

# Short-Term Shareholders, Bubbles, And CEO Myopia

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June 12, 2013

## Abstract

This paper analyses the real economy effects of firms having some shareholders with a short investment horizon on their shareholder register. Short-term shareholders cause informed management to be concerned with the path of the share price as well as its ultimate value. Such shareholders in an economy lead to bubbles in the prices of key inputs, to the misallocation of firms to risky business models, and to increased costs of capital. For individual firms short-term shareholders induce the Board to reduce deferred incentives in CEO pay prompting CEO myopia and reduced investments in the long-run capabilities of the firm.

**Keywords:** investor time-horizons; bubbles; CEO compensation; cost of capital; short-termism; bonuses; shareholder register.

**JEL Classification:** G12, G34, L21, L25.

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I would like to thank Vincent Crawford, Alexander Gumbel, Harrison Hong, James Malcolmson, Alan Morrison, Mungo Wilson, and Peyton Young for helpful comments, as well as seminar audiences at Oxford University, Cambridge University, and at the Swiss IO day. All errors remain my own.

“As long as the music is playing, you’ve got to get up and dance. We’re still dancing.”

Chuck Prince, former Chairman and CEO of Citigroup, July 2007.

# 1 Introduction

The Board of a firm must account for its actions to the firm’s shareholders. However there is widespread concern that some shareholders are not sufficiently committed to the long term success of the firms they own. Lack of appropriate shareholder oversight has been blamed for many corporate failings, from a lack of investment by manufacturing firms in the UK for over a century, to over-paid executives in the US and elsewhere who took excessive ill-judged risks.<sup>1</sup> Recently there have been a number of proposals in the US and UK designed to encourage long-term share ownership and engagement.<sup>2</sup> Shareholders are indeed heterogeneous, some will be vulnerable to liquidity shocks, others may have short investment horizons. However such shareholders who sell invite the market to judge the firm’s prospects and performance and so arguably act in support of value creation. This study uses theoretical Finance and Industrial Organization techniques to analyse the implications on the real economy of firms having some shareholders with a short investment horizon on their shareholder register.

To explore the relationship between short-term shareholders and the real economy, I build a tractable general equilibrium model in which firm business choices, resultant input purchases, and shareholders interact. To analyse the implications for CEO pay and shareholder voting I then augment the analysis by a partial equilibrium study of the pressures on an individual firm. The driving assumption of this work is that the Board of a firm seeks to maximise the aggregate value of the shareholders on their register at the time a business decision is taken. This is one of two standard paradigms used in the Finance literature. For example, the Pecking Order theory of capital structure uses this assumption. Specifically, the seminal work of Myers and Majluf (1984) has the firm maximising the value of the old shareholders as opposed to those who might buy the stock in the future, and this distinction gives rise to the negative signalling effects of issuing equity. The second paradigm is to posit that firms maximise net present value. With

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<sup>1</sup>For example Mayer (2013) argues that dispersed shareholdings lead to over-rapid expansion and the ultimate death of many venerable UK companies over the course of the 20th century. Bebchuk (2007) argues that dispersion of ownership leads to reduced oversight of US corporations leading to excessive pay and ill-judged risks. However Stout (2007) cautions that shareholders may not have the long term interests of the firm at heart.

<sup>2</sup>In the US the Aspen Institute (2009) allege short-termism in the US is ‘*system-wide*.’ They propose, inter alia, that shareholders should be able to vote only after a minimum holding period. In the UK the Kay review (2012) also concluded that ‘*short-termism is a problem* (Executive Summary, para ii)’. They proposed, inter alia, that CEO remuneration should be altered to forcibly reduce the weighting on current performance. In the EU the Commission are consulting on increasing the voting weight of shareholders who are long-term holders of the stock. (See *Brussels aims to reward investor loyalty*, Financial Times, Jan 23, 2013.)

the presence of shareholders this approach of npv value maximisation is delivered by the Fisher Separation Theorem (Fisher (1930, p141)). The Separation Theorem notes that value maximisation maximises every owner's consumption opportunity set and so would be unanimously supported. In capital markets in which risk-sharing opportunities are not complete, or asymmetric information exists, the application of the Fisher Separation Theorem is disputed (DeAngelo (1981)).

In the model studied the firms in an industry must decide between two competing business models. One offers a safe payoff, the second a risky one. Firms are not identical, they differ in their ability to harness the risky technology. For some firms the expected payoff from the risky technology will outweigh that from the safe technology. The Board has better information as to the firm's ability than investors. These assumptions have broad applicability. For example, prior to the financial crisis a bank could decide to pursue a business model of securitising mortgage backed securities, or not. Not all banks would be equally adept at assessing the value and riskiness of the underlying assets.

If the firms were held solely by long-term investors, each firm's Board could maximise its value by pursuing the business model with the greatest expected long run payoff. However, suppose there are a proportion of short-term shareholders in the investing population. These are shareholders who will sell their stake before payoffs are fully realised. Such shareholders care about the price of the shares at the point they sell. The Board, representing the totality of the shareholder base, is therefore concerned for both the time-path of the share price as well as the final payoff.

An implication of asymmetric information is that the firm's choice of business model sends a signal to the market. Firms with greater ability to profit from the risky technology will choose it over the alternatives. As a result the choice of the risky business model leads to an increase in the short run market value as the market infers that the firm type must be drawn from a set which includes high ability firms. Firms in an economy containing short-term shareholders will be willing to sacrifice some long run expected payoff for this short run price increase. This increases the demand amongst firms to develop the risky technology. In the words of the former CEO of Citigroup, the short-run shareholders encourage the firms to *get up and dance*. It follows that the presence of short-term shareholders increases the demand for the inputs required for the risky technology above the level justified by fundamentals. This pushes the price of the inputs required for the risky technology up. A bubble is created.

If the elasticity of supply of the input is high, the price response of the input asset will be muted. However this will exacerbate the firm misallocation effect. These effects imply that an economy with short-term shareholders causes its firms to ex ante have reduced expected value. The equity cost of capital is therefore higher than it would be with solely long-term investors.

Extending the analysis, firm type can be endogenised by allowing it to be improved

by CEO / management-team effort. I expand the analysis to have the Board set a private incentive contract for the risk averse CEO. The CEO can be induced to select the risky technology by offering sufficient reward on the short-run price. However the early share price will not be impacted by private efforts the CEO makes to raise future performance. The Board therefore faces a dilemma as excessive focus on the short-run weakens CEO incentives to take efforts for the long run. Growth in the proportion of short-term shareholders on the register leads to reduced long term incentives, increased CEO myopia, reduced effort for the long term, and too great an allocation of firms to the risky technology. The market infer this and so the uplift in the short-run share price is modest. As a result it becomes expensive to motivate the CEO to select the risky technology at all, and so the benefit to saving money by focusing on less risky short-run incentives is further reinforced.

The results are all robust to endogenising the Board's objective function through a shareholder voting game.

By hand collecting data I demonstrate that short-termism in share ownership differs significantly between countries (Germany/Switzerland vs. US, Figure 3). I also document substantial difference in short-termism between firms in the same country (Figure 4). Hence understanding short-termism is relevant. The analysis suggests empirical predictions linking investor time horizons with the cost of capital, firm allocation to risky business decisions, and the structure of CEO pay. I document that the recently available empirical literature which begins to study investor time horizons adds further support to this analysis.

## 2 Relationship To The Literature

An empirical literature exists which seeks to assess how substantial a problem short-termism in investor horizons might be for corporate behaviour. Asker, Farre-Mensa, and Ljungqvist (2010) compare investment behaviour amongst listed firms to matched unlisted ones. The authors provide evidence that the listed firms are less responsive to investment opportunities and smooth their earnings, arguing that this is evidence of short-termism. An alternative approach with complementary results is pursued by Derrien, Kecskes, and Thesmar (2013) who measure the frequency with which investors turnover their portfolios to proxy for their investment horizons. Other empirical studies also provide evidence that short-term shareholders can adversely impact corporate performance. Polk and Sapienza (2009) demonstrate that firms held by shareholders with shorter investment horizons are less sensitive to investment opportunities. Bushee (1998) provides evidence that if a firm has short-term shareholders then it tends to reduce R&D expenditures. Gaspar, Massa, and Matos (2005), and Chen, Harford, and Li (2007) provide evidence that firms who have investors with short investment horizons appear to do less well in acquisition situations.

