SHOULD PUBLIC VENTURE CAPITALISTS INVEST, CO-INVEST, OR NOT INVEST IN START-UP FIRMS?

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Abstract

We depict the decision faced by Public Venture Capitalists (PVCs) and Governments on the best mechanism to promote the investment in Start-up Firms: should PVCs invest directly in Start-up Firms, should they co-invest alongside Independent Venture Capitalists (IVCs), should they let IVCs invest, or should Governments directly subsidize Start-up Firms, instead? Focusing on the economic payoffs earned by PVCs and IVCs, we model each of the alternative investing mechanisms as real options and illustrate that co-investing might be the most effective mechanism in anticipating optimum investment timing. Grounded on this theoretical framework, we list a set of both public policy and managerial implications, derive a set of empirically testable propositions on the determinants of PVC investment volumes and analyze their prevalence on a sample of European countries. Even though taxation proved not to be correlated with PVC investment volumes, the remaining results provide overall empirical support to our theoretical hypothesis.

Keywords: Venture Capital, Entrepreneurial Finance, Real Options, Public Venture Capital, Investment Decisions

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1. INTRODUCTION

Public Venture Capital (PVC[2]) initiatives are popular amongst Governments worldwide. In Europe, and according to the European Venture Capital Association (EVCA[3]), PVC investment stood for 1.1% of total investment amounts in Private Equity (PE) and Venture Capital (VC) and 8.0% of total investment volumes between 2007 and 2014, with a record high being reached in 2014, both in terms of investment amounts (2.6%) and investment volumes (10.3%)[4]. In the United States, the Government created the first PVC programs in the 1970s (Jenkins and Leicht, 1996; Leicht and Jenkins, 1998) and launched the Small Business Innovation Research (SBIR) program in the 1980s, which provided over $ 7 billion to small high-technology firms between 1983 and 1997 (Lerner, 1999), and has been successfully extended by the Congress since 2000 and until 2017. Argentina (Butler et al., 2015), Australia (Lerner and Watson, 2008), Canada (Ayayi, 2004; Brander et al., 2008), Chile (Avnimelech and Teubal, 2008; Murray, 2007), New Zealand (Murray, 2007), Israel (Avnimelech et al., 2010; Avnimelech and Teubal, 2008) and Taiwan (Chen et al., 2012) also established similar PVC initiatives, most of which targeting Entrepreneurial Firms on the early stage/ high-tech segment.

Why should Governments sponsor such PVC initiatives aimed at funding young and innovative Entrepreneurial Firms? On the one hand, investment opportunities held by such

[2] We will use the acronym PVC throughout the paper interchangeably either to refer to "Public Venture Capital" or "Public Venture Capitalists", depending on context.

[3] EVCA was recently renamed as "Invest Europe".

[4] Figures from "*EVCA Yearbook – European Private Equity Activity in 2014*". Sample includes Belgium, Bulgaria, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, Netherlands, Norway, Poland, Portugal, Romania, Spain, Sweden, Switzerland, Ukraine, and the United Kingdom. It is worth mentioning that Bulgaria, Czech Republic, Greece, Italy, Luxembourg, Poland, Romania and Ukraine do not record any PVC volumes or amounts during the 2007-2014 period.

Entrepreneurial Firms are deemed to hold *positive externalities*, in the sense that returns from their R&D expenditures may actually exceed their private returns (Lerner, 1999; Lerner, 2002). Knowledge generated within such context is hardly appropriable and intellectual property protection is limited in Entrepreneurial Firms. As a result, private returns lag behind social returns leading to under-investing on this firm segment (Peneder, 2008)[5]. On the other hand, investing in Entrepreneurial Firms requires significant *information asymmetries* risks to be mitigated by Independent Venture Capitalists[6] (IVCs[7]). By investing in such Entrepreneurial Firms, PVCs provide a signaling or certification effect (Lerner, 2002) to private investors which might be relevant for IVCs to assess their willingness to participate in future equity rounds. Additionally, the establishment of PVC initiatives might be particularly relevant on the nascent stages of the VC industry, by allowing investment professionals to be trained and then moved to private VC organizations (Lerner, 1999)[8]. This not only contributes to a lower informational gap on VC as an asset class itself, but also to promote the investment on the Entrepreneurial Firms segment, as such investment professionals become acquainted with this early-stage market segment both from a demand and supply side perspective. Finally, as a result of its vast economies of scale (Murray, 1998), *VC fund economics* feature strong incentives for General

[5] Peneder (2008) lists a set of institutional mechanisms to overcome the under-investing phenomenon in Entrepreneurial Firms, including (i) the establishment of an effective system of intellectual property rights, (ii) the existence of public research centers that favor industrial applications over long run and (iii) the provision of public subsidies to innovation.

[6] Independent Venture Capitalists (IVCs) should be more accurately mentioned as Private Venture Capitalists, as this category comprises the broader range of VCs, such as Captive Venture Capitalists, Corporate Venture Capitalists, Institutional Venture Capitalists and Informal Venture Capitalists (Sapienza & Villanueva, 2007). However, throughout this paper we are particularly interested in analyzing the behavior of non-captive (i.e., independent) VC organizations and, for the sake of convenience, we will adopt acronym IVC with the purpose of more easily distinguish from PVC.

[7] We will use the acronym IVC throughout the paper interchangeably either to refer to "Independent Venture Capital" or "Independent Venture Capitalists", depending on context.

[8] Please refer to the Small Business Investment Company (SBIC) example which we refer on this Section.

Partners (GPs) to abandon early-stage equity finance as their track-record allows them to sustain their presence on the market. Independent GPs have the incentive to focus on significantly increasing the amount of funds under management – with the purpose of maximizing their management fees – and on minimizing monitoring and portfolio risk (Murray, 2007) – in order to increase the probability of providing consistent returns on investment. The investment record of early-stage funds is poor (EVCA and Reuters, 2014) – with 10-year internal rate of returns standing for 1.32% on the VC segment against 9.63% on the buyout segment as of 31st December 2013. Moreover, small, early-stage funds have a series of structural weaknesses that hinder their potential risk-adjusted profitability. These funds face higher due diligence and monitoring costs, need to provide high levels of management support and guidance to investees, have a more limited ability to fully benefit from diversification, bear higher ownership dilution risks, and present a skewed risk/ return profile which requires exceptional successes to be generated within the portfolio so that an attractive risk-adjusted return is provided to their Limited Partners (LPs). In addition, they are unable to attract the largest and most professional LPs[9] and hold limited ability in recruiting experienced professional investment executives (Hood, 2000; Lawton, 2002; Murray, 2007).

The combination of *positive externalities*, *information asymmetries* and *VC fund economics* lead to a *market failure* on the Entrepreneurial Financing segment (Giacomo, 2004; Murray, 2007; van der Schans, 2015), which motivates public authorities to intervene on the VC market.

[9] Large institutional LPs typically seek for bigger-ticket fund allocations, so that these may have an influential impact on their overall fund performance. As early-stage fund sizes tend to be small when compared to other PE and VC segments, they become less attractive to large institutional LPs.

Such intervention should target the provision of equity – in order to close this *equity gap*[10, 11] – when efficient IVCs avoid the Entrepreneurial Firm segment due to an unattractively priced investment proposal[12], or should target the improvement of entrepreneurial quality and context (Lerner, 2010)(Lerner, 2010)(Lerner, 2010), when IVCs avoid this segment due to an insufficient supply of investment opportunities[13] (Mason and Brown, 2013; Mason and Harrison, 2001; Murray, 2007).

Criticism on PVC initiatives highlight that such instruments may primarily serve interest groups or politicians seeking for private benefits. As a result, Entrepreneurial Firms may seek transfer payments that increase profits, by conducting transfers to politically connected companies, while Governments may seek to select firms based on their likely success, regardless of their actual need for capital. In this case, Governments launch PVC initiatives so that they can claim credit on the success of the investees, even when their marginal contribution to value creation is low (Lerner, 1999; Lerner, 2002).

[10] Murray (1995) distinguishes two different types of equity gaps: the *initial equity gap*, which describes the financing problems faced by Start-up Firms looking for seed capital and *the second equity gap*, which happens at a stage when initial seed or start-up capital is exhausted and no additional equity providers are prepared to provide follow-on financing.

[11] Interestingly, research carried by Da Rin et al. (2006) on a set of 14 European countries found no evidence of a shortage of supply of VC funds in Europe.

[12] This seems to be the case of Italy, where Colombo et al. (2007) carried an empirical research on a net of 550 NTBFs, whose results "only partially confirm the relevance of founders' competencies as important drivers of VC investment decisions", suggesting the presence of other inefficiencies in the VC market.

[13] Murray (2007) illustrates that the inexistence of attractive investment opportunities by citing a set of statistics relating to the proportion of small business owners seeking for external financing, and the proportion of Small and Medium Enterprises (SMEs) that point easy access to finance as their primary concern.

According to Harrison and Mason (2000), Giacomo (2004) and Murray (2007), Governments may intervene on the VC market either through a *direct intervention*[14] – where a PVC organization is established and the Government simultaneously assumes the role of a GP and of a LP – or through an *indirect intervention*, where IVCs act on behalf of the Government. In this case, Governments essentially act as LPs and may establish *equity enhancement schemes*. Within these, Governments may subsidize the operating costs of VC funds, co-invest with private LPs matching their requirements, be willing to accept a capped return, concede a buyout option for private LPs, underwrite part of all of the risk of financial loss borne by GPs and LPs and enhance the internal rates of return earned by private LPs by accepting a reordering of cash-flows, so that public LPs are the first to provide capital and the last to have their capital reimbursed[15].

Given that Governments may let their decision-making process be influenced by the dynamics of political conditions, *indirect* or *hybrid* interventions on the Entrepreneurial Financing markets are seen as a best practice (Gilson, 2003; Lerner, 2010). In addition, PVC organizations might be hindered by their inability of hiring and retaining appropriate investment

[14] One of the most original forms of public intervention on the Entrepreneurial Financing markets is pictured by Ayayi (2004), who assessed the performance of the Canadian LSVCFs (Labor-Sponsored Venture Capital Funds). These operated similarly to open-ended mutual funds, were capitalized by individual investors and had a regional focus. Significant tax benefits were awarded to investors with the purpose of committing their capital for eight years to inherently risky SMEs. LSVCFs were managed by labor unions or federations and had the purpose to fulfill a set of social goals, including job creation and regional economic development. Results reveal that even though LSVCFs were able to attract significant amounts of capital due to its tax benefits, their performance was significantly poor when compared to a wide range of benchmarks (from sectorial mutual funds to stock indexes) due to poor management and fund regulations. Still, Ayayi (2004) found evidence that LSVCFs did not use their funds to aggressively price their deals and that were able to deploy their capital into local communities.

[15] Governments may also engage on a *fund of funds* initiative, which may specifically target Entrepreneurial Firms or other firms of policy interest. Examples include the *Fonds de Promotion pour le Capital Risque – FPCR* established in France with € 150 million under management in 2001 and the *UK High Technology Fund*, established in 2000 by the British Government with £ 126 million under management, of which £ 20 M were provided by Public Authorities.

professionals or their incapacity of learning and benefiting from their own investment experience. As a result, PVCs become less capable of providing valuable advice[16] to their portfolio firms and are therefore less prone to generate benchmark returns. Moreover, and depending on their size and on how the industry matures, PVC organizations might negatively influence the institutional framework of the local VC industry – especially when it is still nascent – by crowding out private investors (Munari and Toschi, 2015) and offering finance below an appropriate risk premium (Jääskeläinen et al., 2007). Hence, taking into account the previously described features of *VC fund economics* and the risk/return profile of early stage investing, only by providing more attractive profit expectations to private LPs may Governments actually contribute to narrow the *equity gap* (Gilson, 2003; Hirsch, 2006; Jääskeläinen et al., 2007). By co-investing *pari passu* with other private LPs, Governments merely help VC funds reaching their minimum efficient scale (Murray, 2007)[17].

Several studies attempt to empirically assess the impact and the performance of the wide range of PVC initiatives worldwide. Beuselinck and Manigart (2007) analyzed the relevance of PVC investment on a set of ten European countries for the 1989 to 2003 period, having concluded that early stage and high-tech VC investments are higher in countries where PVC

[16] Value creation effects from IVCs on investee led academia to discuss whether IVCs provide a *treatment effect* – i.e., whether their monitoring and advice activities actually contribute to improve their performance (Hellmann and Puri, 2002) – or benefit from a *selection effect*, in which experienced IVCs evidence better performance since they are able to select the best deals (Bertoni, 2011; Croce et al., 2013). Still, Cumming and Fischer (2012) analyzed the contribution of a non-profit business advisory center in Canada, having found that, in this case, public funded business advisory services to Entrepreneurial Firms are positively associated with firms' sales growth, patents, finance and alliances.

