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Venture Capitalists Investment Incentives Under Public Equity Schemes

by

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Abstract

This paper analyses the impact of public equity schemes on venture capitalist's incentives to finance start-up enterprises and to support the management teams. In a double-sided moral hazard model, it is shown that experienced venture capitalists, who have already financed start-up enterprises, reduce their intensity of management support under public equity schemes. However, public equity offers inexperienced venture capitalists, who have not yet financed start-up enterprises because of insufficient experience, incentives to enter the venture capital market so that they can start to accumulate experience.

Keywords: Double-sided moral hazard, public equity, venture capital

JEL classification: D82, G24, G28, L14

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1 Introduction

Several European governments have started to support venture capital investments in young high-technology enterprises (OECD 1997, Lessat et al. 1999). There are two main reasons for supporting these enterprises via venture capital. First, these enterprises seem to have a significant impact on productivity and employment growth. Second, venture capitalists take on more functions and add more valuable resources in the enterprises than traditional intermediaries do. Brav and Gompers (1997) find some evidence that venture-capital-backed enterprises indeed outperform non-venture-capital-backed ones even after the initial public offering. Moreover, the empirical analysis by Kortum and Lerner (2000) shows that venture capitalists affect the patenting behaviour of the enterprises they finance. Venture-capital-backed enterprises patent significantly more than other comparable enterprises.

This paper analyses the impact of public equity schemes on venture capitalists' incentives to finance young high-technology enterprises. Under public equity schemes, publicly supported co-investors offer capital to high-technology start-ups if private venture capitalists also make an investment. Examples for this kind of publicly supported co-investors are the German Technologie-Beteiligungs-Gesellschaft (tbg, technology participation company) and the French Banque du Développement des Petits et Moyennes Entreprises (BDPME, Bank to Develop Small and Medium-sized Enterprises).

When analysing the impact of public equity on venture capitalists' incentives to finance young high-technology enterprises, venture capitalists' active involvement in the enterprises must be taken into account. Public equity can influence the intensity of venture capitalists' involvement in the enterprises because public equity increases the expected return of venture capitalists' investments (otherwise the venture capitalists would not accept public equity). This increase in expected returns reduces the venture capitalists' incentives to carefully monitor, select and support the enterprises.

The profit of the enterprise does not solely depend on venture capitalist's involvement but also on the entrepreneur's behaviour who has the innovative idea and the technological knowledge which is needed to realize the innovative idea. This leads to a double-sided moral hazard problem

between the venture capitalist and the entrepreneur (Schmidt 1999, Lülfelsmann 2000). When a double-sided moral hazard problem exists, both contracting parties have to provide the opposite party with sufficient incentives to do something after the contract has been signed. For example, the entrepreneur needs incentives to use her technological expertise in the development of the enterprise, while the venture capitalist needs incentives to pledge his contacts to customers and suppliers as well as his specific technological experience to the enterprise he has chosen to finance.

In addition to venture capitalists' active involvement, the heterogeneity of venture capitalists with respect to their experience must be taken into account when analysing the impact of public equity on venture capitalists' incentives to finance high-technology start-ups. Considering the heterogeneity is important because venture capitalists whose levels of experience differ may react differently to public equity. Venture capitalists have to gain stage- and technology-specific experience to add valuable resources to the enterprises and to handle the high investment risks associated with high-technology start-ups. Gaining experience is time consuming because it is a learning-by-doing procedure.

The impact of public policies on venture capital activity has been investigated in the recent literature. Keuschnigg and Nielsen (2001) analyse how subsidies to equipment investment affect total venture capital investments. They show that this subsidy reduces venture capitalists' incentives to support the management and that it causes an inefficient increase in total investments. This is because venture capitalists lower their support per start-up so that they can finance and support more start-ups, while the number of successfully started enterprises remains unchanged. But in this partial equilibrium model, venture capitalists are homogenous, and the role of experience as well as accumulation of experience is not considered. Moreover, the optimal number of start-ups is financed independent of the government's subsidy. Thus, the subsidy causes a welfare loss.

This paper shows that public equity does not only cause an inefficiency but that it can also offer a positive stimulus under certain conditions. Under public equity, experienced venture capitalists, who have already gained sufficient experience, have incentives to make use of the public equity and then to reduce their management support in the enter-

prises, which reduces the surplus of the enterprises. But under public equity inexperienced venture capitalists have incentives to finance young high-technology enterprises for the first time so that these venture capitalists may start to accumulate stage- and technology-specific experience. Thus, the welfare effects of public equity depend on whether venture capitalists have already gained the experience that is needed to finance young high-technology enterprises.

This analysis is to some extent similar to that in Schertler (2000), in which the implications of public loans with a guarantee component are analysed. However, the mechanisms embedded in public loan and public equity schemes differ with respect to incentive effects. A public loan scheme reduces the venture capitalist's incentives to add value-increasing management support since the government partly covers venture capitalist's realized losses. A public equity scheme, however, does not only change venture capitalist's incentives but also the incentives of the entrepreneur to exert effort in the development of the new prototype since under public equity a third party, the publicly supported co-investor, participates in the enterprise's profits as well.

The paper is organized as follows. In Section 2, the basic model for the analysis is introduced. Section 3 identifies the inefficiency caused by an equity-based scheme, and scrutinizes the positive stimulus of a public equity scheme. Section 4 concludes.