Graham, Harvey, and Rajgopal (2005), offer survey evidence in which managers claim to being willing to sacrifice long run profitable projects to meet short run earnings targets.

This rich empirical body of work connecting investor horizons and corporate behaviour has grown with a body of theoretical literature exploring what the effects of executive short-termism might be.<sup>3</sup> In general the literature has built upon an assumption that executives' utility is a function of the firm's long term value and the current share price. In this setting Stein (1989) studies a CEO being able to undertake an unobserved investment decision. In this case the CEO is in a prisoner's dilemma. The CEO under-invests to boost the current stock price and so hope to convince the market that the firm is better than it is. This behaviour is anticipated by the market and so ultimately there is no share price gain. As in equilibrium the CEO actions do not transmit any information to the market, this is a signal jamming model. Bebchuk and Stole (1993) instead offer a model in which the firm chooses an investment level which is observable to the market. Hence the CEO is able to build a reputation for the firm. In this setting the CEO who is exogenously concerned with the short-term share price will over invest. Miller and Rock (1985) make the same point in a model in which dividends are used to signal. As in Bebchuk and Stole (1993) and Miller and Rock (1985) mine is a model of signalling, not of signal jamming. Relative to this body of work I embed the CEO in a general equilibrium framework and so derive implications for the assignment of firms in an economy with short-termism to risky/safe business models; I derive implications for the asset prices of required inputs and document the rationale for bubbles; and I endogenise the CEO's utility by modelling the relationship between the composition of the shareholder register, and the CEO incentive contract with both deferred and immediate incentives.

Investor planning horizons and adverse corporate outcomes have been explored in some other studies. Shleifer and Vishny (1990) suggest that long term investments can be mispriced for longer. Therefore assuming that executives are more sensitive to a drop in the short-run share price, than to an increase in its level, the authors argue that long run investments will be avoided. Goldman and Strobl (2013) argue that the manager can inflate the share price by investing in complex assets whose payoff times differ from those of the managers of large institutional blockholders. The study I offer here endogenises the CEO utility function, and provides an analysis of economy wide outcomes on prices and firm allocations to business models, all of which are extensions to this literature.

The study here, and those documented above, are of rational short-termism: investors and managers have common priors and are expected utility maximisers. Short-termism amongst managers can also be explained when investors have behavioural features, such as differing priors as to a firm's prospects. Bolton, Scheinkman and Xiong (2006) derive the optimal remuneration structure when the owners of a firm calculate that they can sell to over-optimistic outside investors. The CEO can be encouraged to select projects

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<sup>3</sup>See Stein (2003) for a broader survey of agency problems and corporate investment.

which will be misvalued by buyers by rewarding the CEO sufficiently in terms of short-term results. Like Bolton et al. (2006) this study calculates optimal CEO remuneration. However unlike Bolton et al. the study here is one of rational investors and signalling, thus the mechanism analysed is entirely different. Further, the study offered here embeds the analysis in a general equilibrium framework allowing results on the assignment of firms to business models, and on bubbles in the price of inputs to be derived.

There is a rich literature on bubbles in asset markets, but to my knowledge this is the first study which links shareholders with corporate behaviour and hence with bubbles.<sup>4</sup> Allen and Gale (2000) offer a model of asset bubbles in which investors borrow from a banking sector which cannot observe their investments. Due to assumed limited liability the investors seek to risk-shift and move the funds into the risky asset, thus pushing the price of the risky asset above fundamental levels. Using a similar mechanism Allen and Gorton (1993) have both skilled and unskilled portfolio managers. The unskilled managers seek to profit from their limited liability and so are willing to buy assets at a price which is above fundamentals. Unlike these works, there is no risk-shifting rationale in the framework here. Rather maximisation of shareholder value is linked to firms' business allocation decisions, and hence to the equilibrium price of input assets. Further this prior work on bubbles is silent on the optimal incentive contracts for the CEOs of firm's subject to these effects.

Finally the work here contributes to the literature on the optimal time profile for executive compensation to manage myopia. Bolton, Scheinkman and Xiong (2006) has been discussed above. Thanassoulis (2013) links optimal CEO incentives with industry structure. Thanassoulis (2013) argues that in concentrated industries some firms will endogenously decide to offer contracts which overweight short-term results relative to long term performance. Edmans et al. (2012) and He (2012) derive the optimal contract in a principal-agent setting if an executive can save and take myopic actions. All of these models endogenise the CEO contract and demonstrate that deferral of pay is part of the optimal contract. Unlike these prior works, here I link the optimal CEO incentive contract to the composition of the shareholder register. Further, by embedding the study in a general equilibrium context the implications for bubbles and firm allocations to different technologies are derived and are entirely new.

### 3 The Model

Consider a continuum of firms indexed by type variable:  $\tau \in [0, 1]$ . The types of firms in the population are distributed according to the commonly known cumulative distribution function  $G(\tau)$  with probability density  $g(\tau)$ . The Board of the firm privately knows its type and publicly selects and announces a business activity choice at time  $t = 1$ . There

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<sup>4</sup>For a review of the broader literature on bubbles see Camerer (1989).

are two possible business activities to select from. The Board can choose to develop a safe technology. This technology requires an input priced at the numeraire of 1 and yields a certain payoff at  $t = 2$  of  $r > 1$ . Alternatively the Board can choose to develop a risky technology. In this case the firm must buy a different input labelled the input asset. It has a price per unit of  $P$ . The  $t = 2$  payoff from a unit of the risky technology is random and denoted  $h(\tau)$ . The distribution of payoffs is indexed by the firm type,  $\tau$ , which captures the ability of the firm in this activity. Higher  $\tau$  firms have a payoff from developing the risky technology which first order stochastically dominates the payoff from a less able, lower  $\tau$ , firm. Hence if  $\tau_1 > \tau_2$  then  $E_{\tau_1}(h) > E_{\tau_2}(h)$ . Setting  $\bar{R} := E_{\tau}(h|\tau = 1)$  to be the expected payoff of the most talented firm, by relabelling the index  $\tau$ , we can without loss of generality set the expected payoff from developing the risky technology of a firm of type  $\tau$  to be:<sup>5</sup>

$$\Pi^{\text{risk}}(\tau) = \bar{R}\tau \quad (1)$$

Each firm is assumed to have a unit of capital, and the input asset is assumed to be in restricted supply of  $b$ . I assume that

$$\bar{R}b < r < \bar{R} \quad (2)$$

This guarantees that we remain within an interior solution so that an intermediate proportion of firms will develop the risky technology. The price,  $P$ , of the input asset will be determined in equilibrium by the balance of demand and supply. This is a model which captures a firm's decision as to whether or not to enter a potentially risky business line. The input asset captures the specific input needed to access the risky business line. For example, the input asset may be sub-prime mortgages which can be used to create CDOs, or it may be appropriately skilled labour in a developing country which could be used to offshore production to a cheap but distant location. The type  $\tau$  captures that firms differ in their ability to value and/or harness these assets.