[17] Lerner (2010) points out other policy principles that should govern the functioning of PVC initiatives, including (i) the establishment of efficient technology transfer offices, (ii) the acceptance of the generalized accepted standards regarding partnerships and preferred stock structures, (iii) the establishment of shorter lead times on the public-side regarding shared decision-making processes with IVCs, and (iv) the establishment of evaluation initiatives of public programs.

initiatives are more important, that PVC programs are less dependent on economic cycles than IVC investments – providing a contribution to stabilize a traditionally cyclical industry – and that PVC investment is negatively correlated with the number of listings on the local stock market[18]. Similar results were obtained by Jeng and Wells (2000). Leleux and Surlemont (2003) found that PVCs do not favor labor-intensive industries, nor even that PVCs co-invest their investments less than IVCs. Alongside del-Palacio et al. (2012) whose study focused on the Spanish market, as well as Jeng and Wells (2000) and Brander et al. (2014) whose samples compare developed countries worldwide, Leleux and Surlemont (2003) did not find support to the *crowding-out* hypothesis of PVC initiatives, obtaining empirical evidence to support the opposite assertion. The authors showed that PVCs actually lead to a spillover on the flow of private investors into the VC markets and found a positive association between PVC volumes and later-stage deals, in general[19]. Differently, Munari and Toschi (2015) empirically investigated the performance of PVC funds according to three performance measures – exit rate, and IVC attraction rate through staging and syndication – having found support for the *crowding-out* hypothesis and having showed that PVCs exhibit lower performance than their

[18] Michelacci and Suarez (2004) and Keuschnigg and Nielsen (2007) show that the presence of liquid stock markets allow VCs to exit from their portfolio companies more easily and allow VC financing to become more attractive to Entrepreneurs, since VC control ownership is expected to last for a more limited period of time. By enabling a faster turnover of portfolio firms, liquid portfolio markets allow a larger rate of firms to be backed by IVCs. Carpentier et al. (2010) analyze the Canadian experience on the TSX Venture Exchange – a public equity market for newly created companies with no history or sales are allowed to list – with the ultimate goal of "graduating" its best performers to the main exchange, the Toronto Stock Exchange (TSX). These authors found that the returns of this "public VC market" are able to compete with the private ones.

[19] Lerner (1999) also provides positive guidance on the impact of PVC initiatives performed by the SBIR program in the United States, as well as Cumming (2007), who observed that the Innovation Investment Fund (IIF) set up by Australia facilitated investment in start-up, early stage and high tech firms, alongside the provision of monitoring and value-added advice to investees. On a set of seven European countries, Luukkonen et al. (2013) found no statistically significant difference between the performance of firms held by PVCs and IVCs. However, the contributions of IVCs funds proved to be significantly higher than those of PVCs regarding the development of the business idea, professionalization and exit orientation.

private peers[20,21]. Similar results on performance and on the *crowding-out* hypothesis were obtained by Cumming and MacIntosh (2006), when studying the impact of the LSVCFs established in Canada.

Munari and Toschi (2015) also point out that PVC initiatives may actually serve the purpose of encouraging the involvement of qualified GPs and LPs in depressed regions (Mason and Harrison, 2003; Murray, 1998; Sunley et al., 2005). Such catalyst effect is assessed by Brander et al. (2014) and Grilli and Murtinu (2015). The former found that enterprises funded both by PVCs and IVCs obtain more investment than enterprises uniquely funded by PVCs or by IVCs. The latter studied the impact of PVC on sales of new-technology-based firms (NTBFs). Results revealed that PVC-backed NTBFs underperformed IVC-backed firms, but when PVCs co-invested alongside IVCs, the former are able to inflict a positive and statistically significant impact on sales. This is consistent with Grilli and Murtinu (2014), who showed that, on a dataset of firms based on the European Union, firms held by IVC investors generate a significant and positive performance on sales growth, firms held by PVCs record a negligible change on sales, and firms in which IVCs and PVCs co-invested – while letting IVCs retaining the lead – also

[20] Munari and Toschi (2015) argue that the reason behind the poor performance of the PVC initiatives is grounded on the existence of unclear, multiple and conflicting goals for PVCs – from local development, to employment, entrepreneurial culture or industry restructuring – which incentivize self-serving behaviors and low PVCs accountability for selecting and monitoring high-quality firms (Fisher, 1998; Hood, 2000). In addition, PVCs are not able to attract and retain talented investment professionals – when compared to IVCs – and are therefore unable to positively influence the performance of their portfolio companies. This restraints the ability of PVCs to attract private LPs as investors or private GPs as co-investors, since these form limited profit expectations. Finally, PVCs frequently support regional investment initiatives, driving investment to less innovative regions and underachieving companies, subordinating financial objectives to policy goals (Mason and Pierrakis, 2013). In fact, such regional VC funds tend to establish contacts in their neighborhoods, whose value creation resources might be less valuable when compared to other regions, leading to unintended effects that may contradict the aims of closing regional disparities in risk finance and entrepreneurship (Harrison and Mason, 2000; Sunley et al., 2005).

[21] Munari and Toschi (2015) based their research on a sample of 628 VC-backed companies in the United Kingdom, from 1998 to 2007, in which they are able to distinguish PVCs between regional and governmental types.

had a positive and significant performance on sales. Co-investing exemplifies the establishment of close relationships with the IVC community with the purpose of improving the performance of PVC initiatives, which is advocated by Hood (2000) and Lerner (2002).

Overall, the literature provides multiple and dissimilar results on the success of PVC programs, leading to the idea that there are no "one-size-fits-all" impacts and that their performance is significantly mediated by contextual conditions, not only on the supply-side but also on the demand-side.

In spite of its growing prominence, several authors highlight that public intervention on the VC and Entrepreneurial Financing markets lacks theoretical guidance (Avnimelech and Teubal, 2008; Lerner, 1999). Therefore, Governments often undertake programs without a clear understanding on the full consequences of their actions and without synchronizing political and investment cycles (Gilson, 2003). Murray (2007) understands that a standardized evaluation method is "urgently required" for better understanding the impact of PVC initiatives, alongside a set of best-in-class programs from which performance benchmarks could be derived (Jeng and Wells, 2000).

Avnimelech and Teubal (2008) provided a theoretical approach to guide public intervention on the Entrepreneurial Financing markets. Grounded on the successful initiatives by Israel, Chile and Korea, the authors propose a conceptual three stage model, where Government support is crucial on transiting countries from the first stage – where there is a *direct* public support to research and development initiatives – to the third stage, where they should essentially provide *indirect* support to the existing ecosystem of IVCs and Entrepreneurial Firms. During the second stage, Governments should simultaneously carry a *direct*, *indirect* or

hybrid intervention, as the *privatization* of finance is taken as a gradual process that should be adapted to the variety of countries' institutional, cultural and political contexts. Such evolutionary perspective was further described in Avnimelech et al. (2010) and Lerner and Tag (2013).

Still, in spite of such conceptual contributions, analytical grounded literature on the topic is scarce and, to the best of our knowledge, limited to Keuschnigg and Nielsen (2001) and Keuschnigg and Nielsen (2007). However, these do not deal with the topic of direct intervention of public authorities on the VC and Entrepreneurial Financing markets, but rather with the instruments that public authorities may use in order to indirectly stimulate equity financing markets. Other relevant existing theoretical contributions are focused on understanding the behavior and performance of private GPs and LPs, but not from a public intervention perspective (Liu and Yang, 2015; Sorensen et al., 2014).

Keuschnigg and Nielsen (2001) designed a partial equilibrium model for analyzing how government spending on entrepreneurial training, subsidies for investing in equipment and output subsidies may influence VC activity. Model outputs reveal that a subsidy for investing in equipment induce GPs to reduce their managerial support to investee firms, while an output subsidy should be neutral regarding professional advice. However, only entrepreneurial training provides welfare gains, by decreasing costs to market, and favoring industry output alongside firm creation. Still, improving entrepreneurial training holds the downside effect of crowding out managerial support from GPs to Entrepreneurial Firms.

Keuschnigg and Nielsen (2007) set up a two-period model in industry equilibrium with the purpose of analyzing how taxes and subsidies may contribute to foster the VC market, in terms

of quality and quantity of investees. Corporate income taxes reduce firm creation, even when the tax is paid by mature companies, as lowering the value of mature firms diminishes the gains from setting up new companies as well. Corporate income taxes will postpone and impair the reward to effort in Start-up Firms. Since subsidies are independent from firm performance, they do not strengthen incentives towards improved entrepreneurship quality and even reduce social welfare. Capital gains tax has an ambiguous effect on firm creation, while personal income tax holds a positive effect[22]. From a policy making perspective, and alongside Murray (1998), the authors highlight that public policy should be designed with the purpose of generating higher quality entrepreneurship, rather than higher firm creation volumes. Such theoretical findings are close to those of Holtz-Eakin (2000), whose empirical findings showed that introducing preferential tax treatments for VCs would not be enough to eliminate the *equity gap*, but somehow contradict Gompers and Lerner (2004), who found evidence of a moderately negative effect on the capital gains tax on VC investing and fund raising.

We intend to provide a contribution to fill this literature gap, by taking a real options perspective on the decision-making process faced by IVCs, PVCs and Governments in general, when considering investing in or subsidizing a certain Start-up Firm. In particular, we are interested in assessing (i) how optimum investment timing may change between IVCs and PVCs, (ii) how a co-investment by IVCs and PVCs might be put in place and how such co-

[22] Some of these results are not consistent with the empirical evidence provided by Da Rin et al. (2006) on a dataset of 14 European countries. The opening of stock markets provided a positive effect on the development of active VC markets, while reductions in the corporate capital gains tax rate increased the share of both high-tech and early stage investment. Additionally, a reduction in labor regulation also led to a higher share of high-tech investments and increased public spending on R&D was found not to have significant influence on the early stage investment.

investment will affect optimum investment timing, and (iii) how a subsidy might be set up with the purpose of anticipating optimum investment timing by IVCs.

On the IVC side, we will properly account for the partnership structure that features typical VC investing. In this setting, GPs will be compensated by the value creation effect of the investment they will back (essentially, the net present value from the investment on the Start-up Firm) – net of expected taxation on capital gains– and by the performance compensation GPs will earn if return on investment exceeds a certain benchmark (i.e., the carried interest).

When scrutinizing the decision-making process of PVCs, we will take into account that taxation is neutral for their capital budgeting process (i.e., tax expenditures borne by Start-up Firms stand for tax revenues to the Government), and, based on the literature findings, that investments undertaken by PVCs will generate a lower value creation effect than those carried by IVCs. In addition, assuming that optimum investment timing by IVCs is observed, we consider that PVCs take into account the opportunity cost they bear, as when investing on the Start-up Firm, PVCs forego the option of not undertaking the investment, waiting for the profitability of Start-up Firms to reach the trigger required by IVCs, and providing Governments with the benefits from incremental tax revenues without carrying any investment, either through a PVC organization or through a subsidy to the Entrepreneurial Firm. Our model explicitly deals with such waiting option.

We will also investigate the co-investment case, where IVCs invest alongside PVCs. We show that – on the absence of portfolio risk mitigation procedures, financing constraints, perceived investment performance contributions or other drivers of co-investment decisions – IVCs would only be willing to co-invest with PVCs if they are able to benefit from an *equity*

enhancement effect, which we will model as a share premium to be offered to IVCs by PVCs. Within this context, PVCs would be willing to co-invest and offer a share premium to IVCs with the purpose of benefiting from the incremental efficiency on investment outcomes and avoiding the opportunity cost borne when fully investing on Start-up Firms by themselves.

Finally, we compare the co-investment case with the subsidy case, in which Governments, instead of acting as PVCs, provide a subsidy to Start-up Firms with the purpose of supporting their investment, anticipating optimum investment timing from IVCs and benefiting from the incremental tax revenues brought by the exercise of such option to invest by IVCs.

Through a numerical example with representative assumptions on its underlying variables, model reveals that co-investment will actually be more effective in anticipating optimum investment timing than subsidies. This will allow us to derive a set of empirically testable propositions regarding the determinants of PVC, which we will investigate through a dataset of European countries.

The paper is structured as follows. In Section 2, we setup the real options framework that will support our investigation and present its underlying economic intuition through a numerical example. Based on such insights, we outline the major public policy and managerial implications in Section 3, while in Section 4, we point out the theoretical hypothesis that may govern the relevance of PVC initiatives and render an empirical study on their prevalence. We conclude in Section 5.

2. MODEL

Our setting comprises one Start-up Firm which is expected to generate a flow of profits before taxes and payroll named as *V*, following a Geometric Brownian Motion (GBM) diffusion process given by:

$$dV = \alpha V dt + \sigma V dz, \quad (1)$$

where $V > 0$, α stands for the trend parameter (i.e., the drift) and σ to the instantaneous volatility. Considering that agents shall be risk neutral within this setting, $\alpha = r - \delta$, where $r > 0$ is the risk-free rate and $\delta > 0$ stands for the asset yield. Lastly, *dz* is the increment of a Wiener process.

Assuming that no debt is available to support such investment opportunity, and that the Entrepreneur will support an exogenously determined $Q^E \in]0;1[$ fraction of the total capital expenditures, the Start-up Firm will be seeking for an equity investor – taken as a IVC and/ or a PVC – to obtain a capital commitment of $k > 0$, in exchange for a $(1 - Q^E)$ ownership. Entrepreneurs and investors are then assumed to share firm ownership according to the amount of capital that each party provided to the Start-up Firm[23].

The Start-up Firm will bear payroll costs amounting to *w.V*, where $w \in]0;1[$ and corporate income tax given by $T_C \in]0;1[$. Investors will be liable on capital gains tax – named as $T_G \in]0;1[$ – at the moment in which they will divest from the Start-up Firm – given by $ex > 0$ – while wages are subject to personal income tax, named as $T_P \in]0;1[$. If the Start-up Firm is

[23] Therefore, we implicitly assume that the Entrepreneur is able to offer the Start-up Firm an amount of capital equal to $Q^E \times \frac{k}{(1-Q^E)}$.

subsidized by the Government to support the investment amounting to *k*, it will get a subsidy named as *sub > 0*.

