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RESEARCH PAPER

New Applied Mechanism for Fair Equity Sharing to Overcome The Challenges of Venture Capital Financing

Komeil Fattahi[1], Ali Bonyadi Naeini[2]*& Seyed Jafar Sadjadi[3]

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ABSTRACT

Venture capital (VC) financing is associated with the challenges of double-sided moral hazard, and uncertainty, which leads to the difficulty in estimating the venture's value accurately and consequently the impossibility of determining the optimal equity sharing between the entrepreneur and investor. Traditionally, convertible preferred equity mechanisms used to be implemented as an incentive to decline moral hazard. However, despite the emphasis on investor risk-taking, such mechanisms transfer the investor risk to the entrepreneur and do not mitigate the incentive of opportunistic behaviors. Furthermore, according to the literature review, and to the best of the authors' knowledge, there has not been developed any practical mechanism for equity sharing in VC financing up to now. This paper proposes a fair equity sharing mechanism, which alleviates the above-mentioned deficiencies. It adjusts both parties' share during the equity dilution in each stage of financing, regarding the difference between the venture's ex-ante and ex-post values. Moreover, it manages uncertainty by applying staged financing and the option of abandonment at the end of each stage. The proposed mechanism has been verified by using mathematical tools and drawing its curves for a case study.

KEYWORDS: *Venture capital (VC) financing; Fair equity sharing; Double-sided moral hazard; Convertible preferred equity mechanisms.*

1. Introduction

Some scholars have pointed to the role of entrepreneurs in economic growth [1, 2]. However, they have a lot of difficulties in accessing capital in order to commercialize their technological ideas [3], most of which are due to the impossibility of providing collateral and also the lack of financial standards required by banks [4]. Therefore, debt financing is not tailored for them and they have tended to use financing via equity such as venture capital firms (VCFs) or business angels [5]. Interestingly, only after almost 30-year age of venture capital industry, its key role has been proven in providing financial resources for the development of famous innovative ventures, such as Google, Intel, Apple, Microsoft, Amazon, FedEx, Ali Baba, etc. [6,7]. Moreover, Gornall and Strebulaev [8] have represented that about 38% of total employment and 85% of research and development activities in the United States are arising from VCFs-backed ventures. Furthermore, since the late 1990s, China as a country with high economic growth has paid special attention to the development of VCFs [4] as entities in upgrading the industrial structure [9]. Besides, some countries have contributed to sustainable development [10] via sustainable venture capital investments [11]. Furthermore, the ratio of investments via venture capital to GDP is known as an attribute of regional innovation performance [12]. All of the above illustrate the key role of this industry in entrepreneurial development, sustainable development, economic growth, and the national innovation system.

In addition to the role of VCFs in the financing of ventures, the advisory services must be taken into

* Corresponding author: *Ali Bonyadi Naeini*
bonyadi@iust.ac.ir

1. *Management of Technology at Iran University of Science and Technology (IUST), Tehran, Iran. komeilfattahi@alumni.iust.ac.ir.*
2. *Department of Management and Business Engineering, School of Progress Engineering, Iran University of Science and Technology (IUST), Tehran, Iran.*
3. *Department of Industrial Engineering, Iran University of Science and Technology (IUST), Tehran, Iran; sjsadjadi@iust.ac.ir.*

account as their other important role, which is necessary for the success of ventures [6, 7, 13]. According to research conducted by Casamatta [14], entrepreneurs have the creativity and technical skills to develop their innovative ideas and they are skilled in technology development, production, and innovation, albeit they do not have enough business experiences such as marketing, networking and financial advisory skills, which can be provided by VCFs [14,15]. Thus, the complementary partnership of entrepreneur capabilities and VCFs' experiences lead to a synergy, which has a positive impact on the ex-post value of the venture [6]. In this regard, the entrepreneur requests finance and advisory services and in return dilutes a part of his (her) ownership equity in favor of VCFs as the investor. Here, the double-sided moral hazard problem is appeared, so that the efforts of each party are neither observable nor measurable [6]. Furthermore, at the beginning of their cooperation, the investor tends to underestimate the value of venture and thereby possess more percentage of the venture's ownership. On the other hand, due to the interest in his (her) idea as an owner and misunderstanding of the market, the entrepreneur overestimates the value of venture in order to dilute the fewer amounts of ownership equity [16,17]. Vividly, most investors and entrepreneurs have the incentive to behave opportunistically and conceal their private information, which has a negative impact on the precise estimation of the venture's ex-ante value. Therefore, both parties pay special attention to the venture's value, which has a key role in optimal equity sharing between them [18]. Nonetheless, because of the existence of uncertainty and moral hazard [19, 20] as factors that can't be eliminated completely, the accurate estimation of the venture's value is not possible. In order to alleviate the two mentioned factors, a number of financing and governance mechanisms such as; staged financing with direct oversight, real options, convertible preferred equity, and participating convertible preferred equity have been applied to put more effort and manage the uncertainty [17,21, 22]. In the research by Repullo and Suarez [23], it was noted that appropriate incentive mechanisms are needed to be designed for increasing the willingness of entrepreneurs and investors to put more effort into venture development. Herein, how to divide the ownership equity of venture between them and their optimal equity sharing contracts were mentioned as the most important incentive mechanisms [7, 24], especially in the early stages of growth [6], which theoretically and practically need further attention pay to this field of VC financing [25].

It should be noted that traditional VCFs used to be entered into the later stages of venture's growth such as start-up and commercialization [19, 26] because of the high uncertainty, moral hazard, and adverse selection in the early stages [27-29]. Recently, the direction of VCFs has dramatically changed, so that they invest during all stages of the venture's growth, especially in the early stages [30]. For instance, in the VC industry, the number and amount of European investments have been increased in the early stages of growth in contrast to the later stages. Furthermore, in the United States in 2015, more than half of $ 58.8 billion spent on VC investments were dedicated to finance the ventures during the early stages of their growth [31, 32]. Arguably, according to the foregoing and the experts' opinions, the direction change to the early stages of financing is due to applying the new mentioned mechanisms.

Some mechanisms such as convertible preferred equity are applied in the form of clauses in VC financing contracts to encourage entrepreneurs and investors to put in more effort. Nevertheless, it is needed to improve them by alleviating their limitations [13, 33-35], which have been resulted in the unwillingness of experienced entrepreneurs to extensive use of mentioned mechanisms [36]. Scholars believe that such mechanisms regarding the redemption value and the possibility of converting the preferred equity to debt or common equity, actually transfer the investor risk to the entrepreneur [22, 37]. Properly, many studies have shown that trust and transparency between the investor and entrepreneur as the revelation of private information lead to increasing the probability of the venture's success [38-41] that as we have found out, there is not any practical mechanism for the revelation of private information in equity sharing. Thereby, we have tried to propose a new practical mechanism for fair ownership sharing between the investor and entrepreneur, which can be able to alleviate the mentioned limitations.

The remainder of the paper is organized as follows. Research background is investigated and dealt with previous mechanisms orientation in describing ownership sharing and their weakness. In the model section, the proposed mechanism and the investor's and entrepreneur's payoffs are described by the definition of variables, and general setting. In the section of model analysis, the advantages of this mechanism are analyzed,

described, and verified by using mathematical tools and drawing its curves for a case study. Finally, in the conclusions and future directions, the results and suggestions for future research are mentioned.

