-T_s-T_r\right)-C_{s0}-\tfrac{1}{2}\left(\beta_s X_s'\right)^2-\tfrac{1}{2}\rho_s d_s{}^2\sigma^2 \end{aligned} \tag{4}$$

For $\forall X_r' \in\left[0, \bar{X}_r\right]$

$$\begin{aligned} & T_r+d_r\left(R\left(X_s, X_m, X_r\right)-T_s-T_r\right)-C_{r0}-\tfrac{1}{2}\left(\beta_r X_r\right)^2-\tfrac{1}{2}\rho_r d_r{}^2\sigma^2 \\ & \geq T_r+d_r\left(R\left(X_s, X_m, X_r'\right)-T_s-T_r\right)-C_{r0}-\tfrac{1}{2}\left(\beta_r X_r'\right)^2-\tfrac{1}{2}\rho_r d_r{}^2\sigma^2 \end{aligned} \tag{5}$$

$$d_s+d_m+d_r=1 \text{ And } X_s \in\left[0, \bar{X}_s\right],$$

$$X_m \in\left[0, \bar{X}_m\right], X_r \in\left[0, \bar{X}_r\right] \tag{6}$$

Where $\bar{X}_s, \bar{X}_m$ and $\bar{X}_r$ represent respectively upper limitation of the levels of innovation effort of supplier, manufacturer and seller. The inequality (2) is the participating constraint of supplier S, and it expresses that the expected profit which the supplier S will gain after participating in the HTVE should surpass his opportunity cost. The inequality (4) expresses that the supplier S will try his best to gain the most profit with a certain of innovation effort $X_s, X_s \in\left[0, \bar{X}_s\right]$. We here call this constraint as motivating constraint. Inequalities (3) and (5) are respectively the participating and motivating constraints for the seller R.

2.2 Analysis of the above model

Based on the mathematic model we can obtain some general principle between some factors relative to cost or risk and the contribution of each partner.

(1) If the PSP is not related with $R\left(X_s, X_m, X_r\right)$, that means $d_s=0$, and then we can get the simplified form of inequality (2), which can be expressed by $Max T_s-C_{s0}-\tfrac{1}{2}\left(\beta_s X_s\right)^2-\tfrac{1}{2}\rho_s d_s{}^2\sigma^2$. In this term, suppose that the supplier want to gain the maximum profit, so X_s must be zero. That means the partners will not make any effort.

(2) If the model has feasible solution, then the inequalities (2) and (4) are equal to the following term:

$$\max T_s+d_s\left(R\left(X_s, X_m, X_r\right)-T_s-T_r\right)-\tfrac{1}{2}\rho_s d_s{}^2\sigma^2-\left(1+i_s\right)\left(C_{s0}+\tfrac{1}{2}\left(\beta_s X_s\right)^2\right) \tag{7}$$

If the objective function is differentiable, then we can get

$$d_s \alpha_s \tfrac{\partial R}{\partial\left(X_s\right)}=\left(1+i_s\right) \beta_s C_s'\left(\beta_s X_s\right) \tag{8}$$

Obviously, the partner S expects the proportion d_s that he can gain to be in direct ratio with his marginal ratio. Going further then

$$\alpha_s \frac{\partial R}{\partial X_s} + \alpha_s^{\,2} \frac{\partial^2 R}{\partial X_s^{\,2}} \frac{\partial X_s}{\partial d_s} d_s = (1+i_s)\beta_s^{\,2} C_s''(X_s) \frac{\partial X_s}{\partial d_s} \tag{9}$$

Easy algebraic manipulations give

$$\frac{\partial X_s}{\partial d_s} = \frac{\alpha_s \frac{\partial R}{\partial X_s}}{(1+i_s)\beta_s^{\,2} C_s''(X_s) - d_s \alpha_s^{\,2} \frac{\partial^2 R}{\partial X_s^{\,2}}} = \frac{\alpha_s \frac{\partial R}{\partial X_s}}{(1+i_s)\beta_s^{\,2} - d_s \alpha_s^{\,2} \frac{\partial^2 R}{\partial X_s^{\,2}}} \tag{10}$$