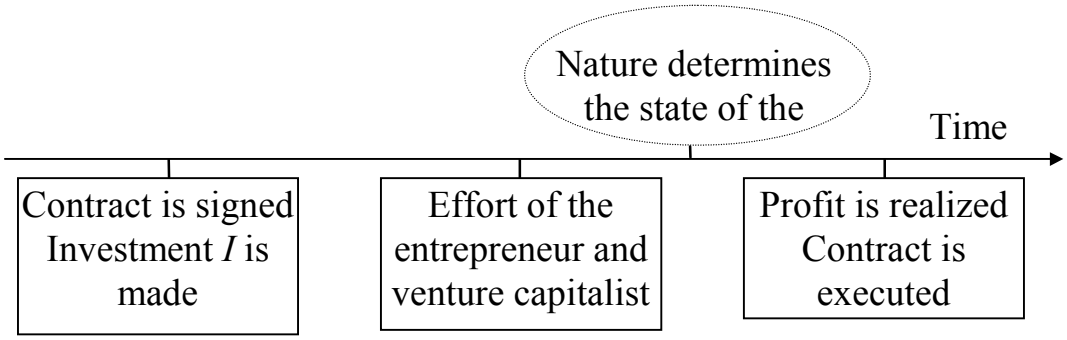
2 The basic model

Although I explicitly consider only a single venture capitalist in the model, there are in fact many venture capitalists in the market who differ with respect to their experience H. Venture capitalists who financed a multitude of high-technology start-ups in the past have more experience than venture capitalists who have financed only some start-up enterprises. If the entrepreneur meets a venture capitalist without sufficient experience, she may look for another venture capitalist who has sufficient experience to make the investment profitable. Therefore, two important effects of public equity can be investigated. How does public equity affect the management support exerted by venture capitalists who have sufficient experience to make high-risk start-up investments profitable? And how does public

equity affect the investment decision of venture capitalists who have not yet built up sufficient experience to make high-risk start-ups profitable?

An entrepreneur (EN) has an innovative product idea, but she lacks the necessary financial means to finance the start-up investment $I > 0$ herself and the experience necessary to manage the enterprise in an efficient manner. Therefore, she needs funding by a venture capitalist (VC), who offers profit-increasing management support. Before the start-up investment is made, the venture capitalist and the entrepreneur sign a contract in which the revenue allocation $(1-\alpha,\alpha)$ is specified. The venture capitalist receives a share α of the enterprise's profits.

Figure 1: Time Structure of the Model



After the capital has been invested, both contracting parties exert their efforts, without observing the effort amount of the respective complementary party. Neither the specific effort of the entrepreneur nor the venture capitalist's effort can be contracted upon. While none of the contracting parties can affect the probability of the product innovation's technical success, both can affect the product innovation's expected revenue. In addition to the effort invested by the two parties, nature determines the revenue of the enterprise that can take two states. In the state with low performance l, reached with probability p_l $(0 \le p_l \le 1)$, the venture capitalist's pay-off does not cover the investment costs independent of the effort invested by the contracting parties. While in the state with high performance h, reached with probability p_h $(0 < p_h \le 1)$, the enterprise's revenue exceeds the effort and investment costs. The sum of the probabilities is equal to one $(p_l + p_h = 1)$. Figure 1 depicts the time structure of the model.

The expected revenue $\hat{R}$ of the enterprise is given by $\hat{R} = (p_l + Ap_h)E^{\beta}\tilde{V}^{\omega}$, with $1 > \beta + \omega$, $0 < \beta, \omega < 1$, and $A = (I - p_l)/p_h$ as a shift parameter ensuring that the revenue of the enterprise is larger in the good state of the project than in the low performance state.[1] In order to ensure a shift parameter larger than one, the start-up investment must also be larger than one $I > 1$. E denotes the entrepreneur's effort, and $\tilde{V}$ is the venture capitalist's management support. The management support offered by the venture capitalist is a function of his time spent in the enterprise V and his experience H, $\tilde{V} = V^{\rho}H^{1-\rho}$, with $0 < \rho < 1$. The venture capitalist has gained his experience by being involved in young high-technology enterprises he financed in the past. Therefore, his experience is exogenously given in the short-run; the venture capitalist maximizes his expected pay-off by choosing his time for doing management support. Inserting the venture capitalist's management support and the shift parameter A into the expected revenue function of the enterprise, and defining $\lambda := (1-\rho)\omega$ and $\delta := \rho\omega$, the expected revenue is given by $\hat{R} = IE^{\beta}V^{\delta}H^{\lambda}$. It is assumed that $\lambda > \delta$.