The equity of the firms is owned by shareholders of which there are two types. Some shareholders are long term buy-and-hold investors. They will hold their shares until the payoffs are realised at  $t = 2$ . The remaining shareholders are short-term shareholders. They will not hold their shares until the payoffs are realised. They are modelled as selling their shares at the end of  $t = 1$ , after the Board make their business line decision, but before the profits are realised. The price will be the fair market value which is the expected  $t = 2$  payoff conditional on all public information. Thus I combine repeated short-life shareholders as in Bhattacharya (1979) with buy-and-hold investors. The short-term shareholders can be motivated as investors who have short time horizons. Alternatively one could interpret the model as one of homogeneous shareholders with a probability of

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<sup>5</sup>This is without loss of generality as variation in the payoffs can be captured through the distribution of firms,  $g(\tau)$ .

a liquidity shock at  $t = 1$  causing some of them to sell. I assume that the proportion of short-term shareholders on a firm's register is common knowledge. In practice this is achieved by consulting the identities of owners on the shareholder register, which is a public document, and acquiring knowledge of the investment methods of given investors, such as the breadth of their portfolio, and their stock turnover rate (Bushee (1998), Gaspar, Massa, and Matos (2005)).<sup>6</sup> I suppose that all firms in the industry have the same proportion  $L \in [0, 1)$  of short-term shareholders. This proportion of short-term shareholders is common knowledge. The objective function of the Board is to seek to maximise the value generated for the shareholders on the register at the time the business decision is made.

The timeline of the entire model is depicted graphically in Figure 1. I restrict attention in the analysis to pure strategy Nash equilibria.

## 4 Analysis of Shareholder Effects

In this section we solve the model to explore the relationship between short-term shareholders, the price of the input to the risky technology, and the allocation of firms to business lines.

### 4.1 Input Asset Fundamental Value

The fundamental value of the input asset can be found by calculating the equilibrium price when all the buyers of the asset are long-term value maximisers. This is the natural analogue of the definition of fundamental value offered by Allen, Morris, and Postlewaite (1993) that every agent holding or buying the asset should be willing to do so if they were forced to maintain their holdings for ever.

If a firm of type  $\tau$  invests in the safe technology then it generates a long-run payoff of  $r$ . If instead it invests in the risky technology then it invests at a scale of  $1/P$  and so its expected payoff is  $\bar{R}\tau/P$ . It is immediate that if a firm of type  $\tau$  would invest in the risky technology, so would all firms of higher type. Market clearing at the fundamental price  $P^f$  requires that the total supply of the input asset is bought. Define the function  $q(y)$  as the type for which there exists a mass  $y$  of more talented firms. Thus  $G[q(y)] := 1 - y$ . The market clearing condition is then that firms  $\tau \in [\hat{\tau}, 1]$  invest in the risky technology

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<sup>6</sup>The composition of the shareholder register is often monitored carefully by the Chairman. For example the Chairman of Cadbury, the main UK confectionery company until its purchase by Kraft, commented in interview that “*the seeds of destruction of this company lay in its [shareholder] register.*” Financial Times, March 12, 2010, ‘The inside story of the Cadbury Takeover.’





## 4.2 Bubbles and Misallocation

We now analyse the general model in which firms have a proportion  $L$  of short-term shareholders on their shareholder register. A strategy for the Board of each firm is a decision function which maps the firm type to a choice between developing the risky technology or the safe technology. Thus a strategy is equivalent to a partition of the firm type space into  $T^{\text{safe}}$  and  $T^{\text{risk}}$  such that  $T^{\text{safe}} \cup T^{\text{risk}} = [0, 1]$ ,  $T^{\text{safe}} \cap T^{\text{risk}} = \emptyset$  and if  $\tau \in T^{\text{risk}}$  then the Board decides to develop the risky technology, and not otherwise. It follows that, observing the business model chosen, the market can make inferences as to the set of types which the firm must be drawn from. This will affect the price short-term shareholders will receive when they sell.

**Lemma 2** *If a firm of type  $\tau$  with a proportion  $L$  of short-term shareholders should develop the risky technology then the Board's objective function at  $t = 1$  takes value  $V^{\text{risk}}(\tau, L)$  given by:*

$$V^{\text{risk}}(\tau, L) = (1 - L) \cdot \underbrace{\Pi^{\text{risk}}(\tau)}_{\text{Expected } t=2 \text{ payoff}} + L \cdot \underbrace{E(\Pi^{\text{risk}}(\tau) | \tau \in T^{\text{risk}})}_{\text{Share price at end } t=1} \quad (5)$$

The Board seeks to maximise the aggregate value of the shareholders. The  $1 - L$  long-term shareholders will see the realised payoffs. The expectation of this payoff is  $\Pi^{\text{risk}}(\tau)$ . The  $L$  short-term shareholders will sell their holding before the business results are realised. Thus what matters to these shareholders is the market price they receive for their stock. The share price at point of sale ( $t = 1$ ) will be the expected payoff at  $t = 2$  conditional on all publicly available information. Here this is the choice of business technology:  $E(\Pi^{\text{risk}}(\tau) | \tau \in T^{\text{risk}})$ .

Lemma 2 demonstrates that an immediate implication of the assumption that the Board maximise the value of the shareholders on the register at the point of taking a business decision is that the Board's objective function is a weighted average over the path of share prices as well as the expected net present value of the business decision. The weights in the objective function depend upon the proportion of short-term shareholders on the register:  $L$ .<sup>7</sup>

The market's inference as to expected firm payoff depends upon the equilibrium strategy of the Board.

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<sup>7</sup>There is no ex-ante disagreement between the two types of shareholder as to the market value of the firm. Long-term shareholders see the ex-ante (start  $t = 0$ ) value of the firm as

$$\Pr(\tau \in T^{\text{safe}}) \cdot r + \int_{\tau \in T^{\text{risk}}} \Pi^{\text{risk}}(\tau) dG(\tau) = \Pr(\tau \in T^{\text{safe}}) \cdot r + \Pr(\tau \in T^{\text{risk}}) \cdot E(\Pi^{\text{risk}}(\tau) | \tau \in T^{\text{risk}}) \quad (6)$$

The right hand side is the expected value placed on the firm by the short-term shareholders. It follows that in a free capital market short and long term shareholders will not self-select to different stocks.

**Lemma 3** *The Board's strategy takes a cut-off form: if firm type is above some level  $\tau^*$  then the Board decides to develop the risky technology; otherwise it develops the safe technology.*

The proof follows by noting that firms of higher type  $\tau$  create greater expected value for their long-term shareholders from the risky technology than firms with lower type. Short-term shareholders are indifferent between all firms which select the same technology. This is because firm type is private information and so not priced in until payoffs are realised. The partition of the type space then follows.

As firms are in part concerned with the path of their share price (Lemma 2), the Board perceive a signalling value and/or cost in the choice of business model. If the Board choose to develop the risky technology then the short-run share price will rise. However the business requires inputs, and as firms seek to buy the input they will force the price of it up. This brings us to the first main results of this analysis:

**Proposition 4** *Suppose that all firms have a proportion  $L > 0$  of short-term shareholders on their shareholder register. The input asset price is uniquely defined by:*

$$r = \frac{\bar{R}}{P}q(bP) + L\frac{\bar{R}}{bP^2} \int_{\tau=q(bP)}^1 1 - G(\tau) d\tau \quad (7)$$

*This implies:*

1. *Short-term shareholders create a bubble in the price of the input asset:  $P > P^f$ .*
2. *Inefficiently many firms develop the risky technology.*

To understand the result suppose that there was no bubble and the price of the input asset were at its fundamental level of  $P^f$  as given in equation (4). Each firm which pursues the risky technology will do so at a scale of  $1/P^f$ . As the supply of the input asset is fixed at a total volume of  $b$ , the marginal firm which invests in the risky technology will have type  $\hat{\tau}$ , from (3), so that the total mass  $b$  of input asset is bought. Long term shareholders of a firm at the cut-off  $\hat{\tau}$  would be left indifferent between the two technologies. Now consider the incentives for the Board of a firm of type just below this level, say type  $\tau = \hat{\tau} - \varepsilon$  for  $\varepsilon$  arbitrarily small yet positive. At the fundamental price  $P^f$  for the input asset the net present value of the risky technology is below that from the safe technology. Thus long term-shareholders would lose out slightly from a decision to invest in the risky technology. The net present value would fall by an amount proportional to  $\varepsilon$ . However, if the Board of the firm of type  $\hat{\tau} - \varepsilon$  did invest in the risky technology then the market would infer, mistakenly, that the firm was drawn from type  $\tau \in [\hat{\tau}, 1]$ . Hence the market price at the end of  $t = 1$  would jump up. This would represent a gain for the short-term shareholders

of constant order and so would outweigh the loss to the long-term shareholders.<sup>8</sup>

This implies that firms of type below  $\hat{\tau}$  would buy the input asset at its fundamental price. However the supply of the fundamental asset is not perfectly elastic. This extra demand at the fundamental price will force the price of the input asset up. Hence a bubble is created in the input asset.<sup>9</sup>

All the firms which invest in the risky technology now face a higher price for the input asset, and so they use less of it and enter the risky technology at a smaller scale. Market clearing for the risky asset then requires that more firms decide to invest in the risky technology. Thus the proportion of firms which seek the risky technology grows as compared to the efficient level with no short-term shareholders.