2. Research Background

In order to arrange the optimal VC contracts, many studies have been conducted in the field of double-sided moral hazard between the entrepreneurs and VC funds as investors [17,42,43] and also have been dealt with ownership sharing arrangements among the members of an entrepreneurial team [44,45]. However, theoretically and especially practically, little attention has been paid to ownership sharing between the entrepreneur and investor during VC financing [6, 13], which to the best of our knowledge, related studies have been mentioned as follows.

Lukas et al. [46] have defined thresholds for the venture value at each stage of VC financing, and whenever the values are less than the thresholds, then both sides spontaneously leave the cooperation or renegotiate to achieve a new agreement on ownership sharing. Thereby, when a partner decides to abandon the partnership due to the low efficiency, the other one can continue by renegotiating and offering more shares to reset the balance and incentivizing the unsatisfied partner to continue the partnership. Furthermore, in the research conducted by Vergara et al. [6], ownership sharing has been used to describe both parties' behavior. They have shown, the entrepreneur tends to find an investor who complements his (her) efforts and the higher complementarity leads to closer sharing to 50% for both sides, and also optimal ownership sharing dedicated to the investor depends on flexibility, efficiency, and complementarity of both parties' efforts. In another research, Narayanan and Levesque [13], focused on ownership sharing at the early stages of the VC process and dealt with to comparison of three applied methods such as; VC method1, VC method2, and contribution-based profit-sharing method, which all of them are based on the investor's gut feeling. Moreover, Chang and Hu [7] shown the optimal equity sharing assigned to the entrepreneur is nonlinear and between 0 and 1. They have also paid attention to the issues of fairness concerns. In such a way, the optimal share assigned to a fair entrepreneur is more than 50%, which by a higher degree of complementarity of efforts, the optimal equity share that is awarded to the entrepreneur tends to be 60%, and the fair entrepreneur will put more level of effort. Finally, Chang et al. [47] dealt with ambiguity distribution and the impact of effort complementarity in venture capital contracting.

In the above-mentioned studies, except for Lukas et al. [46], financing and equity sharing are just considered during one stage, while based on the mentioned limitations in the research of Narayanan and Levesque [13], it was stated as a shortage and the multi-staged financing has been proposed to stage dividing the shares between the investor and entrepreneur. Furthermore, according to the literature review, and as far as the authors have investigated, it has not been proposed an applied mechanism in equity sharing and all the previous studies solely have been spent to describe the effective factors in ownership sharing and both parties' behavior.

Arguably, convertible preferred equity mechanisms lead to encourage the entrepreneur to further attempt and increase the value of the venture as the incentive to regain the venture's control rights. In addition, it will occur in a situation where the investor exits via initial public offering and converts its preferred equity to common shares by a predetermined coefficient and thereby entrepreneur achieves the venture's control rights. Moreover, in a liquidation situation, the investor can convert its preferred equity to debt securities in order to reduce the risk and guarantees minimum returns [22]. As we have found out and according to the experts' opinions, such mechanisms are further unilaterally in favor of investors and are not known for establishing fairness and transparency for both sides. Furthermore, they lead to convincing the investor more than the entrepreneur to participate through VC financing, and they don't deal with to reduce the incentive of opportunistic behavior in order to further revelation of their private information.

In a nutshell, our main findings of the literature review are depicted in Figure 1. Ulterior, the model section of this paper is conducted to propose a new mechanism for fair equity sharing in venture capital financing, which is tried to mitigate the weaknesses of the mentioned mechanisms.

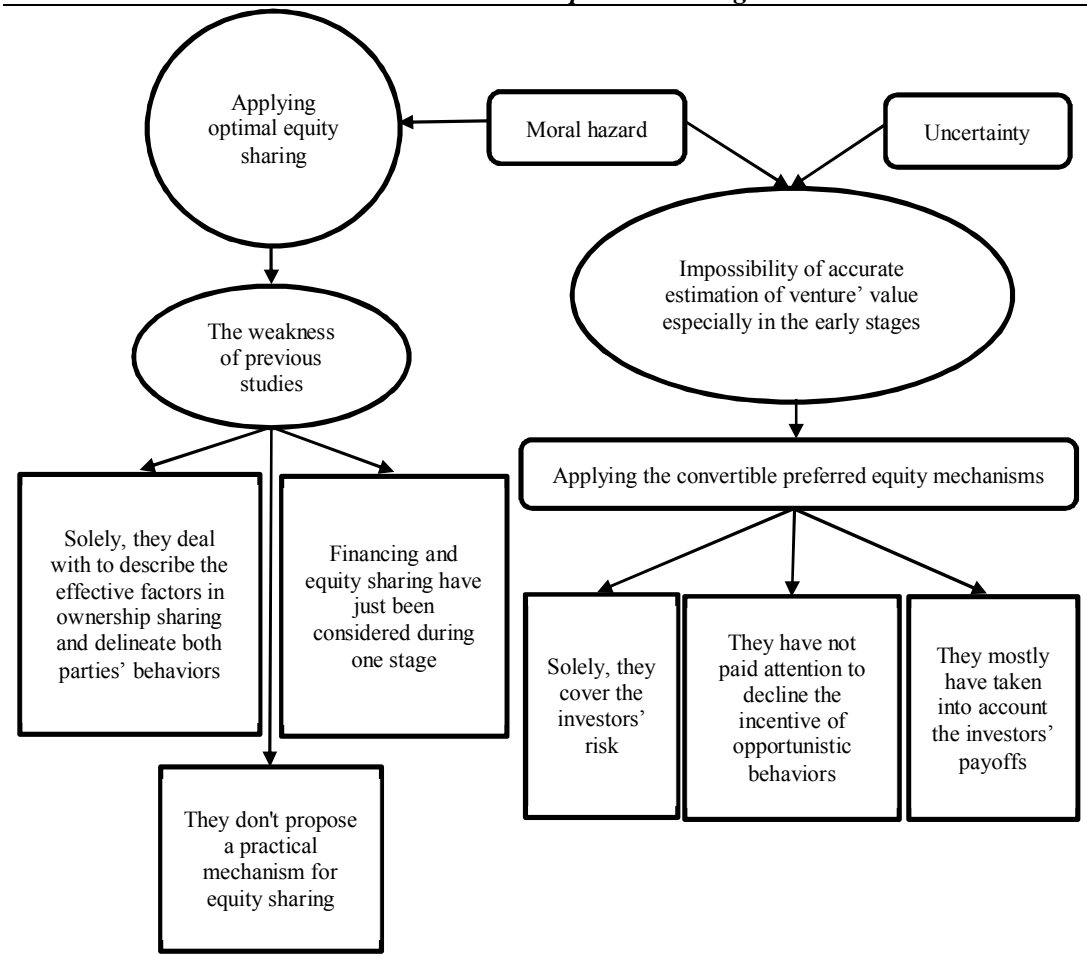

Fig. 1. The main findings of the literature review.

3. The Model

In order to explain the proposed mechanism, we take into account a venture established by an entrepreneur or a team of entrepreneurs as the owner of a technological idea. An entrepreneur or a team of entrepreneurs who are called "entrepreneur" hereafter request finance during the stages of his (her) growth in order to develop the technological idea. At each stage of growth and as a venture, the entrepreneur tries to gain the required investment and advisory services via dilution of his (her) equity in favor of appropriate investors such as business angels, VCFs, and so on.