The venture capitalist receives a share α of the enterprise's expected revenue. He has to carry the costs of the start-up investment I, since the entrepreneur has no funds of her own. Furthermore, he takes the costs for doing management support into account (the value of his outside option). It is assumed that he cannot offer his time without his experience. The higher his time V, or the higher his experience H, the higher the value of his outside option is, which is given by HV. For simplicity, the interest rate is set equal to zero. His expected pay-off function is given by:

[1] $$\hat{U}^{VC} = \alpha IE^{\beta}V^{\delta}H^{\lambda} - HV - I.$$

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[1] The construction of the shift parameter ensures that high-risk start-up enterprises have a higher shift parameter than low-risk ones. A high-risk start-up enterprise has therefore ceteris paribus a higher pay-off in the good state of the project. Let p_l^l be the probability to reach the low performance state of enterprise l that is relatively low compared to the probability p_l^h of the enterprise h $(\text{i.e. } p_l^h > p_l^l)$. Then the enterprise h has a higher shift parameter than enterprise l:
$(I - p_l^h)/(1 - p_l^h) > (I - p_l^l)/(1 - p_l^l)$ so that $(I-1)(p_l^h - p_l^l) > 0$. The last inequality is fulfilled since $I > 1$.

The entrepreneur receives the share $(1-\alpha)$ of the enterprise's expected revenue. Since she has to carry only her effort costs, her expected pay-off function is given by:

[2] $$\hat{U}^{EN} = (1-\alpha) I E^{\beta} V^{\delta} H^{\lambda} - E .$$

This game with simultaneous move between the venture capitalist and the entrepreneur has two Nash equilibriums. In one of these, the efforts by the contracting parties are zero, and this is not of economic interest. Since the expected pay-offs and the realized pay-offs in all states of the project are always zero, nobody would provide venture capital. However, there exists another Nash equilibrium in which the efforts of contracting parties are positive if the venture capitalist has sufficient experience to make the investment profitable. Otherwise, the venture capitalist would not finance the start-up investment.

Differentiating the expected pay-off functions of the entrepreneur [2] and of the venture capitalist [1] with respect to their effort levels E and V and solving this equation system, gives the optimal effort levels as a function of the revenue allocation $(1-\alpha,\alpha)$:

[3] $$E^{*} = \left[(1-\alpha)^{1-\delta} \alpha^{\delta} \beta^{1-\delta} \delta^{\delta} I H^{\lambda-\delta} \right]^{\frac{1}{1-\beta-\delta}} \quad \text{and}$$

[4] $$V^{*} = \left[(1-\alpha)^{\beta} \alpha^{1-\beta} \beta^{\beta} \delta^{1-\beta} I H^{\beta+\lambda-1} \right]^{\frac{1}{1-\beta-\delta}} .$$

For any revenue allocation $(1-\alpha,\alpha)$ fulfilling $0<\alpha<1$, the effort levels of the contracting parties are positive if the venture capitalist funds the start-up investment. The entrepreneur's effort increases with the venture capitalist's experience, since $\lambda > \delta$, while the time that the venture capitalist spends in the enterprise decreases with his experience, since $\beta + \omega - \rho\omega - 1 < 0$ because of $1 > \beta + \omega$. Therefore, venture capitalists with long experience in financing start-up investments need less time to control and support the management team compared to relatively inexperienced venture capitalists.

Inserting the optimal effort levels of the entrepreneur [3] and of the venture capitalist [4] in the expected pay-off functions [1] and [2] gives the expected pay-offs of the contracting parties as a function of the revenue allocation $(1-\alpha,\alpha)$ and of the venture capitalist's experience H:

[5] $$\hat{U}^{EN} = \left[(1-\alpha)^{1-\delta}\,\alpha^{\delta}\,\beta^{\beta}\,\delta^{\delta}\,IH^{\lambda-\delta}\right]^{\frac{1}{1-\beta-\delta}}(1-\beta) \qquad \text{and}$$

[6] $$\hat{U}^{VC} = \left[(1-\alpha)^{\beta}\,\alpha^{1-\beta}\,\beta^{\beta}\,\delta^{\delta}\,IH^{\lambda-\delta}\right]^{\frac{1}{1-\beta-\delta}}(1-\delta) - I\,.$$

For any revenue allocation $(1-\alpha,\alpha)$ fulfilling $0<\alpha<1$, the entrepreneur has a positive expected pay-off, while the venture capitalist's expected pay-off depends on the amount of the start-up investment I and on his experience H. As noted above, in the state of the project with low performance l, the venture capitalist realizes a negative pay-off,[2] while in the state of the project with high performance h, he may receive a positive pay-off depending on his experience and on the revenue allocation. Certainly, if his experience is insufficient he receives a negative pay-off even in the high performance state of the project, and therefore, he does not finance the start-up investment of the enterprise.

In order to solve the model, one does not need an explicit assumption on the bargaining power of the contracting parties. However, to determine the sufficient level of experience that a venture capitalist requires to finance a high-risk investment in a profitable way, the venture capitalist's preferred revenue allocation must be specified. The venture capitalist's expected pay-off reaches its maximum at $\alpha = 1-\beta$, which ensures that the entrepreneur's expected pay-off is positive.

Let me now discuss under which conditions the venture capitalist finances the start-up investment. He is willing to finance a high-risk investment only if his expected pay-off [6], with his preferred $(\alpha = 1-\beta)$ revenue allocation, is non-negative. Thus his experience H, which he has gained in the past, must at least be equal to the following value:

[7] $$\overline{H} = \left[\frac{I}{(1-\delta)}\left[(1-\beta)^{1-\beta}\,\beta^{2\beta}\,\delta^{\delta}\,I\right]^{\frac{1}{\beta+\delta-1}}\right]^{\frac{1-\beta-\delta}{\lambda-\delta}}.$$

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[2] The venture capitalist's pay-off in the low performance state of the project is lower than zero when the start-up investment is sufficiently large: $I > 1/\delta$ (for a detailed discussion see Schertler (2000)).