Where $R'(X_s, X_m, X_r) > 0, R''(X_s, X_m, X_r) < 0$ as we supposed, so $\frac{\partial X_s}{\partial d_s} > 0$ that is, the greater the proportion is, the more effort the partner S will make. If $R''(X_s, X_m, X_r) > 0$ that means, the partner S is not afraid of risk, only under the condition that his expected profit for the increasing rate of effort Cost ($(1+i_s)\beta_s^2$) is more than compensation from contribution coefficient for the increasing rate of his contribution to the total profit ($d_s \alpha_s^2 \frac{\partial^2 R}{\partial X_s^2}$), can the same rule be obtained. That is to say it will be more effective to encourage the partner by raising the proportion only when the proportion partner S can gain is less than his expected. So there is a marginal utility needing consideration when we plan to encourage a partner by raising PSP.

(3) The more risk one partner assumes, the greater apportionment proportion the partner should gain, which is the same as Zheng (2001, P. 27) proposed. As for the manufacturer M , we can have

$$\mathrm{var}(\pi_m) = \mathrm{var}[d_m(R' - T_s - T_r) - C_m] = d_m^{\,2}\sigma^2 \tag{11}$$

While for the supplier S

$$\mathrm{var}(\pi_s) = \mathrm{var}[T_s + d_s(R' - T_s - T_r) - C_m] = d_s^{\,2}\sigma^2 \tag{12}$$

Obviously, if $d_m > d_s$, then $\mathrm{var}(\pi_m) > \mathrm{var}(\pi_s)$.

(4) If partner S wants to maximize his own profit, then we can get $\alpha_s \frac{\partial R}{\partial X_s} = \frac{1+i_s}{d_s} \beta_s C_s'(X_s)$. We can draw a conclusion that profit sharing ratio to the partner should be along with the change of his expected profit marginal ratio. Obviously this rule is fair for every partner by nature.

(5) If the suppliers, manufacturer and sellers agree to maximize their profits under Pareto equilibrium (Rubio, 2006, P. 203), the problem can be represented by the following model:

$$\begin{aligned} &\max\left(R(X_s, X_m, X_r) - T_s - T_r\right) - \tfrac{1}{2}\rho_s d_s^{\,2}\sigma^2 - \tfrac{1}{2}\rho_r d_r^{\,2}\sigma^2 \\ &-(1+i_s)\left[C_{s0} + \tfrac{1}{2}(\beta_s X_s)^2\right] - (1+i_m)\left[C_{m0} + \tfrac{1}{2}(\beta_m X_m)^2\right] \\ &-(1+i_r)\left[C_{r0} + \tfrac{1}{2}(\beta_r X_r)^2\right] \end{aligned} \tag{13}$$

If this objective function is differentiable, then we can obtain:

$$\alpha_s \frac{\partial R}{\partial X_s} \frac{\partial X_s}{\partial d_s} - \rho_s \sigma^2 d_s - (1+i_s)\beta_s C_s'(X_s) \frac{\partial X_s}{\partial d_s} = 0 \tag{14}$$

Combining with equation (5), and after algebraic simplification we can get

$$d_s = \frac{1}{\dfrac{\rho_s \sigma^2}{\alpha_s \frac{\partial R}{\partial(\alpha_s X_s)} \frac{\partial X_s}{\partial d_s}} + 1} \tag{15}$$

From the above equation, we can know that, the greater the value of $\rho_s \sigma^2$ (expressing partner S is more readily to elude risk) is, the less the sharing proportion to partner S is. In this situation the ASC should decrease dependence on partner S and let the partner to assume less risk. The less the value of $\alpha_S \frac{\partial R}{\partial(X_s)}$ and $\frac{\partial X_s}{\partial d_s}$ is(expressing that the increasing in apportionment proportion has no notable effect on the effort level of partner S and that partner S makes less contribution to the total profit of the HTVE), the less apportionment proportion to partner S is.