In the co-investment case, IVCs and PVCs will, respectively, hold a fraction q^{IVC} and $(1 - q^{IVC})$ of the remaining firm ownership $(1 - Q^E)$, while these two parties may agree on a share premium between them, named as p[24,25]. Therefore, when illustrating the results on the investment case performed by the IVC where no co-investment takes place, we will assume that $q^{IVC} = 1, p = 0$ and $sub = 0$, while when going through the investment case performed by the PVC without co-investment, we will assume that $q^{IVC} = 0, p = 0$ and $sub = 0$. In Section 2.3, we analyze the co-investment case, in which q^{IVC} will let be exogenously determined and *p* will be computed such that IVCs and PVCs hold the same optimum investment trigger on *V*.

2.1. The option to invest in the Start-up Firm held by the IVC

Taking into account the typical structuring of venture partnerships, we assume that this investment opportunity shall be screened by an established IVC fund, whose GP is entitled to decide whether to invest or not. GPs usually hold a minor stake on the IVC fund – named as $i \in]0; 1[$ – and benefit from a performance-based compensation mechanism (i.e., the carried interest). Considering that the GP and its IVC fund are already established during investment

[24] The holding retained by the Entrepreneur given by Q^E remains unchanged in the co-investment case.

[25] As a result, IVCs will retain a $(1 - Q^E) \times (q^{IVC} + p)$ share on the Start-up Firm, while PVCs will retain a $(1 - Q^E) \times (1 - q^{IVC} - p)$ share on the Start-up Firm.

screening, we assume that there are no incremental revenues or costs rising from management fees or increasing monitoring costs when GPs exercise the option to invest[26].

Following the contingent-claim approach presented by Dixit and Pindyck (1994), the value of the option to invest in the Start-up Firm – $IVC(V)$ – must satisfy the following ordinary differential equation (ODE):

$$\frac{1}{2}\,\sigma^2\,V^2\,IVC''(V) + (r-\delta)\,V\,IVC'(V) - r\,IVC(V) = 0 \qquad (2)$$

The general solution for (2) is:

$$IVC(V) = A\,V^{\beta_1} + B\,V^{\beta_2}, \qquad (3)$$

where A and B are constants to be determined, while β_1 and β_2 are the roots of the fundamental quadratic, given by:

$$\mathcal{Q}_{IVC} = \tfrac{1}{2}\sigma^2\beta(\beta-1) + (r-\delta)\beta - r = 0, \qquad (4)$$

i.e.,

[26] Typically, management fee structure changes throughout fund life. During the investment period, management fees are charged over total committed capital, while during the divestment period, they are charged over the acquisition cost of portfolio firms. In this sense, it could be argued that deploying a greater amount of capital on the acquisition of portfolio firms would lead GPs to perceive an incremental revenue on the divestment period, which should be introduced on their decision-making model. However, if GPs are profit-maximizers, they have strong incentives to fully deploy the committed capital during the investment stage with the purpose of maximizing their management fees during the divestment period. As a result, regardless of the amount *k*, GPs will always be seeking for additional investment opportunities to exhaust the committed capital and benefit from management-fee maximization. This understanding allows us to consider that management fees may not be regarded as incremental revenues during the screening stage of one given investment opportunity. Still, and even though that is not the focus of this paper, we acknowledge that when comparing two different investment opportunities, GPs hold an economic incentive to prefer the one requiring the greatest amount of capital *k*.

$$\beta_1 = \frac{1}{2} - \frac{(r-\delta)}{\sigma^2} + \sqrt{\left(\frac{r-\delta}{\sigma^2} - \frac{1}{2}\right)^2 + \frac{2r}{\sigma^2}} > 1 \quad (5)$$

$$\beta_2 = \frac{1}{2} - \frac{(r-\delta)}{\sigma^2} - \sqrt{\left(\frac{r-\delta}{\sigma^2} - \frac{1}{2}\right)^2 + \frac{2r}{\sigma^2}} < 0 \quad (6)$$

Assuming that V_{IVC}^* stands for the optimal trigger for the IVC to exercise the option to invest in this investment opportunity, and naming $NPV_{IVC}(V)$ as its pre-capital gains tax net present value, $i.CGT_{IVC}(V_{IVC}^*)$ as the value of the expected capital gains tax and $CI(V)$ as the value of the carried interest earned by the GP (i.e., its performance based compensation), the problem must be solved by considering the following boundary conditions:

$$IVC(0) = 0 \quad (7)$$

$$IVC(V_{IVC}^*) = NPV_{IVC}(V_{IVC}^*) - i.CGT_{IVC}(V_{IVC}^*) + CI(V_{IVC}^*) \quad (8)$$

$$IVC'(V_{IVC}^*) = NPV_{IVC}{}'(V_{IVC}^*) - i.CGT_{IVC}{}'(V_{IVC}^*) + CI'(V_{IVC}^*) \quad (9)$$

Respecting condition (7) and noting that $\beta_2 < 0$, then B on equation (3) must be equal to zero. Therefore, $\beta \equiv \beta_1$. The unknowns A and V_{IVC}^* are obtained by combining conditions (8) and (9), i.e., the value matching and the smooth pasting conditions, respectively[27]. The interpretation of the value matching condition is straightforward: at the moment in which GPs exercise an option to invest in a Start-up Firm, these are entitled to the net present value of such investment given by $NPV_{IVC}(V_{IVC}^*)$, and to the contribution to its carried interest that such

[27] Notice that we do not provide closed-form solutions to this system of equations since it is not possible to obtain closed-form derivatives for $CGT_{IVC}(V_{IVC}^*)$ and $CI(V_{IVC}^*)$, as these will depend on the integral of the cumulative normal distribution density function in order to *t*.

investment opportunity will generate – given by $CI(V_{IVC}^*)$ – net of the capital gains tax GPs are expected to be liable on at the moment in which it divests, given by $i.CGT_{IVC}(V_{IVC}^*)$. We now analytically define each of these three components.

First, $NPV_{IVC}(V)$ shall essentially portray the fraction of the payoff on the investment on the Start-up Firm which is attributable to the GP – given by i. The LPs of the VC fund shall then provide $(1-i)(1-Q^E)$ to support the Start-up Firm. However, and excluding the carried interest, the payoffs for such flow are actually irrelevant for GP, as these are the discretionary fund managers of the IVC fund.

$$NPV_{IVC}(V) = \left(\frac{V(1-w)}{\delta} + sub\right)(1-T_C)(1-Q^E)(q^{IVC}+p)i - kq^{IVC}i \qquad (10)$$

Second, carried interest is contingent on the realized payoff of the investment at the exit date. If such a realized payoff exceeds a given hurdle – determined by the hurdle rate $h > 0$ – GPs are entitled to a fraction $s > 0$ of that excess payoff. Such divestment is expected to occur on the moment $ex > 0$ after the investment is made[28]. Considering that the payoff from such variable compensation resembles that of a call option, we compute $CI(V)$ similarly to Sorensen et al. (2014)[29] following the classic approach by Black and Scholes (1973) and Scholes (1976).

[28] With the purpose of keeping results as tractable as possible, we assume that when screening a given investment opportunity, GPs will take into account the expected value of such performance based compensation. Still, the actual carried interest attributable to GP might be pooled against the overall performance of the VC fund and not awarded to GPs individually, on each of the realized investments. This is more frequent in Europe than in the USA, where carried interest is usually computed and paid to GPs on a deal by deal basis. We will briefly discuss the impact of the pooling effect in Section 3.

[29] Unlike Sorensen et al. (2014) and for tractability purposes, we did not include the "catch-up" region, in which GPs are awarded with a fraction (typically, 100%) of the payoffs above the hurdle until they are entitled with the same share $s > 0$ of the payoffs which are below the hurdle. For similar reasons, we did not account for transaction costs which might be borne by IVCs and PVCs both on investment and divestment, including potential performance fees due to the management of the portfolio firm (commonly mentioned as "ratchet"). Estimates presented by Hunter and Jagtiani (2003) reveal that, on a sample of 635 mergers and acquisitions involving public companies from 1985 to 2004, mean advisory fees stand for 0.524% and 0.659% of the deal value for acquirers

Taking $GR_{IVC}(V)$ as the gross return of the IVC fund on the investment and $H(k)$ as the hurdle, we have:

$$CI(V) = \left[GR_{IVC}(V)e^{-\delta\, ex}N(d1_{CI}) - H(k)e^{-r\, ex}N(d2_{CI})\right](1-i)(1-T_C)s, \qquad (11)$$

where *N(z)* stands for the cumulative normal distribution density function, and

$$GR_{IVC}(V) = \left(\frac{V(1-w)}{\delta} + sub\right)(1-T_C)(1-Q^E)(q^{IVC}+p) \qquad (12)$$

$$H(k) = \int_0^{ex} k\, e^{h\, t}dt \qquad (13)$$

$$d1_{CI} = \frac{log\left(\frac{GR_{IVC}(V)}{H(k)}\right) + ex(r - \delta - \frac{\sigma^2}{2})}{\sigma\sqrt{ex}} \qquad (14)$$

$$d2_{CI} = d1_{CI} - \sigma\sqrt{ex} \qquad (15)$$

Finally, and similarly to carried interest, we define $CGT_{IVC}(V)$ as a short position on a call option, given that taxation on capital gains is contingent on *V* at the moment in which the divestment takes place – since taxation will only occur if divestment consideration exceeds the invested capital *k*. This is similar to a hurdle on carried interest when *h = 0*, as shown below:

$$CGT_{IVC}(V) = \left[GR_{IVC}(V)e^{-\delta\, ex}N\left(d1_{CGT_{IVC}}\right) - q^{IVC}ke^{-r\, ex}N\left(d2_{CGT_{IVC}}\right)\right]T_G, \qquad (16)$$

where $GR_{IVC}(V)$ is the same as before, and

and targets, respectively. We argue that these should be greater on the PE and especially on the VC segment, as deals with private firms are smaller and information asymmetries are more severe, driving acquirers to undertake relatively more time consuming due diligence procedures.

$$d1_{CGT_{IVC}} = \frac{log\left(\frac{GR_{IVC}(V)}{q^{IVC}k}\right) + ex(r - \delta - \frac{\sigma^2}{2})}{\sigma\sqrt{ex}} \quad (17)$$

$$d2_{CGT_{IVC}} = d1_{CGT} - \sigma\sqrt{ex} \quad (18)$$

For generalization purposes – and in order to avoid redundancies with Section 2.3, where we will handle the co-investment case – we kept q^{IVC}, p, and sub on the above formulation. However, please bear in mind that, in this case, we will set $q^{IVC} = 1$, $p = 0$ and $sub = 0$.

2.2. The option to invest in the Start-up Firm held by the PVC

PVCs might be regarded as a specific type of VC organization where Governments simultaneously act as GPs and LPs (Murray, 2007). Therefore, from a public policy perspective, we take PVCs as neutral to carried interest, management fees and any other form of GP compensation that might be set on the PVC organization. For an analogous reason, we take PVCs as neutral to taxation, since Governments offset the tax expenditures borne by portfolio firms through their own tax collection[30]. In fact, one may regard such incremental tax revenues as a proxy of the social welfare generated by the investment opportunity or some kind of spillover effect from Government spending.

Based on the recent literature findings by Grilli and Murtinu (2015) and on the more general assessment of public sector inefficiency in output generation (Adam et al., 2011; Afonso et al.,

[30] We excluded Social Security charges as an incremental tax revenue in the sense that, unlike other income taxes, such incremental revenue leads to an incremental liability related to state pensions or social protection.

2005; Afonso et al., 2010; Gao, 2015), we assume that the value generation effect of the investment undertaken by PVCs will be lower than the one by IVCs by $(1 - \phi)$ and $\phi > 0$.

In addition, assuming that Government is able to observe the investment behavior of IVC, when exercising the option to invest on the Start-up Firm, Governments forego the option to wait for its profitability V to reach V_{IVC}^{*}, let IVC perform the investment on the Start-up Firm and obtain an incremental tax revenue, without having to carry any expenditure on the Start-up Firm. Therefore, when valuing the option to invest in the Start-up Firm, Governments take into account this short position on this contingent asset, which we value as a *cash-or-nothing binary barrier option* (Rubinstein and Reiner, 1991). These options pay a pre-determined amount of cash – in our case, the incremental tax revenues – whether during a certain period of time – given by *ex* – the underlying asset – given by V – reaches a given barrier, which stands for the optimum investment trigger held by the IVC, and named as V_{IVC}^{*}. This opportunity cost is then modelled as a short position on a binary barrier option and shall be named as $\Psi(V)$.

For similar reasons to the previous Section, and except otherwise mentioned, we kept q^{IVC}, p, and sub on the above formulation. However, please bear in mind that, in this case, we will set $q^{IVC} = 0$, $p = 0$ and $sub = 0$.