**Proposition 5** *If the proportion of short-term shareholders in the economy should increase:*

1. *The bubble in the price of the input asset increases.*
2. *The proportion of firms selecting the risky technology rises.*
3. *The average payoff of firms which develop the risky technology falls.*

Proposition 5 demonstrates that the impact of short-term shareholders on the industry's outcomes is monotonic. If the proportion of short-term shareholders increases, then the greater the reduction in long-run value a Board is willing to accept in return for the increase in the value received by the short-term shareholders. This increases the willingness of firms to invest in the input asset and develop the risky technology. This increase in demand for the input asset forces its price up. It also exacerbates the misallocation of firms to technologies as firms are able to buy less of the more expensive input asset, and so market clearing requires more firms to switch to the input asset.

The average payoff of a firm conditional on its developing the risky technology falls as more low type firms join this group. Short-term shareholders therefore also affect the firms' implied cost of capital. Suppose that the firms had to raise their unit of capital from the equity markets prior to the start of the game. At this point investors would be unaware of the firm's type. A firm valued in expectation at  $V$  would have to sell a shareholding of  $1/V$  to secure a unit of equity capital. The larger is the valuation,  $V$ , the lower is the cost of capital.

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<sup>8</sup>The  $t = 1$  share price is not raised here by the absence of short-sellers (Lamont (2004)). Neither long nor short term shareholders have privileged information at  $t = 1$  as to whether the firm is at the top or bottom end of the ability range which self-selects the risky technology. The share price is the expected firm value over this firm ability range.

<sup>9</sup>Here I use the definition that a bubble is a deviation in the price of an asset from its fundamental value. This is standard, see, for example, Allen, Morris and Postlewaite (1993), and Allen and Gale (2000).

**Proposition 6** *The firms' cost of capital grows with the proportion of short-term shareholders in the population.*

With numerous short-term shareholders a larger set of firm types would wish to develop the risky technology to raise their interim share price, even at a cost to long-term shareholders. Hence there is a greater probability that a firm will choose a business line not its long term interests. This is a misallocation effect which lowers the expected payoff of those firms who should have opted for the safe technology, but instead will opt for the risky technology. Further, there is also a second general equilibrium effect. An increase in the proportion of short-term shareholders raises the price of the input asset, and this lowers the expected value of any firm developing the risky technology. Hence through this channel also the representative firm sees its value decline. Both of these effects raise the cost of capital of a representative firm as the expected firm value declines.

Proposition 6 offers support for the policy objective suggested in both the UK and the US that shareholders should be encouraged to be long term holders of a stock.<sup>10</sup> We conclude this section by confirming these results at the individual firm level, as opposed to the industry-wide level:

**Proposition 7** *If an individual firm should see the proportion of short-term shareholders on its register rise then:*

1. *The firm will select the high risk technology with higher probability.*
2. *The firm's cost of capital will rise.*

### 4.3 Input Asset In Elastic Supply

The presence of short-term shareholders in the economy causes bubbles to form in the price of inputs, and it causes firms to invest too frequently in the high risk technology. In this section we demonstrate how the extent of these effects is affected by the supply elasticity of the input asset required for the high risk technology.

To allow comparability across industries, suppose that the supply  $S(P)$  of the input asset responds to price according to the relationship

$$S(P) := b \cdot \left( \frac{P}{P^f} \right)^\zeta \quad (8)$$

Supply function (8) is normalised so that absent short-term shareholders, the price of the input asset is invariant at the level  $P^f$  given by (4), and the critical firm type is  $\hat{\tau}$ , given by (3). The supply function has a constant elasticity  $\zeta$  with respect to price to facilitate the empirical interpretation of the results. The benchmark example had inelastic supply

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<sup>10</sup>See the references in footnote 2.

( $\zeta = 0$ ). As the supply becomes more elastic, the greater the responsiveness of supply to any change in the price of the input asset.

I augment (2) and restrict attention to parameters such that

$$b < \frac{r}{\bar{R}} \cdot \left( \frac{r}{\bar{R}} P^f \right)^\zeta \quad (9)$$

This is sufficient to ensure existence of the equilibrium price for any given elasticity of supply,  $\zeta$ .

We can establish the price of the input asset,  $P$ , and the critical firm type,  $\tilde{\tau}$ , above which the Board will pursue the risky technology.

**Lemma 8** *In an industry with elasticity of supply  $\zeta$  and with  $L$  short-term shareholders, the critical firm type,  $\tilde{\tau}$ , which just selects the risky technology satisfies*

$$\frac{r}{\bar{R}} \left[ \frac{(P^f)^\zeta}{b} (1 - G(\tilde{\tau})) \right]^{\frac{1}{1+\zeta}} = \tilde{\tau} + \frac{L}{1 - G(\tilde{\tau})} \int_{\tau=\tilde{\tau}}^1 1 - G(\tau) d\tau \quad (10)$$

The critical firm type is uniquely defined and the price of input asset,  $P$ , is given implicitly by

$$\tilde{\tau} = q \left( b \cdot P \left( \frac{P}{P^f} \right)^\zeta \right) \quad (11)$$

We know from Proposition 4 that when there are short-term shareholders on the register, the price of the input asset will be pushed up away from fundamentals. Further we know that inefficiently too many firms will pursue the risky technology. We now demonstrate that the misallocation of firms to the risky technology is greatest when the elasticity of supply is greatest.

**Proposition 9** *The extent of misallocation to the risky technology in any industry grows with the elasticity of supply of the input asset, and with the proportion of short-term shareholders.*

Proposition 9 allows a cross-sectional comparison across industries which differ by the elasticity of supply of the input asset required for the high-risk technology. Holding the proportion  $L$  of short-term shareholders in the economy fixed, the misallocation of firms to the risky technology will grow with the elasticity of supply when  $L > 0$ . For example, in the banking industry the high risk technology could be securitisation of mortgage backed securities, and so the input asset would be sub-prime mortgages. In the trainer (sneaker) industry, the high risk technology might be subcontracting production to low cost developing world manufacturers, and so the input asset might be labour in the developing country. The elasticities of supply of these two input assets are unlikely to be the same. By Proposition 4, the presence of short-term shareholders will push up the proportion of

firms opting for the risky technology above the level justified by fundamentals. Proposition 9 predicts that this misallocation effect is strongest in industries where the elasticity of supply of the input asset is greatest.

We have established that short-term shareholders on firms' registers causes firms to, at the margin, seek the high risk technology to drive up the path of the share-price. This raises the demand for the input asset above that justified by fundamentals. In industries where the elasticity of supply of the input asset is high, this increase in demand is met mostly by an increase in supply with the price response remaining muted. As the supply response is so pronounced more firms misallocate to the risky technology, yielding the result. In countries where the short-term shareholding is greatest, this misallocation will also therefore be expected to be greatest.