All venture capitalists who have less experience than this minimum level $\overline{H}$ have no incentive to finance start-up enterprises, since their expected pay-offs are always negative.

All venture capitalists who have at least this experience are capable of financing start-up investments, since their expected pay-offs are non-negative. Venture capitalists whose experience is equal to the minimum level only finance start-up investments if the revenue allocation preferred by them $(\alpha = 1 - \beta)$ is contractually specified, while venture capitalists whose experience exceeds this sufficient level may also accept equity stakes which are lower than their preferred stakes $(\alpha < 1 - \beta)$.

3 The impact of public equity on venture capitalists' investment incentives

In this section, I show that a public equity scheme have two effects on venture capitalist's investment incentives. First, public equity lowers venture capitalist's effort if the venture capitalist has already gained sufficient experience to finance young high-technology enterprises. Second, public equity reduces the minimum level of venture capitalist's experience at least required to make high-risk start-up investments profitable. The first effect can lower the efficiency of venture capital finance because public equity increases the venture capitalist's expected pay-off but lowers the surplus of the enterprise. The second effect may stimulate the venture capitalists' experience accumulation and can have therefore a positive effect on welfare in the long-run.

3.1 Welfare loss in the case of experienced venture capitalists

Public equity changes the venture capitalist's expected pay-off [1] since the venture capitalist and the public co-investor simultaneously invest capital into the start-up enterprise. The venture capitalist has to carry only a part of the investment risk since the co-investor carries the risk of his investment himself. In exchange for his investment, the co-investor participates in the enterprise's profit in the good state of the project, while in the low performance state of the project, the revenue of the enterprise is distributed only among the venture capitalist and the entrepreneur. Suppose that under the public equity scheme, the co-investor takes on a share μ of the start-up investment I in exchange for a profit share $0 \le 1 - \kappa \le 1$. Then, the

expected pay-off function of the venture capitalist [1] under the equity scheme is given by:

$$[8] \qquad \hat{U}_{ES}^{VC} = \alpha\left(p_l + \left(I - p_l\right)\kappa\right)E^{\beta}V^{\delta}H^{\lambda} - HV - \left(1-\mu\right)I,$$

The revenue allocation between the venture capitalist and the entrepreneur is not affected by taking the public equity scheme into account because the revenue distributed among the entrepreneur and the venture capitalist is re-defined by using the parameter κ instead of introducing a second specification of the revenue allocation. Since the co-investor receives a share of the profit realized in the good state of the project, the entrepreneur's expected pay-off [2] changes as well:

$$[9] \qquad \hat{U}_{ES}^{EN} = \left(1-\alpha\right)\left(p_l + \left(I - p_l\right)\kappa\right)E^{\beta}V^{\delta}H^{\lambda} - E.$$

Figure 2: The impact of public equity on the contracting parties' effort

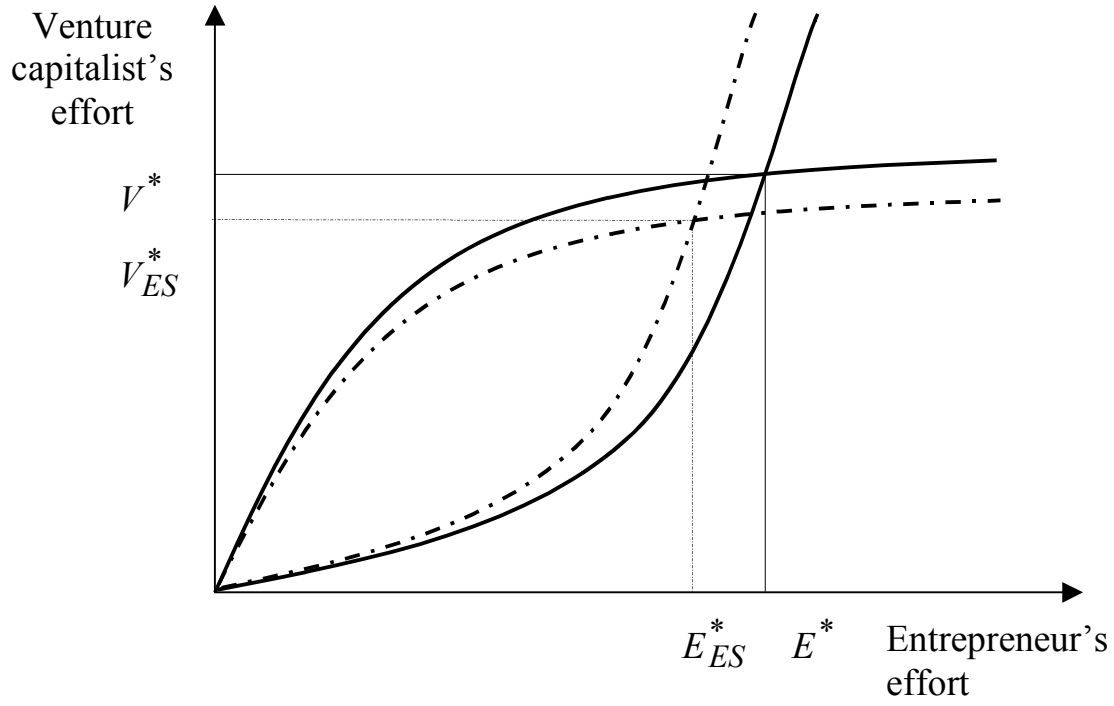

Figure 2 shows the reaction curves of the two contracting parties that can be used to explain the impact of public equity. The reaction curve of the venture capitalist depicts the venture capitalist's effort level as a function of the entrepreneur's effort levels. Under a public equity scheme, the venture capitalist with a particular experience is less willing to support the