(6) Supposed that the total profit function is:

$$R'(X_s, X_m, X_r) = \tfrac{1}{2}(\alpha_s X_s + \alpha_m X_m + \alpha_r X_r)^2 + (\alpha_s X_s + \alpha_m X_m + \alpha_r X_r) + R_0 + \xi \tag{16}$$

Where R_0 is a constant, let X_S^*, X_m^* and X_r^* denote respectively the optimum level of effort made by each partner. If to maximize the total profit, we can get $X_s^* : X_m^* : X_r^* = \alpha_s \beta_m^2 \beta_r^2 : \alpha_m \beta_s^2 \beta_r^2 : \alpha_r \beta_s^2 \beta_m^r$, that means the effort degree of partner x, is in direct ratio with α_x (the innovation contribution coefficient) and in inverse ratio with β_x^2 (the square of its unit innovation cost).

3. Profits sharing tactics based on a partner's contribution

In order to make a fair sharing tactics which will motivate every partner to make its best effort, the PSP of one partner should be consistent with his contribution to HTVE. Based on the above analysis, we can get the following conclusions: (1) the more a partner has cost in HTVE, larger his PSP should be. (2) PSP of one partner $x(x \in A)$ should be in direct ratio with the partner's innovation contribution coefficient α_x, and in inverse ratio with the square of his unit innovation cost β_x^2. (3) Parameter i_x should be modified according to the actual risks each partner assumes. A partner always compares the risk he is facing in HTVE with his previous risks and then plans for a newly expected marginal ratio. So another parameter i'_x standing for the expected margin ratio should be introduced as the following equation:

$$i'_x = \frac{\sigma^2}{\sigma_x{}^2} i_x \tag{17}$$

Where, parameter σ^2 is the deviation of the expected marginal ratio, which denotes the risk degree when partner x joins in the HTVE, and $\sigma_x{}^2$ is the previous one when he is acting as a independent entity. The values of these two parameters can be estimated by fuzzy comprehensive evaluation method (Zhang, 2008, P.58). (4) The PSP of a partner should be in direct ratio with his marginal ratio. According to these conclusions, we can propose a formula to express the desired PSP of a partner in HTVE as follow:

$$d_x = \frac{\frac{\alpha_x}{\beta_x{}^2} C_x (1 + i'_x)}{\sum_{x \in A} \frac{\alpha_x}{\beta_x{}^2} C_x (1 + i'_x)} \quad x \in A \tag{18}$$

Where α_x can describe the partner's core competency, β_x depicts the partner's innovation ability. Lu has provided some methods of how to get the value of parameters α_x and β_x (Lu, 2003, P. 62). Parameter C_x

in right term is the total cost of the partner during the whole cooperation process. But the total cost is very difficult to calculate in a HTVE circumstance.

HTVE, as a dynamic collaborative mode of high-tech enterprises based on network technology, is composed of the partners who always come from the nodes of other supply chains or virtual enterprises. However, during their cooperation process the boundaries between the partners will become blurred for sharing of common information, fix asset or even core competency, and the value chain of the partners are integrated together to construct the virtual value chain of the HTVE, which contains the core competencies of each partner. This status results in that characteristics of the cost system of HTVE are: (1) there are much cooperation cost for the relevancy of partners' activities; (2) probably lead to large amount of sink cost; (4) hard to predict and control. These characteristics result in the inefficiency of traditional cost management method. LIU and GAO (2009, P. 315) proposed a costing management system to calculate the total cost of each partner. They utilized the cost driving factor as the imputation to tackle and apportion the cooperation cost among the relative partners and then provided a new conception of Modified Total Cost (MTC) to substitute the total cost of each partner. MTC is the accumulation of Apportioned Cost, Fixed Cost and individual operation cost. Individual operation cost means the cost that is incurred by a partner for performing his necessary internal activities such as manufacture, daily management and other activities. For example, individual operation cost of supplier includes the cost for producing the components or materials, the daily overhead cost etc; and for distributor, it includes the cost of inventory and operating expenses, the capital interests etc. Fixed cost here is not the whole value of the asset invested in HTVE by a partner. Only can a certain part of its depreciation used for the cooperation among partners be counted into Fixed Cost. The expression for calculating Parameter C_x is as follow (Liu, 2009, P. 315-322)

$$C_x = \sum_{k\in x}\sum_{t=1}^{3} y_{kt} + \sum_{j\in x}\sum_{t=1}^{3} y_{jt} + \sum_{m\in x}\sum_{t=1}^{3} y_{mt} + y_{x4} + y_{x5} + y_{x6} \quad (19)$$