Following the contingent-claim approach as before, the value of the option held by the PVC to invest in the Start-up Firm – $PVC(V)$ – must satisfy the following ordinary differential equation (ODE):

$$\frac{1}{2}\,\sigma^2\,V^2\,PVC''(V) + (r - \delta)\,V\,PVC'(V) - r\,PVC(V) = 0 \qquad (19)$$

The general solution for (19) is:

$$PVC(V) = C\,V^{\beta_1} + D\,V^{\beta_2}, \tag{20}$$

where *C* and *D* are constants to be determined, and β_1 and β_2 are the previously derived roots of the fundamental quadratic given by:

$$\mathcal{Q}_{PVC} = \frac{1}{2}\sigma^2\beta(\beta-1) + (r-\delta)\beta - r = 0, \tag{21}$$

Considering that V^*_{PVC} stands for the optimal trigger for the PVC to exercise the option to invest in the Start-up Firm, the problem must be solved by considering the following boundary conditions, in which $NPV_{PVC}(V)$ is net present value of the investment undertaken by the PVC, $\tau(V)$ stands for the incremental tax revenues that the Government benefits from, and $\Psi(V)$ stands for the opportunity cost borne by Governments from not benefiting from the incremental tax revenues that would be obtained if the IVC invested on the Start-up Firm instead:

$$PVC(0) = 0 \tag{22}$$

$$PVC(V^*_{PVC}) = NPV_{PVC}(V^*_{PVC}) - CGT_{PVC}(V) + \tau(V^*_{PVC}) - \Psi(V^*_{PVC}) \tag{23}$$

$$PVC'^{(V^*_{PVC})} = NPV_{PVC}^{\prime(V^*_{PVC})} - CGT_{IVC}^{\prime(V)} + \tau'(V^*_{PVC}) - \Psi'(V^*_{PVC}) \tag{24}$$

Respecting condition (22) and noting that $\beta_2 < 0$, then *D* on equation (20) must be equal to zero and, as before, $\beta \equiv \beta_1$. The unknowns *C* and V^*_{PVC} are obtained by combining equations (23) and (24), i.e., the value matching and smooth pasting conditions, respectively. Again, the interpretation of the value matching condition is direct. Similarly to IVCs, at the optimum investment timing, PVCs are entitled to the net present value of the investment on the Start-up Firm – $NPV_{PVC}(V^*_{PVC})$ – which should be net of the expected capital gains tax, given by $CGT_{PVC}(V)$. However, unlike IVCs, PVCs benefit from additional corporate, personal and

capital gains tax revenues rising from exercising the option to invest on the Start-Up Firm – $\tau(V_{PVC}^*)$ – and lose the contingent asset $\Psi(V_{PVC}^*)$, which stands for the incremental tax revenues that Governments would obtain if profitability of the Start-up Firm reaches V_{IVC}^* and IVCs exercise their option to invest. We will now depict each of these individual components.

Formulations for $NPV_{PVC}(V)$, $CGT_{PVC}(V)$ are respectively similar to $NPV_{IVC}(V)$ and $CGT_{IVC}(V)$, except for the holding on the Start-up Firm – which will be $(1-Q^E)(1-q^{IVC}-p)$ instead of $(1-Q^E)(q^{IVC}+p)i$ – and for the inefficiency factor on the value creation effect of the investment in the Start-up Firm, which will lead us to introduce the $(1-\phi)$ coefficient, with $\phi > 0$. As a result, $NPV_{PVC}(V)$ and $CGT_{PVC}(V)$ are defined as follows:

$$NPV_{PVC}(V) = \left(\frac{V(1-\phi)(1-w)}{\delta} + sub\right)(1-T_C)(1-Q^E)(1-q^{IVC}-p) - k(1-q^{IVC}) \quad (25)$$

$$CGT_{PVC}(V) = \left[GR_{PVC}(V)e^{-\delta\, ex}N\left(d1_{CGT_{PVC}}\right) - (1-q^{IVC})ke^{-r\, ex}N\left(d2_{CGT_{PVC}}\right)\right]T_G, \quad (26)$$

where

$$GR_{PVC}(V) = \left(\frac{V(1-\phi)(1-T_C)(1-w)}{\delta} + sub\right)(1-T_C)(1-Q^E)(1-q^{IVC}-p) \quad (27)$$

and $N\left(d1_{CGT_{PVC}}\right)$ and $N\left(d2_{CGT_{PVC}}\right)$ are obtained by replacing $GR_{IVC}(V)$ for $GR_{PVC}(V)$ and $q^{IVC}k$ for $(1-q^{IVC})k$ in $N\left(d1_{CGT_{IVC}}\right)$ and $N\left(d2_{CGT_{IVC}}\right)$, i.e., equations (14) and (15), respectively.

The tax collection brought to Governments and rising from the exercise of the option to invest in the Start-Up Firm is given by $\tau(V)$, which will account for either corporate income

tax – given by $C_{TAX}(V)$ – personal income tax – named as $P_{TAX}(V)$ – and capital gains tax collection – set as $CGT_{PVC}(V)$ – as follows:

$$\tau(V) = C_{TAX}(V) + P_{TAX}(V) + CGT_{PVC}(V), \tag{28}$$

where $CGT_{PVC}(V)$ is derived in equation (26), and

$$C_{TAX}(V) = \left(\frac{V(1-\phi)(1-T_C)(1-w)}{\delta} + sub\right)T_C \tag{29}$$

$$P_{TAX}(V) = \frac{Vw}{\delta}T_P \tag{30}$$

Assuming that PVC is able to observe V^*_{IVC}, the contingent asset $\Psi(V^*_{PVC})$ stands for a set of potential incremental tax revenues to the Government – named Δ_τ(V) – that will be valued as a *cash-or-nothing binary barrier option* (Rubinstein and Reiner, 1991), provided that such contingent benefit will only be earned by the Government if *V* hits a certain barrier given by V^*_{IVC}. Such incremental tax revenues are obtained by comparing tax revenues when $qIVC = 1$ and $qIVC = 0$, as shown in equations (36) and (37). Incremental tax revenues are caused by the higher taxable income generation rate of the IVC on the investee firm (which we take as ϕ) – bringing both incremental corporate income tax and capital gains tax revenues to the Government – and by the incremental corporate income tax revenues over the carried interest – set as $CI(V)$ – earned by the GP of the IVC fund. We then have:

$$\Psi(V) = \Delta_\tau(\mathrm{V})\left[\left(\frac{V^*_{IVC}}{V}\right)^{a+b} N(-z) + \left(\frac{V^*_{IVC}}{V}\right)^{a-b} N\left(-z + 2\,b\,\sigma\sqrt{ex}\right)\right], \tag{31}$$

where

$$a = \frac{r - \delta}{\sigma^2} \tag{32}$$

$$b = \sqrt{\frac{(r - \delta)^2 + 2\log(1 + r)\,\sigma^2}{\sigma^2}} \tag{33}$$

$$z = \frac{\log(\frac{V^*_{IVC}}{V})}{\sigma\sqrt{ex}} + b\,\sigma\,\sqrt{ex} \tag{34}$$

$$\Delta_\tau(V) = \Delta C_{TAX}(V) + \Delta CGT(V), \text{ and} \tag{35}$$

$$\Delta C_{TAX}(V) = \frac{V\phi}{\delta} T_C + \frac{T_C}{1 - T_C} \overbrace{CI(V)}^{qIVC\,=\,1} \tag{36}$$

$$\Delta CGT(V) = \overbrace{CGT_{IVC}(V)}^{qIVC\,=\,1} - \overbrace{CGT_{PVC}(V)}^{qIVC\,=\,0} \tag{37}$$

2.3. The option to co-invest in the Start-up Firm held by the PVC

On the co-investment case, we let the proportion of capital to be provided by IVCs and PVCs – given by $qIVC$ and $(1 - qIVC)$ – to be exogenously determined, and let IVCs and PVCs set the share premium p[31], which will enable both parties to have the same optimum investment timing, and co-investment to take place. Such share premium p is obtained by equating their

[31] One could argue that $qIVC$ could also serve the purpose of aligning optimum investment timing. However, in the absence of capital constraints or any other effects not explicitly derived by our framework, changing $qIVC$will not affect V^*_{IVC} or V^*_{PVC}, since it only lead the whole investment opportunity and its value matching conditions to become proportionately smaller or larger, yielding no effect on optimum investment timing.

respective triggers $V^*$and solving for p, and stands for an *equity enhancement* effect that the Government is willing to provide to IVCs, in the sense of Murray (2007).

From the perspective of the IVC, no changes occur to the setting presented in Section 2.1, where no co-investment took place, except that $qIVC \in]0;1[$, instead of $qIVC = 1$ and we do not impose that $p = 0$, as p shall be endogenously determined[32]. Therefore, and as before, we obtain the relevant unknowns A and V_{IVC}^* by combining conditions (8) and (9), while $IVC(V)$ remains as the relevant function for portraying the value of the option to invest in the Start-up Firm held by the IVC.

Things change a little from the perspective of the PVC for three reasons. First, we assume that co-investing allows the inefficient factor ϕ to be eliminated, which is equivalent to set $\phi = 0$ in the no co-investment case presented in Section 2.2. Second, and for the same reason, when exercising the option to co-invest, the Government does not forego the contingent asset $\Psi(V)$, since that there are no incremental tax revenues lost. Third, total tax revenues generated to the Government in this setting – to be named as $\tau_{CO}(V)$ instead of $\tau(V)$ – should include capital gains tax arising from the investment performed by IVCs and PVCs – named as $CGT_{PVC_{CO}}(V_{PVC_{CO}})$ – and should include corporate income tax on the carried interest, which is expected to be earned by the GP of the IVC fund. With this purpose, we set $C_{TAX_{CO}}(V_{PVC_{CO}})$ to capture the amount of corporate income tax revenues which are generated in this setting.

[32] In addition, $sub = 0$ is maintained.

We define $PVC_{CO}(V)$ as the function of the option to co-invest in the Start-up Firm, which is obtained similarly to $PVC(V)$, but considering the following alternative set of boundary conditions:

$$PVC_{CO}(0) = 0 \tag{38}$$

$$PVC_{CO}\left(V^*_{PVC_{CO}}\right) = \overbrace{NPV_{PVC}\left(V^*_{PVC_{CO}}\right)}^{\phi=0} - \overbrace{CGT_{PVC}\left(V^*_{PVC_{CO}}\right)}^{\phi=0} + \tau_{CO}\left(V^*_{PVC_{CO}}\right) \tag{39}$$

$$PVC_{CO}{}'\left(V^*_{PVC_{CO}}\right) = \overbrace{NPV_{PVC}{}'\left(V^*_{PVC_{CO}}\right)}^{\phi=0} - \overbrace{CGT_{PVC}{}'\left(V^*_{PVC_{CO}}\right)}^{\phi=0} + \tau_{CO}{}'\left(V^*_{PVC_{CO}}\right), \tag{40}$$

where

$$\tau_{CO}(V) = C_{TAX_{CO}}(V) + P_{TAX}(V) + CGT_{PVC_{CO}}(V), \tag{41}$$

and

$$C_{TAX_{CO}}(V) = \overbrace{C_{TAX}(V)}^{\phi=0} + \frac{T_C}{1-T_C}\overbrace{CI(V)}^{qIVC=\overline{qIVC}} \tag{42}$$

$$CGT_{PVC_{CO}}(V) = \overbrace{CGT_{PVC}(V)}^{\phi=0} + CGT_{IVC}(V) \tag{43}$$

Analogously to Section 2.2, considering condition (38) and noting that $\beta_2 < 0$, D on equation (20) must be equal to zero and $\beta \equiv \beta_1$ as before. The unknowns C and $V^*_{PVC_{CO}}$ are obtained by combining equations (39) and (40), i.e., the value matching and smooth pasting conditions, respectively. By equating $V^*_{PVC_{CO}}$ and V^*_{IVC} and solving for p, we obtain the optimum share premium p^*, that would allow IVCs and PVCs to jointly co-invest on the Start-up Firm.

2.4. The option to subsidize the Start-up Firm held by the Government

In this setting, we assume that instead of investing or co-investing in the Start-up Firm through its PVC organization, Governments may choose to provide a subsidy to the Start-up Firm, which we name as $sub > 0$. The decision to provide or not such subsidy may also be pictured as a real option as in Dixit and Pindyck (1994) for two reasons. On the one hand, by subsidizing the Start-up Firm, the Government is entitled to benefit from incremental tax revenues from corporate income tax, personal income tax and capital gains tax and, in this sense, the subsidizing decision might be regarded as an investment decision. On the other hand, the flexibility held by the Government in deciding when to support the Start-up Firm, allows the Government to determine the profitability trigger of the Start-up Firm for which it will be willing to subsidize it.

Notwithstanding, the amount of the subsidy that Governments may be willing to offer, may not be enough for the Start-up Firm to be able to perform the envisaged investment on its own. As a result and in any case, we assume that the Start-up Firm will still have to seek for an external equity provider, which we will assume to be an IVC fund with the decision-making process we described in Section 2.1. We will then consider that $qIVC = 1$ and that $sub = 0$[33].

Thus the option to subsidy the Start-up Firm also becomes a "co-investment" decision, in the sense that both the Government and the IVC (managed by its GP) should be simultaneously willing to fund the Start-up Firm so that the investment opportunity might be undertaken. The former should be willing to provide a subsidy, while the latter should be willing to underwrite

[33] We also maintain that $p = 0$ and $\phi = 0$ in this setting.

an equity issuance. We shall now formulate $\mathcal{S}(V)$ – the option to subsidy the Start-up Firm held by the Government – so that the optimum subsidy can be derived.