entrepreneur at all her effort levels. Thus, the venture capitalist's reaction curve with respect to the entrepreneur's effort shifts inwards. Moreover, the entrepreneur is also less willing to exert effort in the development of the innovative product since she has to share the enterprise's pay-off with a third party. Therefore, the entrepreneur's reaction curve also shifts inwards. In the new equilibrium $\left(V_{ES}^{*}, E_{ES}^{*}\right)$, both contracting parties' effort is lower compared to the situation without public equity $\left(V^{*}, E^{*}\right)$.

In analytical terms, the optimal effort levels of the contracting parties under the public equity scheme are given by:

$$[10]\quad E_{ES}^{*} = \left[(1-\alpha)^{1-\delta}\,\alpha^{\delta}\,\beta^{1-\delta}\,\delta^{\delta}\left(p_l + (I-p_l)\kappa\right)H^{\lambda-\delta}\right]^{\frac{1}{1-\beta-\delta}} \quad \text{and}$$

$$[11]\quad V_{ES}^{*} = \left[(1-\alpha)^{\beta}\,\alpha^{1-\beta}\,\beta^{\beta}\,\delta^{1-\beta}\left(p_l + (I-p_l)\kappa\right)H^{\beta+\lambda-1}\right]^{\frac{1}{1-\beta-\delta}}.$$

Inserting the optimal effort levels [10] and [11] into the expected pay-off functions of the venture capitalist [8] and the entrepreneur [9] gives the expected pay-offs under the equity scheme as a function of the revenue allocation:

$$[12]\quad \hat{U}_{ES}^{VC} = \left[(1-\alpha)^{\beta}\,\alpha^{1-\beta}\,\beta^{\beta}\,\delta^{\delta}\left(p_l + (I-p_l)\kappa\right)H^{\lambda-\delta}\right]^{\frac{1}{1-\beta-\delta}}(1-\delta) - (1-\mu)I$$

and

$$[13]\quad \hat{U}_{ES}^{EN} = \left[(1-\alpha)^{1-\delta}\,\alpha^{\delta}\,\beta^{\beta}\,\delta^{\delta}\left(p_l + (I-p_l)\kappa\right)H^{\lambda-\delta}\right]^{\frac{1}{1-\beta-\delta}}(1-\beta).$$

Comparing venture capitalist's expected pay-offs with [12] and without public equity [6] shows that a critical level of experience exists above which the venture capitalist does not prefer a publicly supported co-investment, since his expected pay-off is lower with than without public equity. This level is given by:

$$[14]\quad \overline{\overline{H}}_{ES} = \left[\frac{\frac{\mu I}{(1-\delta)} \left[(1-\alpha)^{\beta} \alpha^{1-\beta} \beta^{\beta} \delta^{\delta} \right]^{\frac{1}{\beta+\delta-1}}}{\left[I^{\frac{1}{1-\beta-\delta}} - \left(p_l + (I - p_l)\kappa \right)^{\frac{1}{1-\beta-\delta}} \right]} \right]^{\frac{1-\beta-\delta}{\lambda-\delta}},$$

with $\overline{\overline{H}}_{ES} > \overline{H}$ if $p_l(1-\kappa) + I\left(\kappa - (1-\mu)^{1-\beta-\delta}\right) > 0$. Since the first term is always larger than zero, I have to ensure only that: $I\left(\kappa - (1-\mu)^{1-\beta-\delta}\right) > 0$. Thus, venture capitalists whose experience exceeds the sufficient level $\overline{H}$ only make use of the public equity scheme if $\kappa > (1-\mu)^{1-\beta-\delta}$. The reason for this is that venture capitalists have no incentive to make use of public equity when the co-investor invests only a small share of the start-up investment and demands large profit participation. Moreover, since the venture capitalist has to carry effort costs himself, he is not willing to exchange one per cent of the investment amount against one per cent of profits. Therefore, public equity has an impact on the behaviour of experienced venture capitalists only if the co-investor's profit participation is low compared with his investment share.