4. Dynamic renegotiation of profits-sharing tactic

Generally speaking, once partners decide to establish a HTVE, profits sharing tactics need to be proposed before the substantial cooperation starts up. In practice, an important task of the management of HTVE is to allocate the profit among partners in uncertain environment (Liu, 2005, P. 14). The original sharing tactics can be designed according to equation (18). But note that some parameter is estimated based on anticipatory cost and risks assumed by partners in the future. However, the factual cost and risks may deviate from the anticipatory one, so that will make the original profits-sharing tactics unreasonable. That means the original one can not motivate the partners to make enough effort for cooperation, or even lead to some conflicts. Sometimes this kind of conflict may become so serious that will threaten the stability of HTVE. Thus, we should find an approach to monitor the conflict degree resulted from uncertainties. In order to solve this problem, we can divide the lifecycle of a HTVE into n stages. Supposed that k is any stage in the lifecycle, which means $k = 1,2,\cdots,n$. Then we can define an indicator called conflict coefficient as follow to monitor the conflict degree.

$$K(d_{xk}) = \frac{2d_{xk} - d'_{xk}(t)}{d'_{xk}(t)} \in (-1,+\infty) \quad k = 1,2,\cdots,n \quad (20)$$

In this equation, variable $K(d_{xk})$ is the Conflict coefficient, variable $d_{xk}(x \in A)$ is the current PSP, and variable d'_{xk} , the desired PSP of partner x in stage k , is given by the following equation:

$$d'_{xk} = \frac{\frac{\alpha_x}{\beta_x^{\,2}} C_{xk}(1+i'_{xk})}{\sum_{x\in I} \frac{\alpha_x}{\beta_x^{\,2}} C_{xk}(1+i'_{xk})} \quad k = 1,2,\cdots,n \quad (21)$$

Where, parameter C_{xk} in right term is the MTC of the partner x which is calculated based on the circumstance in stage k . According to the expression of $K(d_{xk})$, it reflects the deviation of the current PSP with the desired one from the aspect of partner x . In practice, we can identify the conflict degree from the value of $K(d_{xk})$. For example, if in a certain stage we have $K(d_{xk}) \in (a,1] \quad (a \geq 0)$, that means that the current PSP is more than half of but less than the desired PSP. If this situation is acceptable by partner x , we do not have to modify the current PSP and can keep it until $K(d_{xk}) < 0$ or $K(d_{xk}) > 1$. That is to say, $K(d_{xk}) < 0$ or

$K(d_{xk}) > 1$ means the current profits sharing tactics arouse strong conflict among partners, and then we should modify the current PSP to desired PSP. In a word, dynamic profits sharing mechanism emphasize the timely modification of the current profits sharing tactics to a substitutable one which is compatible with the actual risks and cost partners is expecting to assume in different stage. By this way, we can assure that the profits sharing tactic is always fair to every partner during the whole cooperation process. This method compared with the Shapley values based on a fuzzy payoff functions (Chen, 2007, P. 49), don not require to predict the final profit of HTVE in different status. In fact, it is always difficult to estimate the final profit because of the uncertainty of several factors affecting the change of cost or risk of each partner.

5. Conclusions

In this paper, we proposed systematic methods to analyses the relationship between partners' costing, risk preference, efforts etc. with his contribution to HTVE from comprehensive perspective and provided the dynamic profits sharing mechanism based on the analysis. The conflict coefficient can depict conflict degree aroused by the current profits sharing tactics. Dynamic profits sharing mechanism compared with the traditional profits sharing ways can make sure that profits sharing tactic is satisfied by every partner during the whole lifecycle of HTVE. That will be beneficial to encourage the partner's innovation activities and sustain the stability of HTVE. However, note that it is not very easy for the administrator of HTVE to calculate the desired PSP and modify the current on for getting the precise value of MTC is comparatively complicated. In practice, to get precise MTC and calculate the desired PSP require a better management structure with strong executive power to make plan, and to supervise and justify the deviation from the planning. Furthermore, a networked information system is needed in order to get the cost information timely of each partner and transmit conflict feedback information and new profits sharing tactics among partners.

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