## 5 CEO Incentive Pay

I now extend the model to provide a role for the CEO. I consider a single firm and suppose the CEO has the ability to improve the firm's type, at some personal effort cost. Effort will be unobservable, as is standard, giving the Board a moral hazard problem. Secondly, I allow the CEO to ultimately decide which business model should be pursued. In reality the choice of business model is a matter for agreement between the Board and the CEO, thus the polar case of the CEO deciding is a relevant one to consider. I will note that this is not an essential simplification.

Any improvements made by the CEO to the firm type will not be observable until payoffs are realised. Hence to incentivise the CEO to undertake such improvements, pay must include a sufficient delayed and so risky component. A risk averse CEO will discount such pay, and so it is expensive for the Board to reward in this way. Further, deferred pay will align the CEO's choice of technology to develop with the firm's long-run value. Firm's with short-term shareholders on the register therefore face a dilemma between incentivising effort on improving the firm's capabilities and incentivising a desirable share price path. This section analyses this situation in a partial (as opposed to general) equilibrium framework to determine the optimal CEO contract and so explore possible CEO myopia.

### 5.1 Extending The Model To Include The CEO

The firm type,  $\tau$ , is known to the Board and is observed by the CEO prior to contracting at an earlier  $t = 0$ . As in our benchmark model, firm type  $\tau$  is not observed by the market who are aware only of its distribution. To avoid corner solutions I allow the firm type  $\tau$  to be distributed on the positive reals. The proportion  $L$  of short-term shareholder's on the firm's register continues to be common knowledge.

To study CEO contracting I use the standard approach of normal payoffs and CEO mean-variance utility. Such a formulation can be justified, for example, if the CEO's utility function were exponential and of constant absolute risk aversion.<sup>11</sup> More broadly such an approach is a tractable way of modelling a risk averse agent. If the CEO's payment is given by the random value  $W$  then the expected utility, gross of the effort cost is:

$$E(U(W)) = E(W) - (\rho/2) \text{var}(W) \quad (12)$$

The parameter  $\rho$  is the CEO's coefficient of absolute risk aversion.

Once hired, the CEO decides at the start of  $t = 1$  between implementing the safe or the risky technology. If the CEO decides to implement the risky technology then he can raise the type of the firm by an amount  $\eta$  to type  $T = \eta + \tau$ . This comes at a personal effort cost of  $\kappa\eta^2/2$ . Such a quadratic assumption is convenient due to its tractability. It is not an essential assumption. In the case of developing the risky technology, the payoff at  $t = 2$  per unit of input asset is assumed to be distributed according to the normal distribution  $X_2(T) \sim N(\bar{R}T, \sigma^2)$  with mean  $\bar{R}T$  and variance  $\sigma^2$ . This is a restriction on the benchmark model which allowed for any distribution of payoffs. The assumption is made so that the certainty equivalent of the CEO's utility takes the simple form of mean less variance, as given in (12). The variance of the payoff is unrelated to the firm type, so higher type firms have their distribution of payoffs purely shifted to the right. If instead the CEO develops the safe technology then the payoff is known with certainty as  $r$ .

To participate at  $t = 0$  the CEO must receive expected utility at least as great as his outside option, denoted  $u$ . The effort component,  $\eta$ , is chosen by the CEO after contracting. I normalise the discount rate of the CEO and the firm to 0. The Board can remunerate the CEO through a fixed wage payment  $f$  which I allow to take positive or negative values.<sup>12</sup> In addition the Board can use a bonus  $b$  as a proportion of market value at  $t = 1$ , or a deferred (vested) bonus at  $t = 2$  as a proportion  $v$  of realised value, or any combination. The bonus elements agreed between the Board and the CEO at  $t = 0$  are private information to the contracting parties. This assumption captures that in reality the Board is not bound by indicative bonus rates it puts in the public domain. One case study example is provided by the CEO of BP in 2010. The share price performance over the period 07-09 would have led to no share award according to the publicly published criteria. In the event the CEO was awarded a bonus of shares equal to over 80% of base pay.<sup>13</sup>

The market value of the firm at time  $t = 1$  is denoted  $X_1$ . If the firm develops the risky technology then this market value will depend upon market beliefs as to the prevailing

<sup>11</sup>See, for example, Varian (1992, s.11.7).

<sup>12</sup>Negative fixed fee,  $f$ , captures settings in which the CEO must first make a payment to the firm in return for being hired with the incentive pay schedule.

<sup>13</sup>"BP's Hayward Given 41% Increase," Financial Times, March 5, 2010.



CEO contract. Thus the CEO receives the following remuneration:

$$W = f + bX_1 + vX_2$$

Finally I restrict attention to parameter values such that

$$\left(\frac{\bar{R}}{P}\right)^2 > \kappa\rho\sigma^2 \quad (13)$$

This condition is an upper bound on the CEO's risk aversion or effort cost.

## 5.2 Optimal Contracting

As we are considering an individual firm I ignore general equilibrium effects and assume that the price of the input asset is fixed at  $P$ .

### 5.2.1 Optimal Contract Incentivising the Risky Technology

By reasoning analogous to Lemma 3 if the CEO develops the risky technology then the market believes the firm is distributed on  $[\tilde{T}, \infty)$  according to some distribution  $\Gamma(T)$ . This distribution will depend upon the effort the CEO is incentivised to undertake. The market's beliefs as to the CEO's contract is denoted  $\{\tilde{f}, \tilde{b}, \tilde{v}\}$ .

If the CEO chooses the risky technology, the firm will be valued at  $t = 1$  by  $X_1^{\text{risk}}$ :

$$X_1^{\text{risk}} = \int_{T=\tilde{T}}^{\infty} \frac{\bar{R}}{P} T d\Gamma(T) - \left[ \tilde{f} + \tilde{b}X_1^{\text{risk}} + \int_{T=\tilde{T}}^{\infty} \tilde{v} \frac{\bar{R}}{P} T d\Gamma(T) \right] \quad (14)$$

Equation (14) states that the market value at  $t = 1$  if the firm has chosen the risky technology will equal the expected payoff conditional on taking this technology, less the expected payment to the CEO. This payment itself depends upon the market value at  $t = 1$ . Note also that, by definition, the deferred payment  $v$  is proportional to the realised payoff.

The Board can, in private, alter the incentives offered to the CEO and select the remuneration contract with parameters  $\{f, b, v\}$ . If the CEO chooses the risky technology then the payment to the CEO will be  $W^{\text{risk}} = f + bX_1^{\text{risk}} + vX_2(\tau + \eta)$  where the resultant type  $\tau$  is improved by the CEO's efforts to  $\tau + \eta$ . The market at  $t = 1$  does not observe the remuneration contract and so will not price the type improvement into the share price. The utility of the CEO from the risky choice is denoted  $U^{\text{risk}}(\tau)$  and is given, using the mean-variance assumption, by

$$U^{\text{risk}}(\eta, \tau) = f + bX_1^{\text{risk}} + v \frac{\bar{R}(\eta + \tau)}{P} - \frac{\kappa}{2}\eta^2 - \frac{\rho}{2}v^2\sigma^2 \quad (15)$$

**Lemma 10** *If the CEO decides to invest in the risky technology, he will improve the firm type by an amount  $\eta^*$ :*

$$\eta^* = \frac{v \bar{R}}{\kappa P} \quad (16)$$

**Proof.** Direct optimisation of CEO utility, (15), with respect to the effort level  $\eta$ . ■

Lemma 10 demonstrates that the CEO's effort choice only depends upon the deferred bonus. Before the realisation of results, private effort exerted to raise the expected payoffs of the business cannot be verified by the market, and so is not fully reflected in the early share price. Hence early bonuses do not incentivise CEO effort on improving the long run capabilities of the firm.

Early bonuses affect the CEO's incentives over the choice of business technology. Denote the market value of a firm which selects the safe technology as  $X_1^{\text{safe}}$ .