3.1. The variables and general settings for the proposed mechanism

In this section, the accepted principles such as; staged financing [27, 46, 48], the possibility of abandonment of the investment in ventures with low-efficient at any stage of growth, and the possibility of entrance of a new and appropriate investor in each stage of financing [19, 27, 30, 49] are used to arrange the general settings for the proposed mechanism. In this way, the entrepreneur has a right to opt-out the previous investor and opt the new investors for the next stage of financing and also investor has the options to continue or abandon the next stage of financing. Furthermore, it is necessary to determine the stages of venture financing, which in some studies have been indicated to different stages [5, 46, 50, 51]. This research has taken into account three stages of financing, though, depending on the conditions of the venture and according to the agreed contract between the entrepreneur and investor, this mechanism allows deciding on the number of stages. In addition, although the initial public offering (IPO) is represented as the exit way of the investor in Figure 2, parties can agree on the other ways of exit such as the sale of equities to a bigger company and so on. In this regard, the variables are indicated in Figure 2, which are defined as follows.

- The sum of investment amount and the cost of advisory services (I) in each stage.
- Time period (n) of each stage
- The venture's agreed value between the entrepreneur and investor as ex-ante value (V_A)
- The venture's real value as ex-post value (V_R) for each stage.

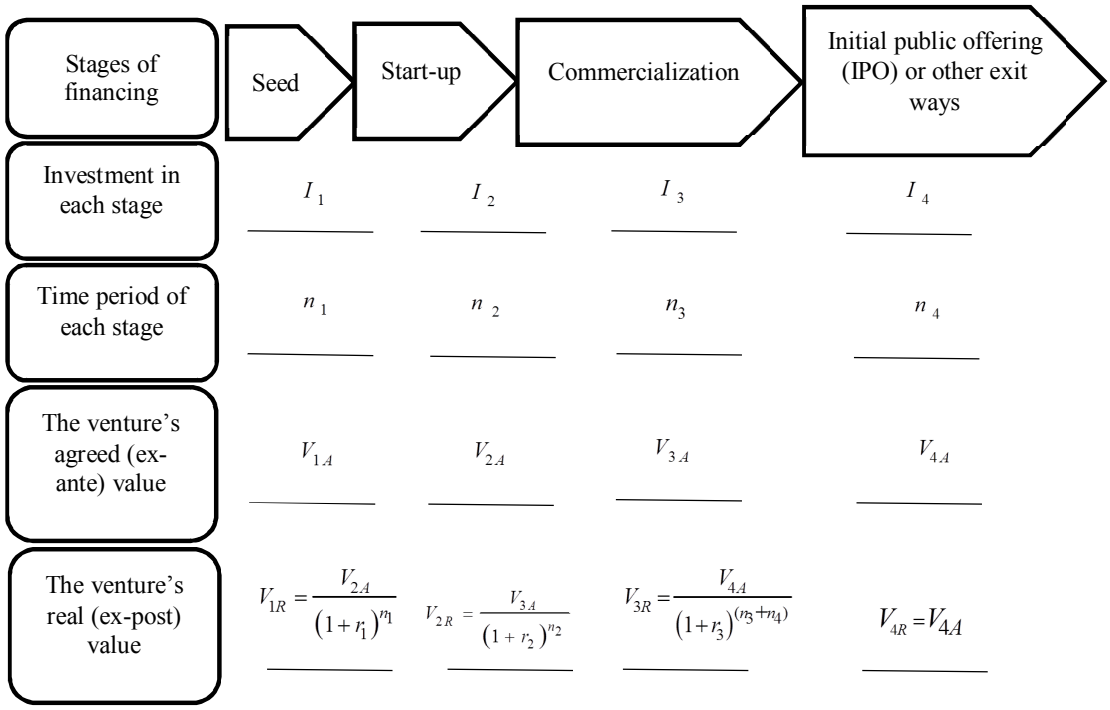

Fig. 2. Stages of financing and related variables to set the proposed mechanism.

During the implementation of this mechanism and for each stage, the venture's agreed (ex-ante) value is estimated according to the guides of both parties and determined with the final comment of the investor. Furthermore, the venture's real (ex-post) value of each stage, can be calculated through the net present value (NPV) of related ex-ante value in the next stage according to the investor's expected discount rate (r). It should be noted that the related investor has the right to determine the venture's ex-ante value in each stage and must declare his (or her) expected discount rate in the agreed contract. In return, the entrepreneur also can choose the related investor or search for a more desired one. Logically, the entrepreneur investigates the existing investors with their different expected discount rates and capabilities, and opt-out of them in cases with high irrational discount rates. Vividly, the conflict between the investor and entrepreneur is always based on the estimation of the venture's cash flow, which leads to the estimation of the venture's value and affects both parties' incentives and efforts, so that investors tend to underestimate and entrepreneurs tend to overestimate it. In this way, both parties after a period of time between the next and previous stages can find out the difference ratio between the venture's ex-post and ex-ante values in each stage of financing. As depicted in Figure 2, it is clear that the venture's ex-post value in the exit stage equals the ex-ante value achieved in the market via initial public offering, the sale of equities to a bigger company, or other exit ways.

Considering the two first stages of the proposed mechanism in Figure 2, variables and equations from (1) to (6) have been defined as follows, which can be expanded to all stages.

V_{1A}= The venture's agreed (ex-ante) value between investor and entrepreneur in the first stage of financing.

V_{2A}= The venture's agreed (ex-ante) value between investor and entrepreneur in the second stage of financing.

V_{1R}= The venture's real (ex-post) value in the first stage of financing.

$$V_{1R}=\frac{V_{2A}}{(1+r_1)^{n_1}} \rightarrow V_{2A}=V_{1R}(1+r_1)^{n_1} \quad (1)$$

I_1= The total amount of investment and the cost of advisory services for the first investor in the first stage of financing.

I_2= The total amount of investment and the cost of advisory services for the second investor in the second stage of financing.

n_1= The time period in the first stage of financing.

α_{VC11A}= The amount of equity devoted to the first investor in the first stage of financing based on the ex-ante value in this stage.

$$\alpha_{VC11A} = \frac{I_1}{V_{1A}} \tag{2}$$

α_{E1A}= The amount of equity devoted to the entrepreneur in the first stage of financing based on the ex-post value in this stage.

$$\alpha_{E1A} = 1 - \alpha_{VC11A} \tag{3}$$

α_{VC11R}= The amount of equity which can be devoted to the first investor in the first stage of financing if the ex-post value is determined.

$$\alpha_{VC11R} = \frac{I_1}{V_{1R}} = \frac{I_1}{\frac{V_{2A}}{(1+r_1)^{n_1}}} \tag{4}$$

α_{E1R}= The amount of equity which can be devoted to the entrepreneur in the first stage of financing if the ex-post value is determined.

$$\alpha_{E1R} = 1 - \alpha_{VC11R} \tag{5}$$

α_{VC22A}= The amount of equity devoted to the second investor in the second stage of financing based on the ex-ante value in this stage.