Following the contingent-claims approach, $\mathcal{S}(V)$ must satisfy the ODE described in equation (44), whose general solution is presented in (45):

$$\frac{1}{2}\,\sigma^2\,V^2\,\mathcal{S}''(V) + (r-\delta)\,V\,\mathcal{S}'(V) - r\,\mathcal{S}(V) = 0, \tag{44}$$

$$\mathcal{S}(V) = E\,V^{\beta_1} + F\,V^{\beta_2} \tag{45}$$

E and *F* are constants to be determined, while β_1 and β_2 are the previously derived roots of the fundamental quadratic given by:

$$Q_{\mathcal{S}} = \frac{1}{2}\sigma^2\beta(\beta-1) + (r-\delta)\beta - r = 0, \tag{46}$$

Naming $V_{\mathcal{S}}^*$ as the optimal trigger for the Government to exercise the option to subsidy the Start-up Firm, the problem is solved by introducing the following boundary conditions, in which $\tau_{\mathcal{S}}(V)$ is the incremental tax revenues that the Government benefits from and *sub* is the amount of the subsidy to be awarded to the Start-up Firm:

$$\mathcal{S}(0) = 0 \tag{47}$$

$$\mathcal{S}(V_{\mathcal{S}}^*) = \tau_{\mathcal{S}}(V) - sub \tag{48}$$

$$\mathcal{S}'(V_{\mathcal{S}}^*) = \tau_{\mathcal{S}}{}'(V), \tag{49}$$

where

$$\tau_S(V) = C_{TAX_S}(V) + P_{TAX}(V) + \overbrace{CGT_{IVC}(V)}^{qIVC=1} \tag{50}$$

and

$$C_{TAX_S}(V) = \overbrace{C_{TAX}(V)}^{\phi=0} + \frac{T_C}{1-T_C}\overbrace{CI(V)}^{qIVC=1} \tag{51}$$

Regarding condition (47) and considering that $\beta_2 < 0$, then F on equation (45) must be equal to zero and, as before, $\beta \equiv \beta_1$. The unknowns E and V_S^* are obtained by combining equations (48) and (49), i.e., the value matching and smooth pasting conditions, respectively. Finally, we obtain the optimum subsidy sub^* by equating V_S^* and V_{IVC}^* and solving for *sub*.

2.5. Numerical example

This illustration aims to demonstrate the numerical solutions for the framework we derived on the previous Sections and highlight the economic intuition that governs its results. With this purpose, we will render a set of sensitivities on the base case for all of its relevant variables. A summary of key variables and numerical parameters is presented in Table 1. Where possible, we use parameters from Sorensen et al. (2014).

Our assumption for *w* was computed through a sample of 4,523,712 companies obtained in Bureau van Dijk – Amadeus (Amadeus) database for the 2011 to 2014 period, covering firms located in Austria, Belgium, Cyprus, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Liechtenstein, Luxembourg, Malta, Monaco, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, and United Kingdom, and excluding companies from the financial services, real estate and insurance industries. As costs with payroll available in

Amadeus include Social Security charges and *w* does not, we grossed-down those through an estimate of the average employer Social Security contributions obtained on the OECD Tax Database, for the same period, whose sample included European-only OECD members.

Variable	Symbol	**Parameter**	Symbol	Value	Source
Earnings before taxes and gross payroll	V	Risk-free rate	r	0.05	Sorensen et al. (2014)
IVC's investment trigger on *V*	V_{IVC}^{*}	Volatility on *V*	σ	0.25	Liu and Yang (2015)
PVC's investment trigger on *V*	V_{PVC}^{*}	Expected Start-up Firm return	δ	0.11	Sorensen et al. (2014)
Co-investment trigger on *V*	V_{CO}^{*}	Amount of the investment	k	150	-
Optimum share premium	p^{*}	Gross payroll on *V*	w	0.60	Bureau van Dijk Amadeus
Subsidy trigger on *V*	V_{S}^{*}	Ownership retained by the Entrepreneur	Q^{E}	0.20	-
Optimum subsidy	sub^{*}	Co-investor ownership allocated to IVC	q^{IVC}	0.50	-
IVC's Start-up Firm investment value to investment opportunity value at trigger	ωNPV_{IVC}	PVC efficiency gap	ϕ	0.18	Afonso et al. (2005), Afonso et al. (2010), Adam et al. (2011) and Gao (2015)
IVC's capital tax liability to investment opportunity value at trigger	ωCGT	Average personal income tax	T_P	0.19	OECD
IVC's carried interest value to investment opportunity value at trigger	ωCI	Average effective corporate income tax	T_C	0.25	Eurostat et al. (2015)
PVC's Start-up Firm investment value to investment opportunity value at trigger	ωNPV_{PVC}	Average capital gains tax at fund level	T_G	0.15	EVCA (2013)[34]
PVC's incremental tax revenues to investment opportunity value at trigger	ωTAX	Expected holding period (years)	ex	4.00	Braun et al. (2015)
PVC's contingent asset value to investment opportunity value at trigger	$\omega\psi$	Hurdle rate	h	0.08	Metrick and Yasuda (2011), Sorensen et al. (2014), Liu and Yang (2015)
Output Parameters		Carried interest	s	0.20	Sorensen et al. (2014)
β = 3.39 a = 0.96 b = 0.39		GP stake on the IVC fund	i	0.01	-

Table 1. Baseline variables and assumptions

Our assumption for ϕ was based on an arithmetic average from the estimates of the output efficiency gap on public spending for European countries, presented in Afonso et al. (2005),

[34] We assumed $T_G = 15.0\%$ as the average minimum and maximum capital gains tax at fund level reported for Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, the United Kingdom and the United States.

Afonso et al. (2010), Adam et al. (2011) and Gao (2015), amounting to 16.0%, 22.0%, 27.0% and 6.0%, respectively. Excluding the lower estimate from Gao (2015) would lead to $\phi = 22.0\%$ instead of $\phi = 18.0\%$, which we would not materially change results. Still, we will run sensitivities on ϕ and show that the economic intuition of our results remains unchanged.

The list of variables resembles the set of decision-making criteria that were introduced in the previous Sections – namely, V_{IVC}^*, V_{PVC}^*, V_{CO}^* and V_S^* – while introducing ωNPV_{IVC}, ωCGT, ωCI, ωNPV_{PVC}, ωTAX and $\omega\psi$. This group of variables is intended to capture the weight that each of these components holds on the value of the investment opportunity when IVCs and PVCs exercise their option to invest in the Start-up Firm, i.e., when $V = V_{IVC}^*$ and $V = V_{PVC}^*$. Formally, and for example,

$$\omega NPV_{IVC} = \frac{NPV_{IVC}(V_{IVC}^*)}{IVC(V_{IVC}^*)} \tag{52}$$

$$\omega TAX = \frac{\tau(V_{PVC}^*) - CGT_{PVC}(V)}{PVC(V_{IVC}^*)} \tag{53}$$

Analyzing these output variables will also allow us to depict how value creation is governed when IVCs and PVCs exercise their option to invest in the Start-up Firm.

Following our discussion from Section 1, we take the view that investing in early stage Start-up Firms generates *positive externalities* (Lerner, 1999; Lerner, 2002). As a result, from a public policy perspective, we assume that Governments will be interested in fostering investment volumes in such firm segment. We will then compare how each of the four different deal arrangements anticipate optimum investment timing or, equivalently, minimize optimum profitability triggers.

2.5.1. Baseline results

Our baseline results show that $V_{IVC}^{*} = 99.12$, $V_{PVC}^{*} = 75.32$, $V_{CO}^{*} = 51.80$ with $p^{*} = 45.7\%$ and $V_{S}^{*} = 57.10$ with $sub^{*} = 106.33$, meaning that $V_{IVC}^{*} > V_{PVC}^{*} > V_{S}^{*} > V_{CO}^{*}$.

Taxation on personal income, taxation on corporate income, as well as taxation on capital gains that would be borne by PVCs, allow Governments to generate a set of incremental revenues from exercising the option to invest, when compared to IVCs, enabling them to offset their efficiency gap – measured by ϕ – and still significantly exceed the return on investment obtained by IVCs. As a result, we find that $V_{IVC}^{*} > V_{PVC}^{*}$.

Our results also reveal that $V_{S}^{*} > V_{CO}^{*}$. On each of these two scenarios, Governments benefit from incremental revenue taxes, since by letting IVC co-invest alongside PVC or by letting IVC invest on the Start-up Firm and then partly subsidizing *k*, they do not bear the efficiency gap when PVCs invest on their own. From the perspective of the IVC, the subsidy provides a one-time effect on the value of the investment opportunity, while co-investing generates an actual *equity enhancement* effect (Murray, 2007), as IVCs provide $(1 - Q^{E})\, q^{IVC} = (1 - 20.0\%) \times 50.0\% = 40.0\%$ of the required capital, but retain a $(1 - Q^{E})\,(q^{IVC} + p^{*}) = (1 - 20.0\%) \times (50.0\% + 45.7\%) = 76.5\%$ share on the Start-up Firm. In the absence of capital constraints, portfolio risk mitigation and value creation policies held by IVCs, we show that a mere allocation of money from PVCs on the co-investment is not enough for anticipating their optimum investment timing.

As the baseline example illustrated some of the intuition governing the framework derived throughout the previous Sections, we now carry a set of sensitivity analysis with the purpose of further depicting results and highlighting further insights to our research.

2.5.2. Efficiency gap (ϕ) and gross payroll on V (w)

The results of the sensitivity analysis on ϕ and w are presented in Table 2. As expected, an increase in w leads to an increase in V_{IVC}^*, V_{PVC}^*, V_{CO}^* and V_S^*, as it decreases the profitability of the Start-up Firm. In turn, the greater the efficiency gap measured by ϕ is, the greater V_{PVC}^* is, as the value of the investment on the Start-up Firm becomes lower for PVCs. In addition, we observe that the greater the efficiency gap is, the greater is the gap between $V_{PVC}^*$and $V_{CO}^*$is or, equivalently, the lower the ratio $\frac{V_{CO}^*}{V_{PVC}^*}$ is. For example, when $\phi = 0.12$ and $w = 0.45$, $\frac{V_{CO}^*}{V_{PVC}^*} =$ 83.1%, but when ϕ increases to $\phi = 0.24$, $\frac{V_{CO}^*}{V_{PVC}^*} = 65.7\%$. Therefore, we conjecture that more inefficient Governments should be more likely to make use of co-investing, as incremental tax revenues become more significant. V_{IVC}^*, V_{CO}^* and V_S^* remain unchanged to changes in ϕ as they do not depend on this parameter. When the investment is carried by IVCs, whether it is subsidized or not, or when co-investment takes place, $\phi = 0$.

	$\boldsymbol{\phi = 0.12}$		$\boldsymbol{\phi = 0.18}$		$\boldsymbol{\phi = 0.24}$	
$\boldsymbol{w = 0.45}$	$V_{IVC}^* = 72.09$	$V_{PVC}^* = 51.18$	$V_{IVC}^* = 72.09$	$V_{PVC}^* = 57.04$	$V_{IVC}^* = 72.09$	$V_{PVC}^* = 64.65$
	$V_{CO}^* = 42.53$ $p^* = 34.7\%$	$V_S^* = 46.22$ $sub^* = 89.89$	$V_{CO}^* = 42.53$ $p^* = 34.7\%$	$V_S^* = 46.22$ $sub^* = 89.89$	$V_{CO}^* = 42.53$ $p^* = 34.7\%$	$V_S^* = 46.22$ $sub^* = 89.89$
$\boldsymbol{w = 0.60}$	$V_{IVC}^* = 99.12$	$V_{PVC}^* = 65.47$	$V_{IVC}^* = 99.12$	$V_{PVC}^* = 75.32$	$V_{IVC}^* = 99.12$	$V_{PVC}^* = 89.20$
	$V_{CO}^* = 51.80$ $p^* = 45.67\%$	$V_S^* = 57.10$ $sub^* = 106.33$	$V_{CO}^* = 51.80$ $p^* = 45.67\%$	$V_S^* = 57.10$ $sub^* = 106.33$	$V_{CO}^* = 51.80$ $p^* = 45.67\%$	$V_S^* = 57.10$ $sub^* = 106.33$
$\boldsymbol{w = 0.75}$	$V_{IVC}^* = 158.59$	$V_{PVC}^* = 91.11$	$V_{IVC}^* = 158.59$	$V_{PVC}^* = 111.22$	$V_{IVC}^* = 158.59$	$V_{PVC}^* = 144.58$
	$V_{CO}^* = 66.25$ $p^* = 69.69\%$	$V_S^* = 74.72$ $sub^* = 132.93$	$V_{CO}^* = 66.25$ $p^* = 69.69\%$	$V_S^* = 74.72$ $sub^* = 132.93$	$V_{CO}^* = 66.25$ $p^* = 69.69\%$	$V_S^* = 74.72$ $sub^* = 132.93$

Table 2. Sensitivity analysis on ϕ and w *(baseline case is grey shadowed)*

2.5.3. Amount of investment (k) and volatility on V (σ)

Profit triggers V_{IVC}^*, V_{PVC}^*, V_{CO}^* and V_S^* increase with k as shown in Table 3, in order to sustain return on investment. Similarly, as σ increases the value of the option to invest, V_{IVC}^*, V_{PVC}^*, V_{CO}^* and V_S^* increase with σ. However, σ leads to asymmetric effects between $V_{IVC}^*$and V_{PVC}^*, with changes in V_{IVC}^* being much greater than those in V_{PVC}^*, especially when $\sigma > 0.25$. This behavior points out the existence of a gap on the financing market for high risky projects that might be filled by PVCs, even when comparing with the option to co-invest. This would be the case on the early stage segment, where we then expect PVCs to have a higher share in deal volumes. The corollary from this view posits that for very high degrees of uncertainty ($\sigma > 0.25$) subsidizing may actually be preferable to co-investing, as $V_{CO}^* > V_S^*$, as subsidizing acts as a remedy to the impact of uncertainty on the profitability of the Start-up Firm.