**Lemma 11** *The CEO will prefer the risky to the safe technology if:*

$$b \underbrace{\left[ X_1^{\text{risky}} - X_1^{\text{safe}} \right]}_{(i)} \geq v \underbrace{\left[ r - \frac{\bar{R}\tau}{P} \right]}_{(ii)} - \frac{v^2}{2} \left[ \left( \frac{\bar{R}}{P} \right)^2 \frac{1}{\kappa} - \rho\sigma^2 \right] \quad (17)$$

*If (17) is satisfied, the CEO will accept the contract if*

$$f + bX_1^{\text{risky}} + v \frac{\bar{R}\tau}{P} + \frac{v^2}{2} \left[ \left( \frac{\bar{R}}{P} \right)^2 \frac{1}{\kappa} - \rho\sigma^2 \right] \geq u \quad (18)$$

Lemma 11 determines the restrictions on the contract the Board can offer which ensure that the CEO both accepts the contract, and then selects the risky technology. Equation (17) is the CEO's incentive compatibility constraint. It ensures that the CEO prefers implementing the risky technology to the safe technology. If the CEO implements the risky technology, then the share price of the firm will increase due to the signalling effect which pools the firm with high type firms. This effect is captured in bracket (i). The CEO internalises this jump in short-run value via his short-term bonus,  $b$ . If  $b$  is made sufficiently large then the CEO is incentivised to select the risky technology. For high types of the firm, long term bonus alone will be sufficient to incentivise the firm to select the risky technology. But if the firm type is low enough ((ii) positive) then for some long term bonus values, a strictly positive short-run bonus is required to ensure that the CEO pursues the risky technology.

Equation (18) is the participation constraint. It measures the CEO's utility from developing the risky technology, allowing for the result from Lemma 10 which determines the effort the CEO will exert. If the utility from the contract exceeds the outside option, then it is acceptable to the CEO.

Now we consider the Board's optimisation problem. The Board internalises the views

of all their shareholders. Short-term shareholders will sell at a price of  $X_1^{\text{risk}}$  if the CEO is incentivised to pursue the risky project. This price is not affected by private changes to the CEO contract, unless the contract should incentivise the CEO to alter technology choice. Assuming that the Board do incentivise the risky technology then the objective function is:

$$V^{\text{risk}}(\tau) = LX_1^{\text{risk}} + (1-L)\frac{\bar{R}}{P}(\eta^* + \tau) - \left[ f + bX_1^{\text{risk}} + v\frac{\bar{R}}{P}(\eta^* + \tau) \right]$$

subject to (17) and (18). (19)

The Board's problem can be solved to yield the following characterisation:

**Proposition 12** *Consider a firm of type  $\tau$  with a proportion  $L$  of short-term shareholders on the register. Conditional on incentivising the risky technology, the Board would*

1. Offer the CEO a deferred bonus rate of  $v(L)$

$$v(L) = (1-L) \frac{\frac{1}{\kappa} \left( \frac{\bar{R}}{P} \right)^2}{\left[ \frac{1}{\kappa} \left( \frac{\bar{R}}{P} \right)^2 + \rho\sigma^2 \right]} \quad (20)$$

2. Offer the CEO an expected short run payment of  $f + bX_1^{\text{risk}}$  given by

$$f + bX_1^{\text{risk}} = u - v(L)\frac{\bar{R}}{P}\tau - \frac{1}{2}v(L)^2 \left[ \frac{1}{\kappa} \left( \frac{\bar{R}}{P} \right)^2 - \rho\sigma^2 \right] \quad (21)$$

3. The CEO is incentivised to improve firm type by an amount

$$\eta^*(L) = (1-L) \frac{1}{\kappa} \frac{\bar{R}}{P} \frac{\frac{1}{\kappa} \left( \frac{\bar{R}}{P} \right)^2}{\left[ \frac{1}{\kappa} \left( \frac{\bar{R}}{P} \right)^2 + \rho\sigma^2 \right]} \quad (22)$$

Proposition 12 gives a characterisation of the optimal CEO incentive contract, conditional on the Board deciding to pursue the risky technology. The deferred bonus rate is declining in the proportion of short-term shareholders on the register. Deferred pay incentivises the CEO to improve the long run capabilities of the firm (Lemma 10). But the benefits of these improvements are not fully reflected in the short-run share price. Hence the Board undervalue these benefits. This leads to the lowering of deferred payments. Part three then follows as a corollary. As deferred payments are reduced, the CEO is less incentivised to improve the long run capabilities of the firm, and so the firm will improve its type by less the greater the share of short-run shareholders. In the extreme of only having short-term shareholders on the register, the CEO will receive no long-term deferred

bonus payments, and will not be incentivised to improve the long-run capabilities of the firm at all.

Even though short-term shareholders do not wish to improve the firm's type, conditional on developing the risky technology, they do (by assumption here) wish to structure the contract to ensure that the risky technology is chosen. The smaller the deferred pay, the greater the total short-run payment must be. This explains (21) as the short-run payment is the fixed wages  $f$  plus the bonus on short-run share price performance  $bX_1^{\text{risk}}$ . The CEO controls the short-run performance with little risk as the share price can be moved purely by the signal sent by the business decision (risky or safe technology). As the risk of the short-run bonus is lower than that of the long-run bonus, it is not an expensive way to remunerate even a risk averse CEO.

**Corollary 13** *For the CEO of a firm of given type which develops the risky technology:*

1. *Expected deferred pay is declining in the proportion of short-term shareholders.*
2. *Expected short-run pay is increasing in the proportion of short-term shareholders.*
3. *Total expected pay declines in the proportion of short-term shareholders, and is given by*

$$[\text{Total expected pay}] = u + \frac{1}{2}v(L)^2 \left[ \frac{1}{\kappa} \left( \frac{\bar{R}}{P} \right)^2 + \rho\sigma^2 \right] \quad (23)$$

Corollary 13 uses the optimal contract determined in Proposition 12 to characterise the expected level of CEO pay as a function of the proportion of short-term shareholders on the shareholder register. The Corollary is depicted graphically in Figure 2. As short-term shareholders increase, the deferred bonus rate of the CEO drops (Proposition 12). This lowers the expected improvements the CEO will conduct, and so the CEO receives a smaller deferred share of a less valuable firm. It follows that as the proportion of short-term shareholders increases, the CEO's pay is made up of a greater proportion of short as opposed to long term pay. As this pay is less risky, the risk premium the CEO commands drops, and so expected pay levels fall. (See Figure 2.)

The analysis has assumed that the CEO chooses the technology. As the Board and CEO will have to agree on the technology choice together, it is natural to explore robustness of the results to the opposite polar assumption in which the Board can direct the CEO to implement a given technology choice, risky or safe. The Board would solely face the moral hazard problem of incentivising effort if they have commanded the risky technology to be adopted. The only change this would introduce to the analysis above is that the Board would not be bound by the Incentive Compatibility constraint (17). If