$$\alpha_{VC22A} = \frac{I_2}{V_{2A}} \tag{6}$$

3.2. The investor's and entrepreneur's payoff functions without the proposed mechanism

In order to measure the capability of the proposed mechanism, both parties' payoffs must be calculated without applying the mentioned mechanism and then be compared with the related payoffs after applying it. Before the mechanism is applied, both parties' payoffs are obtained based on their equity according to the ex-ante value at that stage. In the absence of the mentioned mechanism and for the two first stages, both parties' payoff functions are described in equations (7) to (9).

$$\text{Payoff}_{VC12A} = (\alpha_{VC11A} - (\alpha_{VC11A} \times \alpha_{VC22A})) \times V_{2A} = -\frac{I_1\left(-(1+r_1)^{n_1} V_{1R} + I_2\right)}{V_{1A}} \tag{7}$$

$$\text{Payoff}_{VC22A} = (\alpha_{VC22A}) \times V_{2A} = I_2 \tag{8}$$

$$\text{Payoff}_{E2A} = \left(1 - ((\alpha_{VC11A} - (\alpha_{VC11A} \times \alpha_{VC22A})) + (\alpha_{VC22A}))\right) \times V_{2A} = \frac{(I_1 - V_{1A})\left(-(1+r_1)^{n_1} V_{1R} + I_2\right)}{V_{1A}} \tag{9}$$

3.3. The investor's and entrepreneur's payoff functions by applying the proposed mechanism

In order to apply the proposed mechanism, the negative and positive adjustment are used to adjust the equity of the parties in the next (second) stage of financing. In this way, if the investor underestimates the venture's ex-ante value, he (she) will be adjusted in the proportion of the difference between the ex-post and ex-ante value, and mentioned mechanism acts to more dilution of investor's equity in the second stage so that the variables and both parties' payoff functions at the beginning of the second stage are determined through the equations (10) to (15). Vice versa, if the venture's ex-post value be achieved less than the ex-ante value, the investor's equity will be adjusted via rewarding in the second stage in a proportion of the difference between the ex-ante and ex-post value, then his (her) equity will be diluted less compared to the condition that the mentioned mechanism is not applied. Thus, the entrepreneur will be adjusted via more dilution of his (her) equity, therefore the variables and equations (16) to (21) are used to determine both parties' payoff functions.

If $V_{1A} < V_{1R}$

Y_1= The difference between the equity amount of the first investor in the first stage of financing on the basis of ex-ante and ex-post values.

$$Y_1 = \alpha_{VC11A} - \alpha_{VC11R} \quad (10)$$

W_1= The difference ratio between the ex-post and ex-ante value in the first stage of financing.

$$W_1 = \frac{V_{1R} - V_{1A}}{V_{1A}} = \frac{\frac{V_{2A}}{(1+r_1)^{n1}} - V_{1A}}{V_{1A}} \quad (11)$$

P_2= The amount of further dilution of the investor's equity at the initiation of the second stage of financing as a negative adjustment.

$$P_2 = W_1 * Y_1 \quad (12)$$

$$\text{Payoff}_{VC12R} = ((\alpha_{VC11A} - P_2) - (\alpha_{VC11A} \times \alpha_{VC22A})) \times V_{2A} = -\frac{I_1\left((V_{1A}{}^2 - 3V_{1R}V_{1A} + V_{1R}{}^2)(1+r_1)^{n_1} + I_2V_{1A}\right)}{V_{1A}{}^2} \quad (13)$$

$$\text{Payoff}_{VC22A} = (\alpha_{VC22A}) \times V_{2A} = I_2 \quad (14)$$

$$\text{Payoff}_{E2R} = \left(1 - \left(((\alpha_{VC11A} - P_2) - (\alpha_{VC11A} \times \alpha_{VC22A})) + (\alpha_{VC22A})\right)\right) \times V_{2A} \quad (15)$$

$$= \frac{((I_1 + V_{1R})V_{1A}{}^2 - 3I_1V_{1R}V_{1A} + I_1V_{1R}{}^2)(1+r_1)^{n_1} + I_2V_{1A}(I_1 - V_{1A})}{V_{1A}{}^2}$$

If $V_{1A} > V_{1R}$

K_1= The difference between the equity amount of the first investor in the first stage of financing on the basis of the ex-post and ex-ante values.

$$K_1 = \alpha_{VC11R} - \alpha_{VC11A} \quad (16)$$

L_1= The difference ratio between the ex-ante and ex-post value in the first stage of financing.

$$L_1 = \frac{V_{1A} - V_{1R}}{V_{1R}} = \frac{V_{1A} - \frac{V_{2A}}{(1+r_1)^{n_1}}}{V_{1R}} \quad (17)$$

R_2= The amount of less dilution of the investor's equity at the initiation of the second stage of financing as a positive adjustment.

$$R_2 = L_1 * K_1 \quad (18)$$

$$\text{Payoff}_{VC12R} = ((\alpha_{VC11A} + R_2) - (\alpha_{VC11A} \times \alpha_{VC22A})) \times V_{2A} \quad (19)$$

$$= -\frac{I_1\left((-V_{1A}{}^2 + 2V_{1A}V_{1R} - 2V_{1R}{}^2)(1+r_1)^{n_1} + I_2V_{1R}\right)}{(V_{1R}V_{1A})}$$

$$\text{Payoff}_{VC22A} = (\alpha_{VC22A}) \times V_{2A} = I_2 \quad (20)$$

$$\text{Payoff}_{E2R} = \left(1 - \left(((\alpha_{VC11A} + R_2) - (\alpha_{VC11A} \times \alpha_{VC22A})) + (\alpha_{VC22A})\right)\right) \times V_{2A} \quad (21)$$

$$= \frac{\left((-2I_1 + V_{1A})V_{1R}{}^2 + 2I_1V_{1R}V_{1A} - I_1V_{1A}{}^2\right)(1+r_1)^{n_1} + I_2V_{1R}(I_1 - V_{1A})}{(V_{1R}V_{1A})}$$

4. Model Analysis

Regarding the mentioned payoffs' functions in the previous section for with and without the applying of proposed mechanism, in this section, through three ways of 1) mathematical analysis, 2) drawing its curves for a case study and 3)

comparing the proposed mechanism with the convertible preferred equity mechanisms.

4.1. Mathematical analysis to describe the functions' curves of parties' payoffs

In this section, through the mathematical rules, the behavior of the functions' curves of both parties' payoffs before and after applying the proposed mechanism has been analyzed and illustrated. Hence, through mathematical rules especially the first and the second derivative tests, we can find out the maximum, minimum or inflection points of the mentioned functions' curves. Moreover, we investigate if the curve is ascending or descending in the intended interval in which the behavior of the mentioned function's curve is imaginable generally and parametrically.