	$k = 50$		$k = 150$		$k = 250$	
$\sigma = 0.15$	$V_{IVC}^* = 26.82$	$V_{PVC}^* = 21.17$	$V_{IVC}^* = 80.46$	$V_{PVC}^* = 63.51$	$V_{IVC}^* = 134.10$	$V_{PVC}^* = 105.86$
	$V_{CO}^* = 14.14$ $p^* = 44.81\%$	$V_S^* = 15.62$ $sub^* = 34.95$	$V_{CO}^* = 42.43$ $p^* = 44.81\%$	$V_S^* = 46.88$ $sub^* = 104.85$	$V_{CO}^* = 70.72$ $p^* = 44.81\%$	$V_S^* = 78.13$ $sub^* = 174.75$
$\sigma = 0.25$	$V_{IVC}^* = 33.04$	$V_{PVC}^* = 25.11$	$V_{IVC}^* = 99.12$	$V_{PVC}^* = 75.32$	$V_{IVC}^* = 165.20$	$V_{PVC}^* = 125.53$
	$V_{CO}^* = 17.27$ $p^* = 45.67\%$	$V_S^* = 19.03$ $sub^* = 35.44$	$V_{CO}^* = 51.80$ $p^* = 45.67\%$	$V_S^* = 57.10$ $sub^* = 106.33$	$V_{CO}^* = 86.33$ $p^* = 45.67\%$	$V_S^* = 95.17$ $sub^* = 177.22$
$\sigma = 0.35$	$V_{IVC}^* = 91.82$	$V_{PVC}^* = 31.41$	$V_{IVC}^* = 275.45$	$V_{PVC}^* = 94.22$	$V_{IVC}^* = 459.08$	$V_{PVC}^* = 157.04$
	$V_{CO}^* = 33.81$ $p^* = 85.79\%$	$V_S^* = 24.83$ $sub^* = 37.98$	$V_{CO}^* = 101.42$ $p^* = 85.79\%$	$V_S^* = 74.48$ $sub^* = 113.93$	$V_{CO}^* = 169.04$ $p^* = 85.79\%$	$V_S^* = 124.14$ $sub^* = 189.89$

***Table 3. Sensitivity analysis on k and σ** (baseline case is grey shadowed)*

2.5.4. Taxation (T_C and T_G)

Growing effective taxation rates lead to different effects on IVCs and PVCs, as we show in Table 4. The latter will demand an increasing V_{IVC}^*, since the profitability of the Start-up Firm is hindered by T_C and T_G lowers the net proceeds from divesting to the IVC. The former will benefit from a greater tax collection that will lead V_{PVC}^* to decrease. Equivalently, for very low taxation levels, and depending on the efficiency gap ϕ, we would observe $V_{PVC}^* > V_{IVC}^*$. We then conjecture that Governments whose overall taxation are greater might be more supportive of PVC initiatives.

Similarly to Keuschnigg and Nielsen (2007), V_{IVC}^* reveals a higher sensitivity to T_C than to T_G, as the impact of T_G is contingent on *V* at divestment, while T_C negatively affects NPV_{IVC}, alongside CGT_{IVC}. We would also highlight that the greater taxation is, the more effective co-investing becomes comparing to subsidizing in what regards anticipating optimum investment timing. This is because the share premium mechanism introduced in V_{CO}^* is neutral to taxation at the IVC fund level, differently than subsidization which is subject to T_C.

On the lower panel of Table 4, we depict how ωNPV_{IVC}, ωCGT, ωCI, ωNPV_{PVC}, ωTAX and $\omega\psi$ change with T_C and T_G. As for IVCs, increasing T_C negatively affects ωCI as this component is the only one which is exclusively affected by T_C. As the value of investing on the Start-up Firm is simultaneously affected by T_C and T_G, IVCs are willing to trade-off ωCI in favor of $\omega NPV_{IVC}$and ωCGT. Conversely, increasing T_G makes the value of investing on the Start-up Firm less profitable than carried interest, which is not affected by T_G. As a result, IVCs are willing to trade-off $\omega NPV_{IVC}$and ωCGT for ωCI in this case.

As for PVCs, and before interpreting how T_C and T_G affect its value drivers, we should first highlight two important results. First, the opportunity cost borne by the Government when PVC invests in the Start-up Firm given by $\Psi(V)$ may stand for as much as 13.0% to over 20.0% of the value of the option to invest, having a material impact on the decision-making process of PVCs. Second, and unlike IVCs, PVCs should be willing to exercise their option to invest on the Start-up Firm even when $NPV_{PVC}(V^*_{PVC})$ is negative, as such loss is offset by a set of incremental tax revenues, even in the presence of an efficiency gap.

	$T_C = 0.15$		$T_C = 0.25$		$T_C = 0.35$	
$T_G = 0.05$	$V^*_{IVC} = 87.18$	$V^*_{PVC} = 77.53$	$V^*_{IVC} = 98.66$	$V^*_{PVC} = 75.60$	$V^*_{IVC} = 113.68$	$V^*_{PVC} = 74.23$
	$V^*_{CO} = 52.76$ $p^* = 32.61\%$	$V^*_S = 57.09$ $sub^* = 75.44$	$V^*_{CO} = 51.79$ $p^* = 45.24\%$	$V^*_S = 57.03$ $sub^* = 104.92$	$V^*_{CO} = 50.86$ $p^* = 61.75\%$	$V^*_S = 56.99$ $sub^* = 143.48$
$T_G = 0.15$	$V^*_{IVC} = 87.59$	$V^*_{PVC} = 76.96$	$V^*_{IVC} = 99.12$	$V^*_{PVC} = 75.32$	$V^*_{IVC} = 114.20$	$V^*_{PVC} = 74.13$
	$V^*_{CO} = 52.77$ $p^* = 32.99\%$	$V^*_S = 57.17$ $sub^* = 76.60$	$V^*_{CO} = 51.80$ $p^* = 45.67\%$	$V^*_S = 57.10$ $sub^* = 106.33$	$V^*_{CO} = 50.87$ $p^* = 62.24\%$	$V^*_S = 57.06$ $sub^* = 145.22$
$T_G = 0.25$	$V^*_{IVC} = 88.02$	$V^*_{PVC} = 76.43$	$V^*_{IVC} = 99.60$	$V^*_{PVC} = 75.05$	$V^*_{IVC} = 114.75$	$V^*_{PVC} = 74.04$
	$V^*_{CO} = 52.78$ $p^* = 33.39\%$	$V^*_S = 57.25$ $sub^* = 77.83$	$V^*_{CO} = 51.81$ $p^* = 46.12\%$	$V^*_S = 57.18$ $sub^* = 107.83$	$V^*_{CO} = 50.88$ $p^* = 62.77\%$	$V^*_S = 57.14$ $sub^* = 147.05$

	$T_C = 0.15$		$T_C = 0.25$		$T_C = 0.35$	
$T_G = 0.05$	$\omega NPV_{IVC} = 100.41\%$ $\omega CGT = -2.65\%$ $\omega CI = 2.24\%$	$\omega NPV_{PVC} = -33.39\%$ $\omega TAX = 155.28\%$ $\omega\psi = -21.89\%$	$\omega NPV_{IVC} = 100.69\%$ $\omega CGT = -2.66\%$ $\omega CI = 1.97\%$	$\omega NPV_{PVC} = -41.14\%$ $\omega TAX = 161.22\%$ $\omega\psi = -20.08\%$	$\omega NPV_{IVC} = 100.96\%$ $\omega CGT = -2.67\%$ $\omega CI = 1.70\%$	$\omega NPV_{PVC} = -44.74\%$ $\omega TAX = 158.41\%$ $\omega\psi = -13.68\%$
$T_G = 0.15$	$\omega NPV_{IVC} = 105.96\%$ $\omega CGT = -8.37\%$ $\omega CI = 2.41\%$	$\omega NPV_{PVC} = -35.05\%$ $\omega TAX = 159.01\%$ $\omega\psi = -23.96\%$	$\omega NPV_{IVC} = 106.3\%$ $\omega CGT = -8.4\%$ $\omega CI = 2.1\%$	$\omega NPV_{PVC} = -41.82\%$ $\omega TAX = 162.34\%$ $\omega\psi = -20.52\%$	$\omega NPV_{IVC} = 106.60\%$ $\omega CGT = -8.43\%$ $\omega CI = 1.83\%$	$\omega NPV_{PVC} = -44.89\%$ $\omega TAX = 158.52\%$ $\omega\psi = -13.63\%$
$T_G = 0.25$	$\omega NPV_{IVC} = 112.11\%$ $\omega CGT = -14.72\%$ $\omega CI = 2.60\%$	$\omega NPV_{PVC} = -36.65\%$ $\omega TAX = 162.54\%$ $\omega\psi = -25.89\%$	$\omega NPV_{IVC} = 112.49\%$ $\omega CGT = -14.78\%$ $\omega CI = 2.29\%$	$\omega NPV_{PVC} = -42.46\%$ $\omega TAX = 163.37\%$ $\omega\psi = -20.91\%$	$\omega NPV_{IVC} = 112.86\%$ $\omega CGT = -14.84\%$ $\omega CI = 1.98\%$	$\omega NPV_{PVC} = -45.03\%$ $\omega TAX = 158.60\%$ $\omega\psi = -13.57\%$

Table 4. Sensitivity analysis on T_C and T_G *(baseline case is grey shadowed)*

The influence of T_C and T_G in $\omega\psi$ is mediated by the impact that these two variables inflict in V_{IVC}^*. As increasing T_C and T_G restrain return on investment, they exert positive impact in V_{IVC}^*. Therefore, the gap between V_{IVC}^* and V_{PVC}^* becomes greater and the less likely it becomes for V to reach V_{IVC}^*. As a result, the opportunity cost that Governments incur from readily investing in the Start-up Firm becomes lower, as perceived incremental tax revenues from letting IVCs carry the investment are also lower. In addition, as T_C and T_G anticipate optimum investment timing for PVCs, ωNPV_{PVC} and ωTAX decrease their share on value creation.

2.5.5. Profit sharing (*s*) and holding period (*ex*)

In Table 5 we are particularly interested in understanding how V_{IVC}^* is affected by changes in profit sharing and in holding period, since $V_{PVC}^*$is only indirectly affected by these components through $\psi(V)$. These two variables influence the value of the carried interest component – given by $CI(V)$ – while the expected capital tax gain liability – given by $CGT(V)$ – is not affected by *s*.

	$s = 0.15$		$s = 0.20$		$s = 0.25$	
$ex = 3.00$	$V_{IVC}^* = 101.22$	$V_{PVC}^* = 74.62$	$V_{IVC}^* = 102.69$	$V_{PVC}^* = 74.69$	$V_{IVC}^* = 104.54$	$V_{PVC}^* = 74.78$
	$V_{CO}^* = 52.35$ $p^* = 46.67\%$	$V_S^* = 57.28$ $sub^* = 106.67$	$V_{CO}^* = 52.72$ $p^* = 47.39\%$	$V_S^* = 57.37$ $sub^* = 106.85$	$V_{CO}^* = 53.19$ $p^* = 48.81\%$	$V_S^* = 57.46$ $sub^* = 107.04$
$ex = 4.00$	$V_{IVC}^* = 98.85$	$V_{PVC}^* = 75.31$	$V_{IVC}^* = 99.12$	$V_{PVC}^* = 75.32$	$V_{IVC}^* = 99.40$	$V_{PVC}^* = 75.32$
	$V_{CO}^* = 51.73$ $p^* = 45.53\%$	$V_S^* = 57.08$ $sub^* = 106.29$	$V_{CO}^* = 51.80$ $p^* = 45.67\%$	$V_S^* = 57.10$ $sub^* = 106.33$	$V_{CO}^* = 51.87$ $p^* = 45.81\%$	$V_S^* = 57.13$ $sub^* = 106.38$
$ex = 5.00$	$V_{IVC}^* = 98.41$	$V_{PVC}^* = 75.98$	$V_{IVC}^* = 98.51$	$V_{PVC}^* = 75.98$	$V_{IVC}^* = 98.61$	$V_{PVC}^* = 75.98$
	$V_{CO}^* = 51.62$ $p^* = 45.33\%$	$V_S^* = 57.03$ $sub^* = 106.13$	$V_{CO}^* = 51.64$ $p^* = 45.38\%$	$V_S^* = 57.04$ $sub^* = 106.15$	$V_{CO}^* = 51.67$ $p^* = 45.43\%$	$V_S^* = 57.05$ $sub^* = 106.17$

Table 5. Sensitivity analysis on s and ex *(baseline case is grey shadowed)*

Common sense would suggest that more aggressive profit sharing mechanisms would lead IVCs to anticipate their optimum investment timing, as they would be entitled to retain a greater share of the payoffs generated above the hurdle. However, our results show exactly the opposite result. In fact, and consistently with Liu and Yang (2015), when increasing *s*, $CI(V)$ becomes relatively more valuable than $NPV_{IVC}(V)$, only if the hurdle is achieved at divestment date. The likelihood of the hurdle to be achieved at this moment is greater, the greater V_{IVC}^{*} is. Therefore, performance-based compensation schemes such as carried interest, may actually lead to the counter-intuitive result of postponing optimum investment timing.

Additionally, longer holding periods measured by *ex* lead to a lower present value of both $CI(V)$ and $CGT(V)$. Therefore, IVCs trade-off $CI(V)$ for $NPV_{IVC}(V)$ in their decision-making process, leading V_{IVC}^{*} to decrease with *ex*.

2.5.6. Hurdle rate (*h*) and stake in IVC held by the GP (*i*)

Our sensitivity analysis on *h* describes the opposite effect from the one described for *s* in the previous Section, as presented in Table 6. Increasing the hurdle decreases the likelihood of V exceeding such threshold at divestment date and, as a result, $CI(V)$ becomes less attractive than $NPV_{IVC}(V)$. This is also visible on the lower panel of Table 6, where we observe that ωCI decreases with *h*.