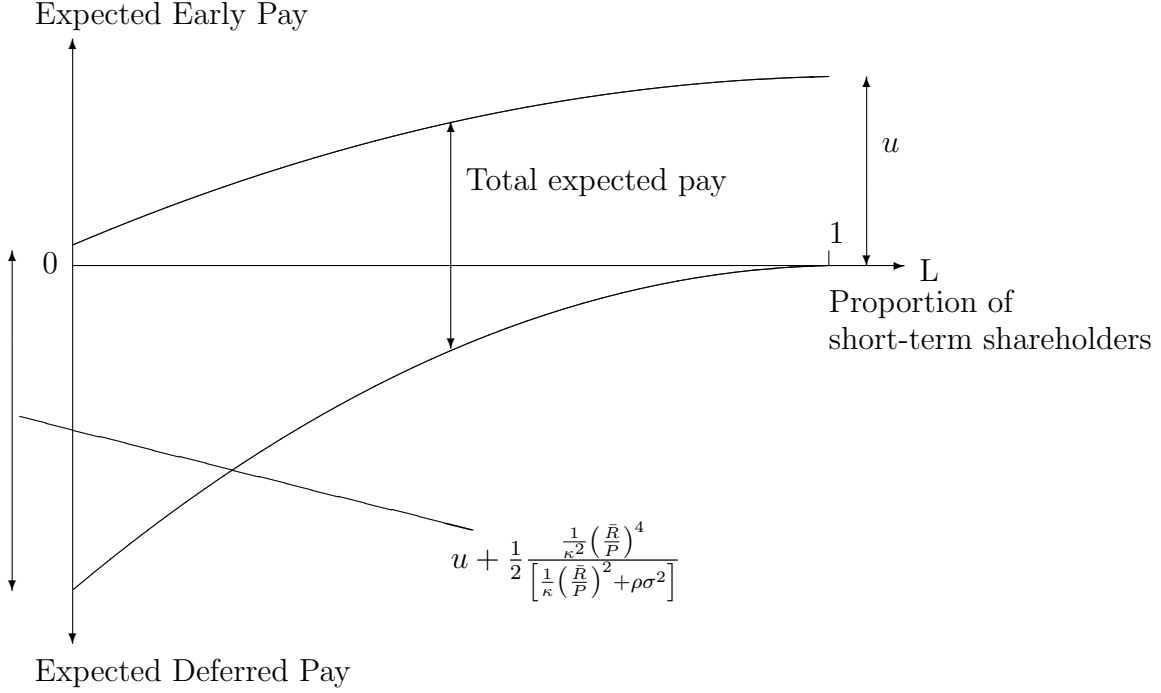


Figure 2: Expected Pay as a Function of the Proportion of Short-term Shareholders

Notes: Expected Deferred Pay is plotted with an inverted scale. As the proportion of short-term shareholders increases, the expected deferred pay drops to zero. Expected early pay consists of fixed wages and short-term performance bonus,  $f + bX_1^{\text{risk}}$ . As the proportion of short-term shareholders increases the early pay rises. Early pay however rises less quickly than deferred pay falls as the lower risk of the remuneration implies that total expected pay is declining in  $L$ . The graph is drawn to scale  $\left( \frac{\bar{R}}{\bar{P}} = 5, \kappa = 1, \rho\sigma^2 = 1/4, \tau = 1/4, u = 15 \right)$ .

the CEO chooses technology the short run bonus is the mechanism by which the Board influence the technology choice. If instead the Board chooses, then the short run bonus becomes directly substitutable with fixed pay. The characterisation offered by Proposition 12 would continue to apply. Hence the results of this section documenting the effect short-term shareholders have on deferred versus early pay (fixed plus short-run bonus) are robust to the modelling of who chooses the technology to be developed.

### 5.2.2 Optimal Incentives Over Technology Choice

I now characterise the fully optimal contract. By reasoning analogous to Lemma 3 the type space will divide at a critical type  $\tilde{\tau}$ . Types above the cut-off develop the risky technology. The CEOs of such firms improve their firm's type by an amount  $\eta^*$  given in Proposition 12. Types below the cut-off develop the safe technology.

**Proposition 14** *For a firm with a proportion  $L$  of short-term shareholders on the regis-*

ter, the critical firm type is unique and is defined implicitly as  $\tilde{\tau}$  by:

$$L \left[ X_1^{risk} - X_1^{safe} \right] + (1 - L) \left[ \frac{1}{2} (1 - L) \frac{\frac{1}{\kappa^2} \left( \frac{\bar{R}}{P} \right)^4}{\left[ \frac{1}{\kappa} \left( \frac{\bar{R}}{P} \right)^2 + \rho \sigma^2 \right]} + \frac{\bar{R}}{P} \tilde{\tau} - r \right] = 0 \quad (24)$$

Where

$$X_1^{risk} - X_1^{safe} = \int_{\tau=\tilde{\tau}}^{\infty} \frac{\bar{R}}{P} \tau \frac{g(\tau)}{1 - G(\tilde{\tau})} d\tau - r + \frac{1}{2} (1 - L^2) \frac{\frac{1}{\kappa^2} \left( \frac{\bar{R}}{P} \right)^4}{\left[ \frac{1}{\kappa} \left( \frac{\bar{R}}{P} \right)^2 + \rho \sigma^2 \right]} \quad (25)$$

Only firms with type above  $\tilde{\tau}$  will develop the risky technology. In equilibrium market values satisfy  $X_1^{risk} \geq X_1^{safe}$ .

The greater the proportion of short-term shareholders, the more weight is put by (24) on the short-run signalling value of choosing the risky technology. The second bracket captures the expected payoff to the long-term shareholders, allowing for the improvement in long-run capabilities which the CEO is incentivised to implement.

The Board are in a prisoners' dilemma. The firm value would be maximised by incentivising long-run value maximisation. This could be achieved by using the optimal contract with  $L = 0$ . However, if the market believed this, then in private a Board representing a positive proportion of short-term shareholders would wish to alter the CEO contract. The Board would wish to privately reduce the deferred bonus as they are less interested in investments which only move the share price in the long term. In addition the Board would wish to increase the weight on the short run bonus so as to encourage the risky technology to be developed. The market anticipates these incentives and so discounts the risky technology as a signal of firm quality. Hence the benefit to the share price of incentivising risks is reduced. In equilibrium the firm types which choose the risky technology is so distorted that the firms do not wish to incentivise the risky technology more than the markets expect. In the extreme of almost all shareholders being short-term ( $L \rightarrow 1$ ), the critical type  $\tilde{\tau}$  would drop so far that the  $t = 1$  market price of the firm will be unaffected by the CEO's choice of technology.

**Proposition 15** *If the gap in  $t = 1$  market prices is large enough,  $X_1^{risk} \gg X_1^{safe}$  then, as the proportion  $L$  of short-term shareholders on the register increases:*

1. *The Board incentivise the risky technology for an increasing range of low-type firms;*
2. *The ex ante firm value declines in the proportion of short-term shareholders, and so the cost of capital increases.*

*A sufficient condition to guarantee that this holds is*

$$E(\tau) > rP/\bar{R} \tag{26}$$

Proposition 15 confirms that the impact of short-term shareholders is, under some conditions, monotonic in their proportion. As the proportion of short-term shareholders increases, the pressure the Board is under to secure the gain in  $t = 1$  value from selecting the risky technology grows. From (24) this creates pressure to accept a reduction in long term value and so the Board wish to incentivise the CEO to go risky for even lower firm types. To achieve this the Board moves the CEO's remuneration more towards short-run pay (Corollary 13). However this pay is less risky, and so the CEO's expected remuneration levels fall. This increases  $t = 1$  firm value marginally. The conditions in Proposition 15 guarantee that the difference in firm value between the two technologies outweigh this CEO pay effect. The critical firm type which chooses the risky technology therefore falls even further below the level which would be chosen if maximising solely long-run value. This confirms that our core results of Section 4 are robust to the explicit modelling of a CEO. Not only does a firm with many short-term shareholders go for the risky technology too frequently, when it does so the CEO is incentivised less and so improvements in the long-run capabilities of the firm are reduced. Both of these effects conspire to lower the ex ante expected value of a firm with a large proportion of short-term shareholders on the register. As a result the ex ante value of such a firm declines. It is an immediate corollary that the cost of capital to such a firm rises, as a larger proportion of the firm would need to be sold to investors to raise a unit of capital.

## **6 Endogenising The Board's Objective Function**

We have analysed the implication of the Board's objective function being to maximise the value of the shareholders on its register at the time that the business decision is taken. As short-term shareholders will sell before the final payoffs are realised, the path of the share price becomes part of the Board's concerns. However, all shareholders, both long-term and short-term, value a company less the more the share-price path is emphasized to the detriment of long run value. Therefore this section endogenises the Board's objective function.