Figure 3: The impact of public equity on venture capitalist's expected pay-off

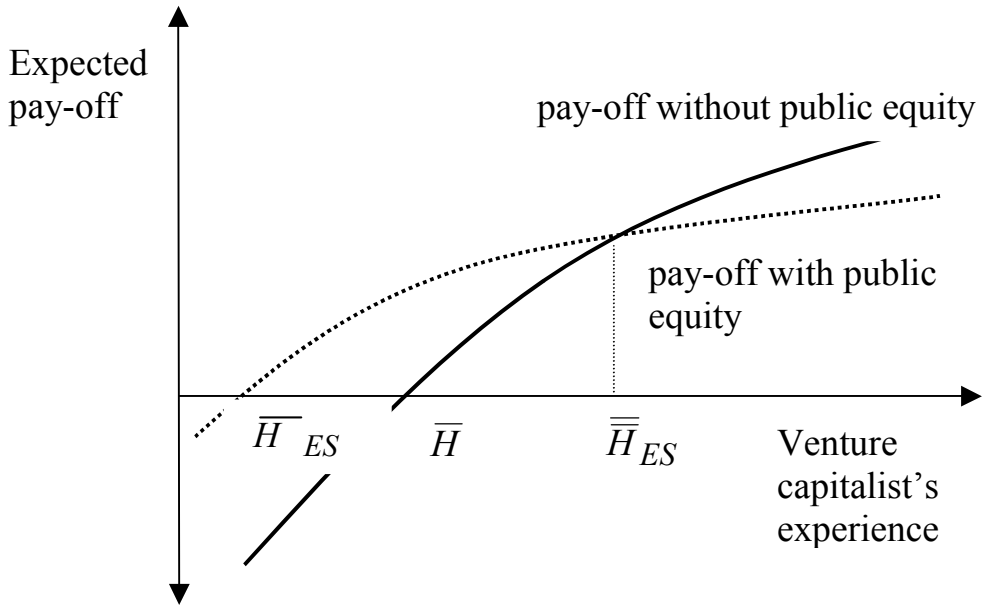

Figure 3 shows the effects of public equity on the venture capitalist's expected pay-off. Venture capitalists whose experience is above the sufficient level $\overline{H}$ and below the critical level of experience $\overline{\overline{H}}_{ES}$ have incentives to use public equity. Venture capitalists whose experience is above the critical level have no incentives to use public equity because their expected pay-off is higher without public equity than with public equity.

The publicly supported co-investor expects a monetary loss in the low performance state of the project, and in the good state he participates in profits instead of receiving a re-payment of the capital invested. His expected pay-off is given by:

$$[15]\quad \hat{U}_{ES}^{G} = (1-\kappa)(I-p_l)\left[\frac{(1-\alpha)^{\beta}\alpha^{\delta}\beta^{\beta}\delta^{\delta}\left(p_l+(I-p_l)\kappa\right)^{\beta+\delta}}{H^{\delta-\lambda}}\right]^{\frac{1}{1-\beta-\delta}} - \mu I .$$

The co-investor's expected pay-off is negative if his profit participation is zero (the remaining profit share distributed among the venture capitalist and the entrepreneur is one). The higher the co-investor's profit participation (the lower the remaining profit share) is, the lower the venture capitalist's and the entrepreneur's effort incentives, and the revenue of the enterprise. The higher the venture capitalist's experience is, the higher the revenue of the enterprise and the co-investor's pay-off. But the pay-off of the co-investor is never positive, since venture capitalists whose experience makes the co-investor's pay-off positive prefer financing young high-technology enterprises without public equity.

The change in the total surplus of the enterprise is given by the sum of the difference in the venture capitalist's expected pay-offs with [12] and without public equity [6], the difference in the entrepreneur's expected pay-offs with [13] and without public equity [5], and the co-investor's expected cost [15]. Using venture capitalist's preferred revenue allocation, it follows:

$$[16]\quad \hat{U}_{ES}^{Total} - \hat{U}^{Total} = \hat{U}_{ES}^{VC} - \hat{U}^{VC} + \hat{U}_{ES}^{EN} - \hat{U}^{EN} + \hat{U}_{ES}^{G}$$

$$= C(1-\delta+\beta)\left((p_l + (I-p_l)\kappa)^{\frac{1}{1-\beta-\delta}} - I^{\frac{1}{1-\beta-\delta}} \right) +$$

$$\frac{C}{1-\beta}(1-\kappa)(I-p_l)(p_l+(I-p_l)\kappa)^{\frac{\beta+\delta}{1-\beta-\delta}},$$

with $C := \left[(1-\beta)^{1-\beta}\, \beta^{2\beta}\, \delta^{\delta}\, H^{\lambda-\delta} \right]^{\frac{1}{1-\beta-\delta}}$

Public equity never increases the surplus of the enterprise for the parameters specified (proof see appendix). The venture capitalist's expected pay-off is higher with than without public equity, since otherwise a venture capitalist would not use the public equity. The opposite is true for the entrepreneur's expected pay-off because both contracting parties reduce their effort levels under the public equity scheme. Therefore, public equity causes an inefficiency when venture capitalist's experience is between the minimum level $\overline{H}$ and the critical level $\overline{\overline{H}}_{ES}$.

Since equation [16] is never positive, the start-up investment should never be financed by more than one investor because co-investments (such as public equity) reduce the surplus of the enterprise. This result is similar to the findings by Repullo and Suarez (1999), who emphasize the role of incentive problems in a model focusing on a stage-financed enterprise. They show that buying back the investor's shares of the first capital infusion, or financing the first as well as the second capital infusion by a single venture capitalist, increases the incentives to exert value-increasing effort.