4.1.1. Mathematical analysis to describe the functions' curves of both parties' payoffs without applying the proposed mechanism

The first and second derivatives of the investor's and the entrepreneur's payoff functions without applying the proposed mechanism are indicated in equations (22) and (23). Based on the first derivative test of the investor's payoff function shown that the function's slope equals to $((1+r_1)^{n1} I_1)/V_{1A}$. Thus, the curve' slope is positive and constant so its second derivative is equal to zero which indicates the mentioned function curve is ascending and linear. Moreover, the equation (23) indicates that according to the first derivative of the entrepreneur's payoff function, the slope of its curve is constant and equal to $((V_{1A} - I_1)(1+r_1)^{n1})/V_{1A}$ and its second derivative is equal to zero which means the function curve is linear. In addition, since the venture's agreed value logically should be more than the investment amount at each stage of financing ($V_{1A} > I_1$) for achieving the venture to economic feasibility, so without applying the mentioned mechanism, the curve' slope of the entrepreneur's payoff function is positive and its curve is ascending.

$$\text{Payoff}_{VC12A} = -\frac{I_1\left(-(1+r_1)^{n_1}V_{1R} + I_2\right)}{V_{1A}} \rightarrow (\text{Payoff}_{VC12A})' = \frac{I_1(1+r_1)^{n_1}}{V_{1A}} \rightarrow (\text{Payoff}_{VC12A})'' = 0 \quad (22)$$

$$\text{Payoff}_{E2A} = \frac{(I_1 - V_{1A})\left(-(1+r_1)^{n_1}V_{1R} + I_2\right)}{V_{1A}} \rightarrow (\text{Payoff}_{E2A})' = \frac{(V_{1A} - I_1)(1+r_1)^{n_1}}{V_{1A}}$$
$$\rightarrow (\text{Payoff}_{E2A})'' = 0 \quad (23)$$

4.1.2. Mathematical analysis to describe the functions' curves of both parties' payoffs with applying the proposed mechanism

4.1.2.1. Mathematical analysis to describe the functions' curves of investor's payoff with applying the proposed mechanism

Where $V_{1A} < V_{1R}$ and through applying the proposed mechanism, the first and the second derivatives of the investor's payoff function are indicated in equations (24) and (25). As described in the equation (24), if we put the first derivative of the investor's payoff function equal to zero, the root of $V_{1R} = (3V_{1A})/2$ will be obtained which means the mentioned function curve is non-linear and its derivative amount (slope) in the above-mentioned root is equal to zero. According to equation (25), it is clear that for all values of I_1, V_{1A}, n_1, $r_1 > 0$, the second derivative of the function is always negative which means in the interval of $V_{1A} < V_{1R}$ the curve is concave downward. Hence, the function has the local maximum at the mentioned root.

$$\text{If} \quad V_{1A} < V_{1R} \rightarrow \text{Payoff}_{VC12R} = -\frac{I_1\left((V_{1A}{}^2 - 3V_{1R}V_{1A} + V_{1R}{}^2)(1+r_1)^{n_1} + I_2 V_{1A}\right)}{V_{1A}{}^2} \tag{24}$$

$$\rightarrow (\text{Payoff}_{VC12R})' = -\frac{I_1(-3V_{1A} + 2V_{1R})(1+r_1)^{n_1}}{V_{1A}{}^2}$$

$$\text{If} \quad (\text{Payoff}_{VC12R})' = 0 \rightarrow V_{1R} = \frac{3V_{1A}}{2}$$

$$(\text{Payoff}_{VC12R})'' = -\left(\frac{2I_C(1+r_c)^{n_c}}{V_{CA}{}^2}\right) \text{and} \quad \text{It is clear} \quad \forall I_1, V_{1A}, n_1, r_1 > 0 \rightarrow (\text{Payoff}_{VC12R})'' < 0 \tag{25}$$

Where $V_{1A} > V_{1R}$, the first and the second derivatives of the investor's payoff function with applying the proposed mechanism are calculated by equations (26) and (27). As presented in equation (26), if we put the first derivative of the investor's payoff function equals to zero, the root of $V_{1R} = (\sqrt{2}V_{1A})/2$ is obtained that shows the function is nonlinear and in the mentioned root, its derivative (slope) is equal to zero. According to equation (27), the second derivative value is always positive for all the values of I_1, V_{1A}, V_{1R}, n_1, $r_1 > 0$, which means the second derivative of the mentioned function is always positive for the specified interval, consequently, it means the function curve is concave upward and has a local minimum point in the relevant root.

$$\text{If} \quad V_{1A} > V_{1R} \rightarrow \text{Payoff}_{VC12R} = -\frac{I_1\left((-V_{1A}{}^2 + 2V_{1A}V_{1R} - 2V_{1R}{}^2)(1+r_1)^{n_1} I_1 + I_2 V_{1R}\right)}{V_{1R}V_{1A}} \tag{26}$$

$$\rightarrow (\text{Payoff}_{VC12R})' = -\frac{I_1(1+r_1)^{n_1}(V_{1A}{}^2 - 2V_{1R}{}^2)}{V_{1R}{}^2 V_{1A}}$$

$$\text{If} \quad (\text{Payoff}_{VC12R})' = 0 \rightarrow V_{1R} = \frac{\sqrt{2}V_{1A}}{2}$$

$$(\text{Payoff}_{VC12R})'' = \frac{2V_{1A}I_1(1+r_1)^{n_1}}{V_{1R}{}^3} \text{and} \quad \text{It is clear} \quad \forall I_1, V_{1A}, V_{1R}, n_1, r_1 > 0 \rightarrow (\text{Payoff}_{VC12R})'' > 0 \tag{27}$$

Furthermore, the direction of the mentioned function changes around the $V_{1R}=V_{1A}$, consequently, this point mathematically is called the inflection point. The changes of the sign in the inflection point are seen by using sensitivity analysis for the second derivative of that function and by taking into account the $V_{1R}=V_{1A} \pm \varepsilon$, $\varepsilon=1\times10^{-15}$. It is found the direction of this function curve changes in the neighborhood of inflection point from positive to negative. The relevant sensitivity analysis by Maple software indicates that the function's curve of the investor's payoff by using the proposed mechanism in $V_{1R}<V_{1A}$ is concave upward and in $V_{1R}>V_{1A}$ is concave downward.

As illustrated in the equation (28), if we put the investor's payoff function equal to zero in the mode that we apply the mentioned mechanism, its intersection point with the horizontal axis is obtained as follow:

$$\text{If} \quad Payoff_{VC12R} = 0 \rightarrow V_{1R} = \frac{3(1+r_1)^{n_1} V_{1A} + \sqrt{5\left((1+r_1)^{n_1}\right)^2 V_{1A}{}^2 - 4I_2(1+r_1)^{n_1} V_{1A}}}{2(1+r_1)^{n_1}} \tag{28}$$

Concretely, the function' curve is ascending until the maximum point of $V_{1R} = (3V_{1A})/2$ and from this point onwards due to the error of more than 50% in estimating the venture's ex-post value, the investor's payoff not only increases but also decreases until the point calculated via equation (28) which it approaches zero. It is worth mentioning that as long as the venture's estimation error is less than 50%, in order to motivate the investor, the function is still ascending with a decreasing rate. Nevertheless, if the above-mentioned error is more than 50%, the function's curve of the investor's payoff is not ascending and is descending, that from this point onward, the investor not only is adjusted but also is punished until the investor gains no payoff in

the point calculated via the equation (28) and all the payoff will be devoted to the entrepreneur.

4.1.2.2. Mathematical analysis to describe the function's curve of entrepreneur's payoff with applying the proposed mechanism

Where $V_{1A}<V_{1R}$ and $V_{1A}>V_{1R}$, the first derivative of the entrepreneur's payoff function after applying the proposed mechanism is obtained through equations (29) and (30). According to calculations in Maple, if we put the first derivative of the entrepreneur's payoff function equal to zero, the function neither has a root nor has extremum (minimum or maximum) points although it is non-linear. Moreover, by sensitivity analysis via the above-mentioned software, it was found that if we increase the value of V_{1R}, the function's curve of entrepreneur's payoff is ascending. Here, due to the lack of enough space, the figures and calculations are not mentioned.