In turn, *i* holds a significant on decreasing V_{IVC}^{*}. The greater is a GP "skin in the game", the less valuable $CI(V)$ is, and the more $NPV_{IVC}(V)$ driven becomes its decision-making process, leading to lower V_{IVC}^{*} levels. This effect is particularly strong for very low levels of *i*, where

V^*_{IVC} significantly lowers from $i = 0.005$ to $i = 0.010$, but reveals a more gradual change when $i > 0.010$.

	$h = 0.00$		$h = 0.08$		$h = 0.16$	
$i = 0.005$	$V^*_{IVC} = 104.51$	$V^*_{PVC} = 75.42$	$V^*_{IVC} = 100.33$	$V^*_{PVC} = 75.34$	$V^*_{IVC} = 98.84$	$V^*_{PVC} = 75.31$
	$V^*_{CO} = 53.17$ $p^* = 48.28\%$	$V^*_S = 57.45$ $sub^* = 107.02$	$V^*_{CO} = 52.11$ $p^* = 46.27\%$	$V^*_S = 57.20$ $sub^* = 106.52$	$V^*_{CO} = 51.73$ $p^* = 45.53\%$	$V^*_S = 57.08$ $sub^* = 106.28$
$i = 0.010$	$V^*_{IVC} = 100.68$	$V^*_{PVC} = 75.34$	$V^*_{IVC} = 99.12$	$V^*_{PVC} = 75.32$	$V^*_{IVC} = 98.45$	$V^*_{PVC} = 75.31$
	$V^*_{CO} = 52.20$ $p^* = 46.44\%$	$V^*_S = 57.45$ $sub^* = 106.57$	$V^*_{CO} = 51.80$ $p^* = 45.67\%$	$V^*_S = 57.10$ $sub^* = 106.33$	$V^*_{CO} = 51.63$ $p^* = 45.34\%$	$V^*_S = 57.04$ $sub^* = 106.22$
$i = 0.020$	$V^*_{IVC} = 99.27$	$V^*_{PVC} = 75.32$	$V^*_{IVC} = 98.58$	$V^*_{PVC} = 75.31$	$V^*_{IVC} = 98.26$	$V^*_{PVC} = 75.31$
	$V^*_{CO} = 51.84$ $p^* = 45.74\%$	$V^*_S = 57.12$ $sub^* = 106.36$	$V^*_{CO} = 51.67$ $p^* = 45.40\%$	$V^*_S = 57.06$ $sub^* = 106.24$	$V^*_{CO} = 51.58$ $p^* = 45.25\%$	$V^*_S = 57.03$ $sub^* = 106.18$

	$h = 0.00$	$h = 0.08$	$h = 0.16$
$i = 0.005$	$\omega NPV_{IVC} = 94.99\%$ $\omega CGT = -7.36\%$ $\omega CI = 12.37\%$	$\omega NPV_{IVC} = 103.78\%$ $\omega CGT = -8.15\%$ $\omega CI = 4.37\%$	$\omega NPV_{IVC} = 107.12\%$ $\omega CGT = -8.48\%$ $\omega CI = 1.35\%$
$i = 0.010$	$\omega NPV_{IVC} = 102.23\%$ $\omega CGT = -8.01\%$ $\omega CI = 5.79\%$	$\omega NPV_{IVC} = 106.28\%$ $\omega CGT = -8.40\%$ $\omega CI = 2.12\%$	$\omega NPV_{IVC} = 107.89\%$ $\omega CGT = -8.55\%$ $\omega CI = 0.67\%$
$i = 0.020$	$\omega NPV_{IVC} = 105.51\%$ $\omega CGT = -8.33\%$ $\omega CI = 2.82\%$	$\omega NPV_{IVC} = 107.48\%$ $\omega CGT = -8.52\%$ $\omega CI = 1.04\%$	$\omega NPV_{IVC} = 108.27\%$ $\omega CGT = -8.59\%$ $\omega CI = 0.33\%$

Table 6. Sensitivity analysis on h and i *(baseline case is grey shadowed)*

3. POLICY IMPLICATIONS

The theoretical model and the numerical example introduced on the previous Section allow us to outline a set of policy implications, which may be relevant not only for public decision-makers, but also for private LPs investing in IVC funds.

First, our results reveal that, in general, co-investment between IVCs and PVCs is more efficient than direct subsidization of the Start-up Firm in anticipating optimum investment timing, if Governments are willing to provide an *equity enhancement* effect to IVCs through a share premium, or any other equivalent mechanism that leverages its value appropriation. This follows from our baseline case, but also from the sensitivity analysis we rendered in Sections 2.5.2 to 2.5.6.

Second, more inefficient Governments should be more willing to allow PVCs to co-invest alongside IVCs as this deal structure may eliminate the efficiency gap between these two types of investors, and the benefits for Governments from its elimination directly increase with their inefficiency. Following the same argument, direct subsidization might be a more effective mechanism in anticipating optimum investment timing than direct PVC investment, as it also enables such efficiency gap to be eliminated, by letting IVCs lead the investment. This was highlighted in Section 2.5.2.

Third, volatility is determinant in establishing a *market failure* on financing the segment of early stage companies by IVCs, whose volatility on their future profit generation is higher. Therefore, PVCs should be focused on this deal segment according to results from Section 2.5.3. In addition, decreasing perceived volatility should be an explicit focus of public policy intended to foster investment volumes. This may encompass either long-term oriented economic and fiscal policies as well as specific policies intended to decrease operating costs, improve entrepreneurial quality or minimizing investment downside risk. In this sense, we showed that subsidies are actually more effective in anticipating optimum investment timing for IVCs, when volatility on profit generation is greater.

Forth, our results from Section 2.5.6 reveal that the stake held by the GP on its IVC fund stands one of the most effective mechanisms to foster investment volumes by IVCs and anticipate their optimum investment timing, while profit sharing mechanisms grounded on carried interest instruments hold the opposite effect. Therefore, public policies aimed at increasing *i* might be regarded as a positive contribution to promoting investment volumes. An example of such instruments includes multi-fund commitments, where public LPs could commit funds to subsequent funds, subject to certain performance benchmarks to be verified on the initial fund and to an increase in commitments by GPs on the subsequent fund.

Finally, results from Section 2.5.5 suggest that public policy should be more or less supportive of PVC initiatives, depending on the average fund age of their IVC peers and on their performance since inception. These two variables influence how GPs value $CI(V)$, which in turn affects V_{IVC}^{*}. In particular, if IVC funds are newborn, they envisage $CI(V)$ as valuable and will therefore demand greater V_{IVC}^{*}, further deepening the gap between the optimum investment timing held by IVCs and PVCs. As the investment period progresses, GPs are informed of the pooled performance of the portfolio firms on its IVC fund and, therefore, of the probability of obtaining a positive carried interest after fund liquidation. Two different scenarios might be in place at this point. First, the pooled performance of the IVC fund is such that GPs understand they will not benefit from carried interest and then will assume that $CI(V) = 0$ for the remaining investment decisions of the IVC fund. Hence, V_{IVC}^{*} shall decrease, meaning that IVCs might be either more willing to directly invest in target companies, or co-invest alongside PVCs, who will have to provide a lower *equity enhancement*. Second, if the pooled performance of the IVC fund is such that the GP admits that it will be entitled to the carried interest, it will assume that $CI(V) > 0$ for the remaining investment decisions of the

IVC fund. As a result, as the carried interest becomes more valuable and the holding period becomes shorter, V_{IVC}^{*} increases. Again, the gap between V_{IVC}^{*} and V_{PVC}^{*} will be greater, and PVCs should be more willing to directly intervene on the equity financing market. Such behavior should however be also influenced by progress on investment execution *vis-à-vis* the investment period, as this may be determinant in securing management fees for the GP during the divestment period. If execution is low and the investment period is about to end, then V_{IVC}^{*} should decrease regardless of prospects on carried interest, as GPs are incentivized to maximize the amount of management fees to be earned during the divestment period, and which are usually a function of the acquisition cost of portfolio firms. In addition, fund raising plans or initiatives by GPs may also exert influence on current investment decision-making. These two effects are not captured in our framework from Section 2.

4. EMPIRICAL EVIDENCE ON THE DETERMINANTS OF PVC INVESTMENT

In this Section we investigate whether some of the outcomes from our theoretical model introduced in Section 2 are empirically supported. We will be specifically interested in examining the determinants of investment volumes carried by PVCs, taking into account that volumes stand for a more appropriate measure of earlier optimum investment timing than investment amounts.

4.1. Hypothesis

Grounded on the relevant literature contributions and on the underlying intuition of the framework we introduced in Section 2, we posit the following set of theoretical propositions:

H1: *Co-investment volumes are positively correlated with the share of PVC investment in total PE and VC investment volumes in countries in which Governments are more inefficient.*

This follows our results from Section 2.5.2, where we showed that the gap between V_{PVC}^{*} and V_{CO}^{*} was followed by a greater efficiency gap, measured by ϕ. This view is also grounded on Murray (2007) and Munari and Toschi (2015), who pointed out that one of the drivers for the establishment of PVC initiatives lays on leveraging private financing through co-investment on Leleux and Surlemont (2003), who revealed that PVCs do co-invest less than IVCs, and on Grilli and Murtinu (2014) and Grilli and Murtinu (2015), who revealed that firms in which PVCs and IVCs co-invested recorded better performance than those in which only PVCs invested.

H2: *Higher shares of PVC investment in total PE and VC investment volumes occur in countries in which Governments are more efficient.*

This is a corollary from H1 and it is also derived from our results in Section 2.5.2. As we expect more inefficient Governments to have a greater share on PVC investment volumes through co-investment practices, we expect more efficient Governments to have a greater share of direct PVC investments.

H3: *Higher shares of PVC investment in total PE and VC investment volumes occur in countries in which a greater proportion of seed stage deals are observed.*

This follows our discussion in Sections 2.5.3 and 3 on the impact of profit volatility over the V_{IVC}^{*} and V_{PVC}^{*}, especially for very high levels of volatility – as in the case of seed investments, which face a hyper-uncertain environment faced by early stage firms (Venkataraman, 1997).

H4: *Higher shares of PVC investment in total PE and VC investment volumes occur in countries in which the macroeconomic environment is more positive.*

This theoretical hypothesis might be either regarded as a control variable, or as a corollary from H3, in the sense that it may also depicts the role that volatility inflicts on the PVC investment decision-making. Following the approach by the World Economic Forum, we take the *macroeconomic environment* as a measure of economic stability, given by Government budget balance, gross national savings, inflation, public debt and country credit rating.

H5: *Higher shares of PVC investment in total PE and VC investment volumes occur in countries in which taxation is greater.*

Governments with higher tax levels should be able to more easily profit from investment activities carried by PVCs and, therefore, as illustrated in 2.5.4, present a lower V_{PVC}^{*} which incentivizes direct PVC investment. Analogously, in countries where greater effective taxation rates are observed, we expect V_{IVC}^{*} to increase and IVCs to become more focused on opportunities yielding a more aggressive return profile, leaving room for PVC initiatives. This follows Keuschnigg and Nielsen (2007) who argued that corporate income taxes would postpone effort in Start-up Firms.

H6: *Lower shares of PVC investment in total PE and VC investment volumes occur in countries in which companies have easier access to equity financing.*

This hypothesis controls for the *equity gap* that Governments may fill by launching PVC initiatives, when perceiving that companies find important restraints on raising capital (Beuselinck and Manigart, 2007). In fact, this hypothesis will allow us to depict whether

perceived *market failures* on the equity financing market (Giacomo, 2004; Murray, 2007; van der Schans, 2015) actually motivate Governments to launch PVC initiatives.

H7: *Shares of PVC investment in total PE and VC investment volumes occur are uncorrelated to macroeconomic business cycles.*

We replicate this hypothesis introduced by Beuselinck and Manigart (2007), arguing that Governments intend to close potential *equity gaps* through PVC initiatives and therefore their investment pattern should not be driven by business cycles or return opportunities. Following their results and following the fact that their sample broadly replicates our sample of European countries, we do expect a similar outcome.

4.2. Data and Method

Our dataset comprises a sample of European countries for which data on PVC investment is available on the annual statistical yearbook published by EVCA, including Austria, Belgium, Denmark, Finland, France, Germany, Hungary, Ireland, the Netherlands, Portugal, Spain, Sweden and the United Kingdom. As data covered the 2007 to 2014 period, a total number of 104 observations was collected. This subset of countries stands for 90.4% of total investment amounts and 89.6% of total investment volumes in Europe for the 2007-2014 period according to EVCA, and allowed us to compute the share of PVC investment volumes on the total PE and VC investment volumes for each the countries in our sample. This will stand for our dependent variable which we will name as $PVCVOL$. Data for the independent variables that follow our theoretical hypothesis was obtained through a range of different sources, which we summarized in Table 7.

As for Government efficiency and access to equity financing, we relied on survey data rendered by the World Economic Forum, which provides annual records for each of the countries included in our sample. While there are several quantitative measures of Government efficiency on the literature (Adam et al., 2011; Afonso et al., 2005; Afonso et al., 2010; Gao, 2015), no consistent data and methodology exists on this indicator for a time series ranging from 2007 to 2014. Differently, ease of access to equity financing is not an observable variable and, as a result, proxies or survey data had to be introduced in our empirical investigation.