At first glance, this result seems to contradict the empirically observed syndication of venture capital investments, i.e. the financing of an enterprise by several venture capitalists. But the model used here and the model by Repullo and Suarez (1999) do not consider all characteristics of the venture capital relationships that might explain the syndication of investments. The continuation decision belongs to these characteristics. In the model by Admati and Pfleiderer (1994), a venture capitalist gets inside information on the enterprise by financing the first stage of capital infusion. They show that the continuation decision of the lead venture capitalist (who financed the first capital infusion) is optimal only if the venture capitalist's share in expected pay-offs is equal to his original investment share. Further

capital infusions must be syndicated in order to ensure a constant share on expected pay-offs.

A public equity scheme reduces welfare if the venture capital market is in its mature stage in which venture capitalists have already gained sufficient experience because experienced venture capitalists reduce their effort that results in a lower surplus of the enterprise. This result is in line with the model result by Keuschnigg and Nielsen (2001). As they have shown in a partial equilibrium model, public subsidies increase the venture capital investment volume since more enterprises are financed. The reason for this is that public subsidies reduce venture capitalists' incentives for supporting the entrepreneurs so that they increase the number of high-technology enterprises financed until their time constraint for management support is binding again. The number of high-technology enterprises without public subsidies is first-best efficient because there is no market distortion. Therefore, public subsidies increase the number of unsuccessfully financed high-technology enterprises as well.

3.2 Welfare gain in the case of inexperienced venture capitalists

Public equity reduces the sufficient minimum level of venture capitalists' experience required to make high-risk start-up investments profitable. Without public equity, inexperienced venture capitalists, whose experience is below the sufficient level $\overline{H}$, have no incentive to finance high-risk investments since their expected pay-off is negative (Figure 3 above). Under public equity, however, relatively inexperienced venture capitalists, whose experience is lower than the minimum level $\overline{H}$ and above the minimum level of experience under public equity $\overline{H}_{ES}$, get incentives to enter the market for high-risk investments. Therefore, if the supply of experienced venture capitalists is insufficient, which can be the case in the early stage of a venture capital market, public equity can be welfare improving.

Since the revenue allocation preferred by the venture capitalist is not affected by public equity, the venture capitalist's preferred revenue allocation $\alpha = 1 - \beta$ can be used and inserted in the expected pay-off of the venture capitalist under public equity [12] in order to determine the minimum level of experience under public equity:

$$[17]\quad \overline{H}_{ES} = \left[\frac{(1-\mu)I}{(1-\delta)} \left[(1-\beta)^{1-\beta}\, \beta^{2\beta}\, \delta^{\delta}\, \left(p_l + (I - p_l)\kappa\right) \right]^{\frac{1}{\beta+\delta-1}} \right]^{\frac{1-\beta-\delta}{\lambda-\delta}}.$$

The minimum level of experience with public equity [17] exceeds the minimum level of experience [7] if the following inequality is fulfilled:

$$p_l(1-\kappa) + I\kappa - (1-\mu)^{1-\beta-\delta}\, I > 0,$$

which is identical to the inequality which ensures that the critical level of experience exceeds the sufficient level. Setting the probability of reaching the project's low performance state equal to zero results in: $I\left(\kappa - (1-\mu)^{1-\beta-\delta}\right) > 0$. Thus, under public equity, inexperienced venture capitalists, who have not yet gained the experience to finance high-technology start-ups, have incentives to enter the market and to finance these enterprises if $\kappa > (1-\mu)^{1-\beta-\delta}$. By financing these enterprises, they may start to gain stage- and technology-specific experience necessary to successfully select, monitor, and support these enterprises.

Inexperienced venture capitalists react differently to public equity than experienced venture capitalists do. If the publicly supported co-investor offers public equity at favourable conditions, i.e. if $\kappa > (1-\mu)^{1-\beta-\delta}$, experienced venture capitalists use the public equity and reduce their management support in the enterprises. The reduction of management support lowers the surplus of the enterprise. Moreover, if the condition is fulfilled, public equity stimulates relatively inexperienced venture capitalists to enter the market for high-technology investments.

Under which condition does public equity increase welfare? Public equity does increase welfare only if it stimulates the gaining of experience in an efficient manner. Thus, it can only increase welfare if venture capitalists have only started to gain experience to finance high-risk investments in a profitable way and if the gaining of experience is hampered significantly, i.e., if the growth rate of experience is below the efficient one.[3] Therefore,

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[3] Venture capitalists are capable of gaining only a specific amount of experience. They do not gain the double amount of experience if they finance the double number of enterprises under government subsidies.

public equity can be important only in the early stage of venture capital markets in which venture capitalists are comparatively inexperienced. In this stage, venture capital activity is low compared with the mature stage of this market.

The gaining of experience can be hampered if venture capitalists have not yet built reputation as specialists and active intermediaries. Venture capitalists need reputation in order to raise funds from passive investors. They build up this reputation by successfully exiting from some of their investments (which they have probably financed with their own financial means) via an initial public offering or a trade sale to an informed outside investor, such as an established firm in the industry.

Moreover, the gaining of experience can be hampered by a rate of unsuccessful venture-capital-backed enterprises that is above the long-term failure rate. The low level of venture capitalists' experience in the early stage of the venture capital market can certainly cause extraordinary high failure rates. Moreover, suppose that the probability to fail is exogenously given. Then the probability to realize a higher failure rate in the early stage of the venture capital market is positive for a particular venture capitalist because of the small number of young high-technology enterprises in the venture capitalist's portfolio in comparison to the number of enterprises in the portfolio in the mature stage. In any case, a failure rate of venture-capital-backed enterprises that exceeds the long-term failure rate reduces venture capital activity and, thus, reduces the gaining of experience.