(29)

$$\text{If} \quad V_{1A}<V_{1R} \rightarrow \text{Payoff}_{E2R}=\frac{\left((I_1+V_{1R})V_{1A}^{\,2}-3I_1V_1V_{1A}+I_1V_{1R}^{\,2}\right)(1+r_1)^{n_1}+I_2V_{1A}(I_1-V_{1A})}{V_{1A}^{\,2}}$$

$$\rightarrow(\text{Payoff}_{E2R})'=\frac{(-3I_1V_{1A}+2I_1V_{1R}+V_{1A}^{\,2})(1+r_1)^{n_1}}{V_{1A}^{\,2}}$$

$$\rightarrow(\text{Payoff}_{E2R})'=0\rightarrow no \quad answer$$

(30)

$$\text{If} \quad V_{1A}>V_{1R} \rightarrow \text{Payoff}_{E2R}=\frac{\left((-2I_1+V_{1A})V_{1R}^{\,2}+2I_1V_{1R}V_{1A}-I_1V_{1A}^{\,2}\right)(1+r_1)^{n_1}+I_2V_{1R}(I_1-V_{1A})}{V_{1R}V_{1A}}$$

$$\rightarrow(\text{Payoff}_{E2R})'=\frac{(1+r_1)^{n_1}(I_1V_{1A}^{\,2}-2I_1V_{1R}^{\,2}+V_{1A}V_{1R}^{\,2})}{V_{1A}V_{1R}^{\,2}}$$

$$\rightarrow(\text{Payoff}_{E2R})'=0\rightarrow no \quad answer$$

Moreover, where $V_{1A}<V_{1R}$, according to the equation (31), the second derivative value for all values of the input variables (I_1, V_{1A}, n_1, $r_1>0$) is always positive. It means the curve is concave upward in the intended interval. Furthermore, if $V_{1A}>V_{1R}$, according to the equation (32), the second derivative value for all values of the input variables (I_1, V_{1A}, V_{1R}, n_1, $r_1>0$) is always negative, which means the curve is concave downward in the intended interval.

(31)

$$\text{If} \quad V_{1A}<V_{1R} \rightarrow (\text{Payoff}_{E2R})''=\frac{2I_1(1+r_1)^{n_1}}{V_{1A}^{\,2}} \; and \quad It \quad is \quad clear \forall I_1,V_{1A},n_1,r_1>0 \rightarrow (\text{Payoff}_{E2R})''>0$$

(32)

$$\text{If} \quad V_{1A}>V_{1R} \rightarrow (\text{Payoff}_{E2R})''=-\left(\frac{2V_{1A}I_1(1+r_1)^{n_1}}{V_{1R}^{\,3}}\right) \xrightarrow{It \quad is \quad clear \forall I_1,V_{1A},V_{1R},n_1,r_1>0} (\text{Payoff}_{E2R})''<0$$

As denoted in equation (33), by putting the entrepreneur's payoff function equal to zero via applying the proposed mechanism, its intersection with the horizontal axis is calculated as below that entrepreneur's payoff in this point is zero and all the payoff gained from investment and partnership in this stage is devoted to the investor.

$$If \quad Payoff_{E2R} = 0 \rightarrow V_{1R} = \frac{1}{2(2I_1 - V_{1A})(1+r_1)^{n_1}} \left(\begin{array}{l} 2I_1 V_{1A}(1+r_1)^{n_1} + I_1 I_2 - I_2 V_{1A} - \\ \sqrt{\begin{array}{l} -4{I_1}^2\left((1+r_1)^{n_1}\right)^2 {V_{1A}}^2 + \\ 4I_1\left((1+r_1)^{n_1}\right)^2 {V_{1A}}^3 + \\ 4{I_1}^2 I_2 (1+r_1)^{n_1} V_{1A} - \\ 4I_1 I_2 (1+r_1)^{n_1} {V_{1A}}^2 \\ +{I_1}^2 {I_2}^2 - 2I_1 {I_2}^2 V_{1A} + {I_2}^2 {V_{1A}}^2 \end{array}} \end{array} \right) \quad (33)$$

4.2. Describing the proposed mechanism with a case study

In order to better illustration of the proposed mechanism and actualize the mathematical analysis in the previous section, the functions' curves of the investor's and the entrepreneur's payoffs before and after the proposed mechanism have been drawn and analyzed with a case study of one venture in the field of Nanotechnology, which have been financed through VCF. Thus, the needed information for the analysis of the mentioned case study indicated in Table 1. In this regard, the total amount of investment and the cost of advisory services for the first and second investor in the first and second stage of financing (I_1 and I_2), the venture's ex-ante value between the investor and entrepreneur in the first stage of financing (V_{1A}), and the time period in the first stage of financing (n_1) have been represented. Considering the implementation of this mechanism for the initial stages of financing in the case study, It is obvious that the discount rate in these stages is higher than the final stages of financing ($r_1 > r_2 > \ldots > r_n$). Consequently, according to the factors such as; the weighted average cost of capital, the risk rate of the venture, and the default rate of financing during the previous years, the investor's expected discount rate in the first stage of financing (r_1) have been obtained and agreed equal to 0.58.

Tab. 1. Variables' value of a case study to describe the proposed mechanism (numbers in dollars)

I_1	I_2	V_{1A}	n_1	r_1
50000	100000	205455	1	0.58

Based on the placement of the variables' values of the Table 1 in equations (7), (9), (13), (15), (19) and (21), then the equations from (34) to (37) are obtained. They respectively indicate both parties' payoff functions before and after applying the mentioned mechanism, which as illustrated in Figure 3, the curves of the above functions have been drawn by Maple software 2019.

$$Payoff_{E2A} = \begin{cases} 1.195487576V_{1R} - \dfrac{3109100000}{41091} & V_{1R} \le 205455 \\ 1.195487576V_{1R} - \dfrac{3109100000}{41091} & V_{1R} > 205455 \end{cases} \quad (34)$$

$$Payoff_{VC12A} = \begin{cases} 0.3845124236V_{1R} - \dfrac{1000000000}{41091} & V_{1R} \le 205455 \\ 0.3845124236V_{1R} - \dfrac{1000000000}{41091} & V_{1R} > 205455 \end{cases} \quad (35)$$

$$Payoff_{E2R} = \begin{cases} \dfrac{166618.90{V_{1R}}^3 - 3.334728805*10^{15}V_{1R} + 1.691639000*10^9{V_{1R}}^2}{205455{V_{1R}}^2} & V_{1R} \le 205455 \\ \dfrac{1.800174109*10^{10}{V_{1R}}^2 + 79000{V_{1R}}^3 - 1.40828103*10^{14}V_{1R}}{42211757025V_{1R}} & V_{1R} > 205455 \end{cases} \quad (36)$$

$$Payoff_{VC12R} = \begin{cases} \dfrac{158000V_{1R}^{\ 3} + 3.334728805*10^{\ 5}V_{1R} - 3.746189000*10^{10}V_{1R}^{\ 2}}{205455V_{1R}^{\ 2}} & V_{1R} \le 205455 \\ \dfrac{4.869283500*10^{10}V_{1R}^{\ 2} - 79000V_{1R}^{\ 3} - 4.362003805*10^{15}V_{1R}}{42211757025V_{1R}} & V_{1R} > 205455 \end{cases} \quad (37)$$