Variable Name	Variable Description	Source	Supporting	Sign
COINV	Share of co-investment deals in total PE and VC deals, per country per year	EVCA Yearbook	**H1**	**(+)**
GOVINEFF	This is the inverse of the Government Efficiency indicator (*GOVEFF*), ranging from a scale from 1 to 7, per country and per year. This is computed by dividing 7 by the result obtained in *GOVEFF*.	World Economic Forum, Executive Opinion Survey		
GOVEFF	Annual composite indicator of Government Efficiency available for each of the countries in our dataset, ranging from a scale from 1 to 7, assessing (i) the wastefulness of government spending, (ii) the burden of government regulation, (iii) the efficiency of legal framework in setting disputes, (iv) the efficiency of legal framework in challenging regulations, and (v) the transparency of government policymaking	World Economic Forum, Executive Opinion Survey	**H2**	**(+)**
SEED	Share of seed deals in total PE and VC deals, per country and per year	EVCA Yearbook	**H3**	**(+)**
MACRO	Annual composite indicator of Macroeconomic Environment, available for each of the countries in our dataset, summarizing (i) public budget balance, (ii) gross national savings, (iii) inflation, (iv) government debt and (v) country credit rating	World Economic Forum, Global Competitiveness Report	**H4**	**(+)**
TAXGDP	Tax and Social Security contributions as a percentage of gross domestic product (GDP), per country and per year	Eurostat	**H5**	**(+)**
VCACCESS	Annual indicator available for each of the countries in our dataset, ranging from 1 (extremely difficult) to 7 (extremely easy), picturing how easy it is for Entrepreneurs with innovative projects to find venture capital	World Economic Forum, Executive Opinion Survey	**H6**	**(-)**
$YEARS_{2007-2014}$	Dummy variables for each of the years on the sample, equal to 1 if data refers to a given year and equal to 0 otherwise	-	**H7**	**Not significant**

Table 7. Variables definition

Similarly to Beuselinck and Manigart (2007), given that our sample covers eight observation years across thirteen different European countries, we set up a panel data regression, with the purpose of mitigating problems of biased and inconsistent parameters in cross-sectional time-series models (Baltagi, 2008). We run three linear regression models, specified as follows[35]:

$$\text{(I)}\quad PVCVOL_{ct} = \beta_{0ct} + \beta_{1ct}COINV \times GOVINEFF + \beta_{2ct}GOVEFF + \beta_{3ct}SEED + \beta_{4ct}MACRO + \beta_{5ct}TAXGDP + \beta_{6ct}VCACCESS + \beta_{7ct}2007 + \cdots \beta_{8ct}2014 + \varepsilon_{ct} \tag{54}$$

$$\text{(II)}\quad PVCVOL_{ct} = \beta_{0ct} + \beta_{1ct}COINV \times GOVINEFF + \beta_{2ct}GOVEFF + \beta_{3ct}SEED + \beta_{4ct}MACRO + \beta_{5ct}TAXGDP + \beta_{6ct}VCACCESS + \varepsilon_{ct} \tag{55}$$

$$\text{(III)}\quad PVCVOL_{ct} = \beta_{0ct} + \beta_{1ct}COINV \times GOVINEFF + \beta_{2ct}SEED + \beta_{3ct}MACRO + \beta_{4ct}TAXGDP + \beta_{5ct}VCACCESS + \varepsilon_{ct} \tag{56}$$

Regression (I) reflects the whole set of theoretical hypothesis described in Section 4.1. Considering that PVC investment volumes are expected not to be correlated with economic cycle, we run regression (II), in which we exclude the dummy variables on investment years. Finally, as H2 might be conceived as a corollary of H1, in regression (III) we exclude its underlying variable $GOVEFF$.

[35] For ease of implementation, variables *PVCVOL*, *COINV*, *SEED* and *TAXGDP* have been multiplied by 100 in the four models. This should be taken into account when interpreting the regression coefficients.

4.3. Results

We show regression results in Table 8[36]. As expected, macroeconomic cycle depicted by dummy variables on investment years does not have any significant statistical impact over $PVCVOL$ in regression (I). Coefficients for $COINV \times GOVINEFF$, $GOVEFF$, $SEED$, $MACRO$, $TAXGDP$ and $VCACCESS$ hold the predicted signs, although coefficient on $TAXGDP$ only reveals statistical significance at 87.4%. Therefore, we found no support for H5. In addition, regression coefficient on $COINV \times GOVINEFF$ was proved to be significant at 15.2%, which does not allow us to obtain strong statistical evidence on H1.

	Regression (I)			**Regression (II)**			**Regression (III)**			**Regression (II)** *ex-TAXGDP*		
Variables	*β*	Standard Error	*t-value*	*B*	Standard Error	*t-value*	*β*	Standard Error	*t-value*	*β*	Standard Error	*t-value*
(Constant)	-23.85***	8.45	-2.82	-24.89***	7.86	-3.17	-23.50***	8.03	-2.93	-24.32***	6.95	-3.50
COINV x *GOVINEFF*	0.04#	0.03	1.45	0.03	0.03	1.19	0.05*	0.03	1.71	0.03	0.03	1.19
GOVEFF	4.37**	2.01	2.18	3.78**	1.57	2.41	-	-	-	3.78**	1.56	2.42
SEED	0.67***	0.08	7.99	0.68***	0.08	8.63	0.73***	0.08	9.31	0.68***	0.08	8.68
MACRO	4.84***	1.90	2.56	4.17**	1.82	2.29	5.72***	1.74	3.29	4.28***	1.67	2.56
TAXGDP	0.01	0.17	0.07	0.03	0.16	0.16	0.02	0.16	0.10	-	-	-
VCACCESS	-4.12*	2.26	-1.82	-2.87**	1.35	-2.13	-1.19	1.18	-1.01	-2.88**	1.34	-2.16
2008	-2.78	3.02	-0.92	-	-	-	-	-	-	-	-	-
2009	-1.54	3.60	-0.43	-	-	-	-	-	-	-	-	-
2010	-5.22	4.07	-1.28	-	-	-	-	-	-	-	-	-
2011	-4.84	3.95	-1.23	-	-	-	-	-	-	-	-	-
2012	-1.00	4.02	-0.25	-	-	-	-	-	-	-	-	-
2013	-2.17	4.13	-0.53	-	-	-	-	-	-	-	-	-
2014	-2.67	3.91	-0.68	-	-	-	-	-	-	-	-	-
Observations	*104*			*104*			*104*			*104*		
R^2	*0.630*			*0.613*			*0.590*			*0.613*		
Adjusted R^2	*0.577*			*0.589*			*0.573*			*0.593*		

***, **, * and # denote statistical significance at the 1%, 5%, 10% and 15% levels respectively

Table 8. Regression results

[36] We ran multicollinearity tests on regression results, which revealed that independent variables are not significantly correlated. VIF levels among independent variables in all regressions stood below the 10.0 threshold suggested by Hair et al. (2010). In addition, we performed robustness tests with transformations on $TAXGDP$, $COINV \times GOVINEFF$, $MACRO$, $SEED$and $PVCVOL$. Regression results were essentially confirmed, with $TAXGDP$ and $COINV \times GOVINEFF$ proving to be statistically insignificant.

This pattern is confirmed in regression (II), where $TAXGDP$ remained statistically insignificant and $COINV \times GOVINEFF$ lost statistical significance to 23.7%, even though maintaining the expected sign. Regression (II) without $TAXGDP$ resembles the same results, providing no clear evidence on the impact of $COINV \times GOVINEFF$ on $PVCVOL$. Still, we obtain supporting evidence for H2, H3, H4, H6 and H7.

By excluding $GOVINEFF$ in regression (III) we attempt to highlight the effect of $COINV \times GOVINEFF$ over $PVCVOL$. In this case, $COINV \times GOVINEFF$ maintains the expected sign and becomes statistical significant at 10.0%, providing some supporting evidence for H1. As $VCACCESS$ becomes insignificant in this specification, we argue that these results may reveal that PVC-sponsored co-investment initiatives may actually eliminate restrictions on the access to equity financing.

Four important considerations should be summarized on regression results. Firstly, we acknowledge that our data poses three relevant restraints to our investigation, providing room for further research on the field: it depicts a relative short period of time which is largely affected by the 2007-2008 financial crisis, it is restricted to the European market and it is only able to capture Government intervention on the equity financing market through PVC (i.e., *direct* and not *indirect*) initiatives. Second, our results clearly show that taxation is not a relevant variable in determining PVC investment volumes, which is in contrast with H5. This means that Governments do not define their policy for intervening on the equity financing markets based on taxation, nor that they make use of PVC initiatives grounded on lower pre-tax return on investment requirements. Third, we found no strong evidence supporting H1, even though we obtained supporting evidence for H2 and the coefficient on $COINV \times GOVINEFF$ revealed the expected sign. This suggests that the most inefficient Governments do not make

use of co-investment mechanisms to overcome their efficiency gap, which may, in fact, be regarded as a feature of the most inefficient Governments. In this sense, even though it may exist an economic rationale for the most inefficient Governments to support co-investment, this may not be empirically observed, since these shall not to choose such efficiency enhancing strategies. Forth, we call attention to the role that the *macroeconomic environment* – portrayed by H4 – plays over $PVCVOL$ and most likely on the investment volumes of IVCs as well. Economic stability – measured by public debt, balance and rating, alongside inflation and saving rate in our regression – then seems to form a common ground for the establishment of relevant PVC initiatives.

Overall, regression results provide empirical support to H2, H3, H4, H6 and H7, of which H2 and H3 are directly derived from our theoretical framework, while H4, H6 and H7 confirmed previous literature findings or inferences. No clear statistical support was obtained for H1.

5. CONCLUSIONS

We derived a real options based framework to investigate how IVCs and PVCs screen their investment decisions and compare their optimum investment timing. Even when taking into account the incremental revenues which might be lost by not letting IVCs undertaking the investment, we showed that PVCs should be willing to invest earlier than IVCs, not only as they are neutral to taxation (unlike IVCs), but also as they present substantially lower profit triggers when facing investment opportunities featuring high volatility on its profit generation.

Still, given that PVCs hold an efficiency gap when compared to IVCs, Governments might be willing to eliminate this gap by letting PVCs co-invest alongside IVCs or by directly

subsidizing Start-up Firms and letting IVCs drive the investment. We showed that both these mechanisms are able to significantly anticipate optimum investment timing, when they provide an *equity enhancement* effect to IVCs. Our results highlight that it is not enough for Governments to commit capital on the equity financing market to foster IVC investment. In turn, co-investing proved to be more effective in anticipating optimum investment timing, except for very high levels of uncertainty, where the opposite is true.

Our framework also offered insights on some of the key drivers of decision-making taken into account by IVCs and how they may influence their optimum investment timing. Surprisingly, we revealed that increasing profit sharing on carried interest may actually postpone optimum investment timing, and increasing its underlying hurdle rate anticipates optimum investment timing. As carried interest becomes more valuable when greater profit sharing is in place, GPs postpone their optimum investment timing with the purpose of maximizing the probability of actually earning their carried interest. The opposite effect is observed concerning the hurdle rate. In fact, increasing the equity stake held by GPs on their IVC funds under management was revealed as one of the most significant variables anticipating optimum investment timing.

We tested whether our theoretical predictions regarding PVC investment volumes would obtain empirical support, on a sample of thirteen European countries for the 2007-2014 period. Even though taxation proved not to be correlated with PVC investment volumes, the remaining results offered overall empirical support to our theoretical hypothesis. In addition, we also showed that PVC investment volume is not correlated with business cycle and that PVC investment volume is intended to suppress perceived gaps on the equity financing market.

We end by pointing out some relevant insights on future research paths. Although we discussed the *direct* involvement of Governments as a PE or VC investor (by establishing itself as a GP), we are not able to test – due to data insufficiency – the determinants of their intervention as a LP, nor the impact of its aggregate direct and indirect intervention on the equity financing market (Buzzacchi et al., 2013; Jääskeläinen et al., 2007).

Potential effects rising from competition on the equity financing market between PVCs and IVCs might be further investigated. We may argue that these could anticipate optimum investment timing. *VC fund economics* also provides GPs running IVC funds with strong incentives to abandon the small business segment, and focus on bigger deals and raising greater amounts of capital per fund. As management fees are proportionately paid to overall fund size, they provide riskless earnings to GPs. Therefore, independent GPs may join the equity financing market by raising small amounts of funds and then, if they succeed, target bigger fund sizes and bigger deals on subsequent funds.

We have also not considered the full range of public stimuli that Governments may offer to foster investment volumes. These may include tax credits, tax allowances, Social Security bonus, or tax based subsidies dependent on incremental employment or allocated to research and development initiatives (Peneder, 2008). Similarly, we have not discussed the nature and effectiveness of different types of Government support (Keuschnigg and Nielsen, 2001). For example, Lerner (2002) found evidence that a prevalent characteristic among under-achieving firms is the existence of research grants from numerous Government sources, which allow them to avoid accountability.

Our framework assumed that Entrepreneurs did not influence the decision-making process of IVCs and PVCs, except for the amount of capital they would be willing to provide to the Start-up Firm. Their option to invest in her or his own Start-up Firm may also be modelled as a real option and we would then extend our framework to a two or three party alignment process, in which the Entrepreneur, the IVC and/ or the PVC would jointly determine the outcomes of this entrepreneurial financing process.

Finally, PVCs are argued to have a relevant role in mitigating some of the risks rising from information asymmetry (Lerner, 1999; Lerner, 2002), providing certification to investee firms, which may specially relevant for raising capital on future equity rounds. Considering that staging is one of the features of VC investment processes (Dahiya and Ray, 2012; Elitzur and Gavious, 2003; Gompers, 1995; Hsu, 2010; Leisen, 2012; Li, 2008; Lukas et al., 2015; Tian, 2011; Wang and Zhou, 2004), the role of PVCs as enablers of future investment rounds could also be depicted.

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