However, public equity schemes will be wasting taxpayer's money if the innovation climate for a liquid venture capital market is poor. Whether an economy has innovation climate for a liquid venture capital market depends on several determinants which are certainly not of a static nature and which are to some extent interdependent. For example, the innovation climate for a liquid venture capital market depends on the innovation system: The more in-house research and development activities are, the less likely the development of a venture capital market is. However, the less developed financial markets are, the more likely in-house research and development activities are. Second, the innovative climate depends on the number of individuals generating ideas. This number is in turn affected by the design of the university system. For example, the more creativity and

individualism a university system initiates, the higher the number of individuals with innovative ideas might be.

4 Conclusions

The analysis has shown that two groups of venture capitalists, experienced and inexperienced venture capitalists, have to be distinguished when the effects of public subsidies on venture capital markets are examined. Experienced venture capitalists have already gained experience to make high-risk investments profitable, while inexperienced venture capitalists have not yet gained sufficient experience to finance high-risk investment in a profitable way.

Experienced venture capitalists reduce their support of the management teams under public equity. A reduction in management support decreases the total surplus of the enterprises, which is the sum of the expected payoffs of the entrepreneur, the government and the venture capitalist. Public subsidies cause an individual efficiency loss if venture capitalists are sufficiently experienced. Moreover, if many venture capitalists are sufficiently experienced, this individual efficiency loss results in a welfare loss.

However, inexperienced venture capitalists have incentives to enter the market for high-risk investments when the publicly supported co-investor offers public equity to venture-capital-backed enterprises. In this way, public equity schemes can aid inexperienced venture capitalists in gaining technology-specific experience and can thereby support the growth of a powerful venture capital industry.

Positive welfare effects of public equity schemes can be expected only if the venture capital market is in its early stage, in which only a relatively small number of venture capitalists have gained experience necessary to profitably finance young high-technology enterprises. In this stage of a venture capital market, public equity can stimulate learning processes. However, this is welfare improving only if the venture capitalists' learning process is hampered significantly so that the realized growth rate of experience is below the efficient rate.

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Appendix: Public equity lowers the surplus of the enterprise

The change in the surplus of the enterprise under public equity is determined by the second bracket term in equation [16] which is given by:

$$f_{ES} = (1-\delta+\beta)\left((p_l + (I-p_l)\kappa)^{\frac{1}{1-\beta-\delta}} - I^{\frac{1}{1-\beta-\delta}} \right). \\ + \frac{(1-\kappa)}{(1-\beta)}(I-p_l)(p_l+(I-p_l)\kappa)^{\frac{\beta+\delta}{1-\beta-\delta}}$$

Public equity does not increase the total surplus of the enterprise if the right-hand term is smaller than or equal to zero for all parameter combinations fulfilling the following parameter restrictions:

$\alpha, \beta \in (0,1)$, $\alpha + \beta < 1$, $I > 1$, and $p_l, \kappa \in [0,1]$.

Assume first that $\kappa = 1$. Then f_{ES} is zero for all parameter combinations of interest.

Assume now a decrease in κ. The effect of this decrease on f_{ES} is given by the partial derivative:

$$\frac{\partial f_{ES}}{\partial \kappa} = \frac{1}{1-\beta-\delta}(1-\delta+\beta)(p_l+(I-p_l)\kappa)^{\frac{1}{1-\beta-\delta}-1}(I-p_l) \\ - \frac{(I-p_l)}{(1-\beta)}(p_l+(I-p_l)\kappa)^{\frac{\beta+\delta}{1-\beta-\delta}} \\ + \frac{\beta+\delta}{1-\beta-\delta}\frac{(1-\kappa)}{(1-\beta)}(I-p_l)(p_l+(I-p_l)\kappa)^{\frac{\beta+\delta}{1-\beta-\delta}-1}(I-p_l)$$

If this partial derivative is non-negative for all parameter combinations fulfilling the restrictions imposed, i.e. if f_{ES} is monotonic in κ, the second bracket term is never larger than zero. Rearranging the terms gives:

$$\frac{\partial f_{ES}}{\partial \kappa} = \frac{1}{1-\beta-\delta}\frac{(I-p_l)}{(1-\beta)}(p_l+(I-p_l)\kappa)^{\frac{\beta+\delta}{1-\beta-\delta}}\beta(1+\delta-\beta) \\ + \frac{1}{1-\beta-\delta}\frac{(I-p_l)}{(1-\beta)}(p_l+(I-p_l)\kappa)^{\frac{\beta+\delta}{1-\beta-\delta}}\frac{(\beta+\delta)(1-\kappa)(I-p_l)}{(p_l+(I-p_l)\kappa)}$$

For the parameter fulfilling the parameter restrictions imposed, the square bracket term is never smaller than zero. Therefore, public equity reduces the total surplus of the enterprise, because if $\kappa = 1$ f_{ES} is zero for all parameter combinations and an increase in κ increases the value of f_{ES}.

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