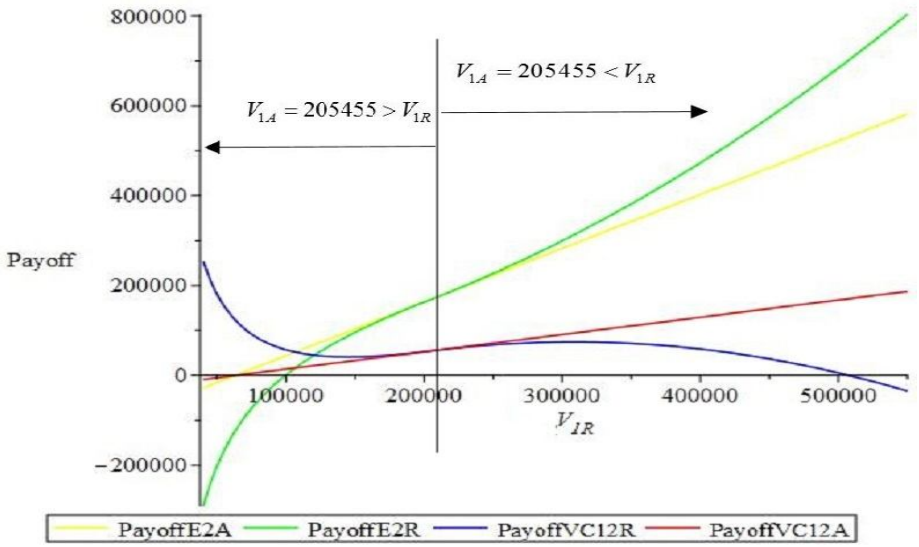

Fig. 3. The curves of investor's and entrepreneur's payoff functions before and after applying the proposed mechanism.

As illustrated in Figure 3, the function's curve of the entrepreneur's payoff without applying the proposed mechanism is linear and ascending, which is denoted with the yellow color and its characteristics are observable as we have found out in the mathematical analysis section. Moreover, the function's curve of the entrepreneur's payoff after applying the proposed mechanism is denoted by green color which means the function is non-linear and ascending and also as it was proved in the section of the mathematical model, the inflection point is $V_{1R}=V_{1A}$. It is worth mentioning that according to Figure 3 and the implemented mathematical analysis in the previous section of this paper, the function's curve of the entrepreneur's payoff after applying the mechanism for values of $V_{1A}=205455<V_{1R}$ is concave upward and for values of $V_{1A}=205455>V_{1R}$ is concave downward. Through the curve analysis we concluded that if the venture's value is underestimated by the investor, as a result, the obtained amount of the venture's ex-post value is more than the amount of the venture's ex-ante value ($V_{1A}=205455<V_{1R}$). In fact, through applying the proposed mechanism, the investor will be adjusted in the way that during the equity dilution of parties in the second (next) stage of financing, the investor's equity will be diluted more in comparison with the condition that the proposed mechanism is not applied and also the entrepreneur will be rewarded via less dilution of his (her) equity in a proportion of the difference between the ex-post and the ex-ante value. Therefore, the entrepreneur's payoff at any point of the function' curve in this interval is more than the condition of not applying the mechanism. Thereby, this mechanism gives the entrepreneur the incentive for more effort in order that the venture's ex-post value will be more as much as possible than the ex-ante value between them. As a result, during the equity dilution in the second (next) stage of financing compared to the condition of not applying the mechanism, the less amount of equity will be diluted from the entrepreneur. Thereby, if the obtained ex-post value gets less than the venture's ex-ante value ($V_{1A}=205455>V_{1R}$), vividly, either the entrepreneur has concealed his private information or has not put enough effort into the development of his idea in a high-quality level that the ex-post value is lower than the ex-ante value. So, for this part of the graph that $V_{1A}=205455>V_{1R}$, the entrepreneur's payoff decreases even it gets less than the condition of not applying the mechanism. It indicates that due to the above reasons, the entrepreneur has been adjusted and compared to the situation that the

proposed mechanism was not applied, more equities will be diluted from him (her). The curve is descending, which based on the mathematical analysis and the indicated equation (33) in the previous section, the entrepreneur's payoff as is shown in Figure 3 is declining until in the point of V_{1R} =99540 dollars will be equal to zero, and all shared payoff that is equal to about 52272 dollars, will be devoted to the investor. Therefore, if the venture's ex-post value gets less than the ex-ante value, lower than the particular point of (V_{1R} =99540), the entrepreneur will be punished and no payoff will be devoted to him.

The behavior analysis of the investor's functions curve before and after the applying of the proposed mechanism is the opposite of the behavior analysis of the entrepreneur's functions curve. As represented in Figure 3, the red curve is related to the investor's payoff function before applying the mechanism and the blue curve is related to the investor's payoff function after applying the mechanism. The investor will be adjusted in the interval of V_{1A} =205455<V_{1R} for the underestimation of the venture's value. As it is indicated in Figure 3, from the point of V_{1R}=V_{1A}, the function's curve is ascending with a decreasing rate up to the point of V_{1R}=308182.5 dollars as a local maximum of the curve, which has been obtained from equation (24). From this point onward, the error of the venture's value estimation exceeds 50 percent and the mentioned function gets descending and according to Figure 3 in the point of V_{1R}= 507585 dollars which is obtained from the equation (28), the investor's payoff is equal to zero. Hence, the total amount of mentioned payoff that is almost 701984 dollars will be devoted to the entrepreneur. Actually, if the estimated venture's ex-ante value be much less than the ex-post value, from the point of (V_{1R}= 507585 dollars), the investor will be severely punished and no payoff will be devoted to him (her).

Taking all of these into account, applying such a mechanism will encourage the investor and the entrepreneur to strive for achieving greater value for the venture. Furthermore, if the each of them tries to conceal his (her) private information and deceive the other party, and hence possess more equity from the venture, then the proposed mechanism adjusts or even severely punishes him (her) until no payoff will be devoted to the deceiving party. Therefore, both parties' incentive for an opportunistic behavior will be alleviated and they will be motivated to reveal the private information and put more effort through applying this mechanism.

4.3. The proposed mechanism versus the convertible preferred equity mechanisms

Some scholars have described the mechanisms of convertible preferred equity, which according to the authors' opinion, the research conducted by Hellmann [52] best has investigated and introduced the mentioned mechanisms. Explicitly, Figures 4 and 5, which are extracted from the mentioned research, illustrate the functions' curves of simple and participating convertible preferred equity mechanisms. Comparing both mentioned mechanisms with this paper's proposed mechanism, it is indicated that they took into account redemption value and vividly, cover the investor's risk even if the minimum expected value of the venture is not being reached. Furthermore, if the venture's ex-post value increases, the investor through converting his preferred equity to public equity with the determined ratio of (e), will be benefited from the value-added in the venture's value anyway. Thereby, the convertible preferred equity mechanisms are further in favor of the investor and give the entrepreneur less motivation for more effort. In this way, the entrepreneur's incentive to put more effort is solely related to the redemption of the transferred equities during the initial public offering as the exiting stage of the investor for possessing the managerial stocks and achieving to venture's control rights. Moreover, the two mentioned mechanisms comparing with the proposed mechanism in this paper do not prevent the incentive of opportunistic behavior and do not contribute to revealing private information. In addition, both parties' payoffs are linear but in the mechanism presented in this paper, both parties' payoffs are non-linear and can be calculated for any points of the obtained ex-post value.

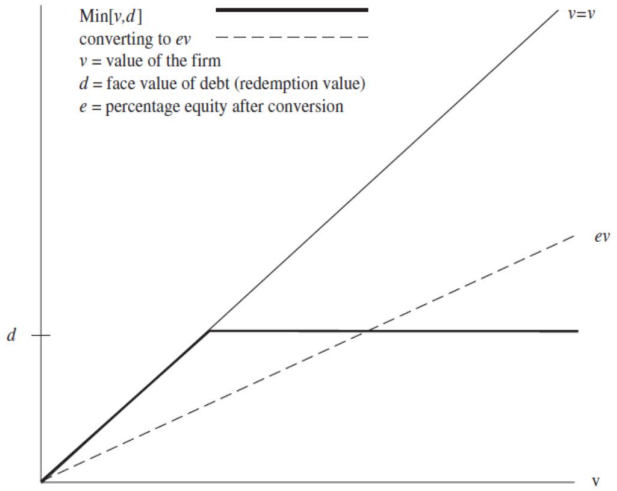

Fig. 4. Simple convertible preferred equity [52].

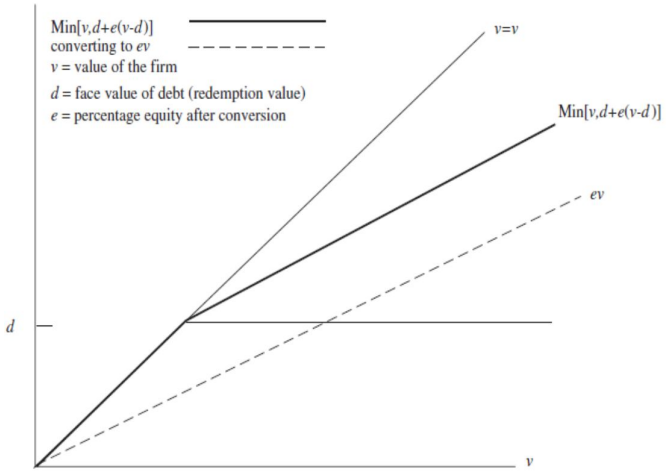

Fig. 5. Participating convertible preferred equity [52].

4.4. Experts' opinions about the proposed mechanism

In order to assess the validity of the proposed mechanism from the perspective of its applicability in the venture capital environment, in addition to illustrating via case study and also comparison with the convertible preferred equity mechanisms, the authors interviewed several experts working in the VCFs and famous related organizations in Iran such as the Nano Fund, Iran Nanotechnology Innovation Council (INIC) and Innovation and Prosperity Fund on the one hand and some entrepreneurs as the owner of technology-based firms on the other. All the experts and entrepreneurs endorsed the mechanism in terms of innovation and practicability and described it as interesting. Some of the experts suggested to authors publishing it as a paper to protect the authors' intellectual property and then run this mechanism in their VCFs through setting up the related contracts so that its deficiencies can be identified over time. The interviewed entrepreneurs also considered this mechanism fair and stated that its implementation would lead to more willingness and participation of entrepreneurs.

It should be noted some experts emphasized to pay particular attention to control rights such as the right to change the CEO in the related contracts as too mentioned by several authors [36, 53, 54]. Although the entrepreneurs like to enjoy the private benefits as the CEO of a venture [52, 55], nevertheless experts believe most of the entrepreneurs initially are not familiar with the legal, financial, organizational, managerial and marketing affairs. As a result, the control rights must not be transferred to them as much as possible in the early stage of ventures' growth. Moreover, they proposed to include clauses in the related contracts in order to prevent the entrance of new nominal investors with opportunistic behavior in high and unrealistic valuation and

consequently the less dilution of the entrepreneur's equity in later stages. They recommended a minimum deal of 10 percent equity for the entrance of a new investor, in which the agreed value will be real and acceptable to the previous investors. Furthermore, the above mentioned 10 percent can be determined by the agreement of the parties at each stage.

5. Conclusions and Future Directions

The optimal ownership sharing between the investor and entrepreneur is one of the major challenges during the venture capital financing which affects the parties' incentives for more effort. Through the literature review and to the best of authors' knowledge, there has not been developed any practical mechanism for equity sharing in VC financing up to now, which using different kinds of convertible preferred equity mechanisms is solely common and applicable for mitigating the moral hazard. In this regard, during the usage of the mentioned mechanisms, in a situation that ex-post value is lower than the expected value, the investor can convert his (her) preferred equity to debt and cover the risk by applying the redemption right. Moreover, in a situation that the venture's ex-post value is more than the expected value, the investor can convert his (her) preferred equity to common equity and benefit the value-added with a predetermined coefficient (e). Concretely and as the previous authors also stated, the mentioned mechanisms are further in favor of the investor and they give less motivation to the entrepreneur for more effort. As a result, a fair equity sharing mechanism proposed in this paper that the authors call it "Fair-Sharing Mechanism". This mechanism mitigates the aforementioned deficiencies and leads to incentivize both sides, to be honest, and reveal their private information for achieving the more accurate estimation of the venture's value, to cooperate in each stage of the venture's growth, even at the early stages of growth. Furthermore, it results in diminishing the incentive of opportunistic behavior and also align both parties' interests for further efforts to decline the moral hazard by adjusting the parties' equity during the equity dilution in each stage of financing. Besides, it manages uncertainty by applying the staged financing and the option of abandonment at the end of each stage. Finally, the mathematical rules and a case study have been used to analyze the related functions of this mechanism and also its advantages have been proved in comparison with the mechanisms of convertible preferred equity and by considering the experts' opinions.

As a subject for future research, investigating the results of the proposed mechanism in several real cases is recommended. In doing so, its shortcomings will appear to eliminate them. Besides, its implementation leads to measuring its effect on the development of venture capital financing and also considering the motivation of investors and entrepreneurs for further participation via this mechanism. Moreover, by considering the project with high uncertainty, the ex-post value may exceed much more than the ex-ante value, somehow it is not logical to punish the investor and put his (her) payoff equal to zero if he (she) surpasses the determined value in equation (28). As a result, future research with regard to the ventures with high uncertainty in developing countries can present a new mechanism that does not put the investor's payoff equal to zero completely and compare its advantages with the proposed mechanism of this paper from the point of view of investors and entrepreneurs. It shows which mechanism will lead more to parties' partnership and development of venture capital financing in developed and developing countries separately. Finally, combining the proposed mechanism with real options analysis can lead to its development in accordance with specific circumstances.

Data availability

The Maple Codes used to support the findings of this study are available from the corresponding author upon request.

Conflicts of interest

The authors declare no conflict of interest regarding the publication of this paper.

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Supplementary materials

This manuscript is included a supplementary material file which entailed three Maple code files for the section of 4.2 in the manuscript as fallow:

- The first file is related to Maple codes for drawing the curves of investor's and entrepreneur's payoff functions.
- The second file is related to Maple codes for determining the intersection of the entrepreneur graph with the x-axis.

- The third file is related to Maple codes for determining the intersection of investor graph with x-axis

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