### **6.1 A Model of Shareholder Voting**

We return to our benchmark model of Section 3 in which the Board make the business decision, and firm types are distributed according to  $g(\tau)$  on  $[0, 1]$ . The firm type is private information to the Board. We extend the model back to a time  $t = 0$  at which point

shareholders privately communicate whether they wish the Board to maximise the long-run value of the firm, or to maximise the short-run ( $t = 1$ ) share price. The Board privately observe the proportion  $\alpha$  of shareholders who vote for  $t = 1$  share price maximisation, and use an objective function weighted  $\alpha$  parts for short-term value maximisation and  $1 - \alpha$  for long-term value maximisation. The privacy of the communication between the shareholders and the Board captures that it is impossible for a shareholder to prove the absence of any communication with the Board or members of it. The rest of the game remains unchanged.

As we are exploring the pressures on an individual Board, we again use a partial equilibrium approach and so set the market price of the input asset at  $P$ .

## 6.2 Shareholder Voting And Board Objectives

We solve the model by backward induction from the point at which the business decision is taken,  $t = 1$ . If the Board received  $\alpha$  votes in favour of short-term value maximisation then their  $t = 0$  objective function is  $V(\tau, \alpha) = \alpha X_1 + (1 - \alpha) X_2(\tau)$  where  $X_1$  is the value of the firm at the end of  $t = 1$ , and  $X_2(\tau)$  the expected  $t = 2$  payoff. The variable  $X_1$  is not a function of the firm type as this will not have been revealed when the  $t = 1$  share-price is set.

Denote the market's expectation of the vote as  $\tilde{\alpha}$ . This expectation is a function of the publicly known proportion of the short-term shareholders,  $L$ , on the register. Let us suppose that the Board elect to pursue the risky technology. The market would infer that types  $[\tilde{\tau}, 1]$  would choose to develop the risky technology (Lemma 3). The share prices will therefore be:

$$X_1 = \int_{\tau=\tilde{\tau}}^1 \frac{\bar{R}}{P} \tau \frac{g(\tau)}{1 - G(\tilde{\tau})} d\tau \text{ and } X_2(\tau) = \frac{\bar{R}}{P} \tau \quad (27)$$

The Board of the lowest type  $\tilde{\tau}$  receiving  $\tilde{\alpha}$  votes for short run ( $t = 1$ ) value maximisation must be indifferent between developing the risky technology and not. Hence

$$r = \tilde{\alpha} \int_{\tau=\tilde{\tau}}^1 \frac{\bar{R}\tau}{P} \cdot \frac{g(\tau)}{1 - G(\tilde{\tau})} d\tau + (1 - \tilde{\alpha}) \frac{\bar{R}\tilde{\tau}}{P} \quad (28)$$

This delivers the critical type  $\tilde{\tau}$  which just opts for the risky technology as a function of the market beliefs of the voting,  $\tilde{\alpha}$ .

Now we move to the voting part at time  $t = 0$ :

**Proposition 16** *The equilibrium of the shareholder voting game is for short-term shareholders to privately vote for share price maximisation, and long-term shareholders to vote for npv maximisation. The Board's objective function will be given by  $\alpha = L$  so that  $V(\tau, L) = LX_1 + (1 - L) X_2(\tau)$ .*

This time the short-term shareholders are in a prisoners' dilemma. Ex ante all share-



holders prefer firms whose Boards maximise long-run value. However, once a short-term shareholder owns the stock, if the firm pursues the safe technology it will be valued in the short-run at less than a firm which pursues the risky technology. Hence short-term shareholders always face an incentive to press, in private, for the risky technology to be adopted, no matter what the actual skill of the firm is. Hence these shareholders vote for short-term share price maximisation.

Given the presence of some short-term shareholders, the market will infer that the Board will, to some extent, be internalising the path of the share price. Hence there exist border line firm types who would select the risky technology even though it is long term value reducing. Long-term shareholders wish to minimise these misallocation situations. They would therefore vote for the Board to focus on long-run value only. This would bring the Board's decision making closer to their preferred ideal of long-run value maximisation.

The resultant equilibrium is that short-term shareholders vote for short run share price maximisation, validating the objective function used in the benchmark model.

## 7 Empirical Discussion

I have offered a model of firm decision making and CEO pay when there are short-term shareholders on the firms' register of shareholders. In this section I consider to what extent the empirical evidence supports that short-termism amongst shareholders is economically meaningful. I will also assess the empirical predictions afforded by the analysis in the light of the available empirical evidence.

### 7.1 The Relevance Of Short-Term Shareholders

Measuring the extent of short-termism amongst shareholders is an ongoing topic of research.<sup>14</sup> This endeavour is complicated by the fact that short-termism cannot be proxied by the share turnover rate. Froot, Perold and Stein (1992) note that a firm can have a high turnover rate if a small percentage of the firm is repeatedly bought and sold, whilst the vast majority of the firm remains under stable ownership. Froot, Perold and Stein (1992) demonstrate that reliance on this statistic is often misleading. Holderness (2009) suggests that little is known about ownership patterns due to the need to hand collect reliable data.

To assess the economic relevance of an assumption that firms have a proportion of short-term shareholders on their register, I therefore construct a bespoke dataset. I collected the shareholder register data for the largest 20 firms by market capitalization in the Germanic civil law countries of Germany, Austria and Switzerland. In addition I constructed a matched sample of 20 US firms which were in identical 3-digit SIC codes

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<sup>14</sup>See, for example, Holderness (2009), and Gaspar, Massa, and Matos (2005).

as their primary business, and whose size was as near to the Germanic firms as possible. I then derive a lower bound for the short-termism of ownership over two, four, six and eight quarters using the following construction:

$$\left[ \begin{array}{l} \text{Percentage of} \\ \text{Short-termism} \\ \text{over } z \text{ quarters} \end{array} \right] = \sum_{\substack{j \text{ named} \\ \text{on shareholder} \\ \text{register at} \\ \text{Sep 2012}}} \left\{ \left[ \begin{array}{l} \% \text{ common} \\ \text{stock owned by} \\ j \text{ at Sep 2012} \end{array} \right] - \left[ \begin{array}{l} \text{Minimum \% stock} \\ \text{held by } j \text{ over} \\ \text{prior } z \text{ quarters.} \end{array} \right] \right\} \quad (29)$$

The database (CapitalIQ) lists the ownership data of all common stock owners with a stake in excess of 0.1% of the firm. Definition (29) is a conservative measure of short-termism. First (29) assumes that all unnamed owners are long-term as they do not count towards the short-termism measure. Second, if an owner of shares should sell part of their stake over the  $z$  quarters, only the part which is sold counts towards the short-termism measure. The remainder which has been held over the entire  $z$  quarters finishing in Q3 2012 is assumed to be long-term held. I compare civil law countries to the leading common law country as the legal differences in shareholder protection, it is argued, might lead to differences in ownership patterns and corporate behaviour (see La Porta, Lopez-de-Silanes, Shleifer, and Vishny (1998)).

Using the matched sample I have constructed we can interrogate to what extent short-termism in share ownership differs between Germanic civil law countries as compared to the US. Figure 3 demonstrates that the Germanic firms enjoy substantially lower levels of short-termism than their matched US firms. Over 4 quarters the top 20 Germanic firms have a lower bound on short termism of 11.1% of common stock, whereas the matched US sample over 4 quarters faces 15.7% of short-term held common stock. These differences in short-termism are significant over 2 and 4 quarters. The difference remains constant at longer time horizons with Germanic country firms enjoying about 4% less of their common stock being short-term held. However the variance of short-termism in the sample rises over 6 and 8 quarters causing the difference in the mean to lose statistical significance in this small sample.

We can further interrogate the dataset to ask to what extent short-termism differs between firms. Figure 4 plots the pooled sample of the top ten largest firms from the Germanic countries and their US matches. The figure demonstrates that short-termism differs markedly between firms within, and indeed across, countries. For example, Nestle enjoys that only 4% of stock owned by its named shareholders was sold over the year prior to September 2012, whereas for Siemens (German) or Ely Lilly (US) the short-termism was more than triple at around 15%.

From Figures 3 and 4 I conclude that short-termism in shareholders differs meaningfully between firms and between countries, re-enforcing the economic relevance of the

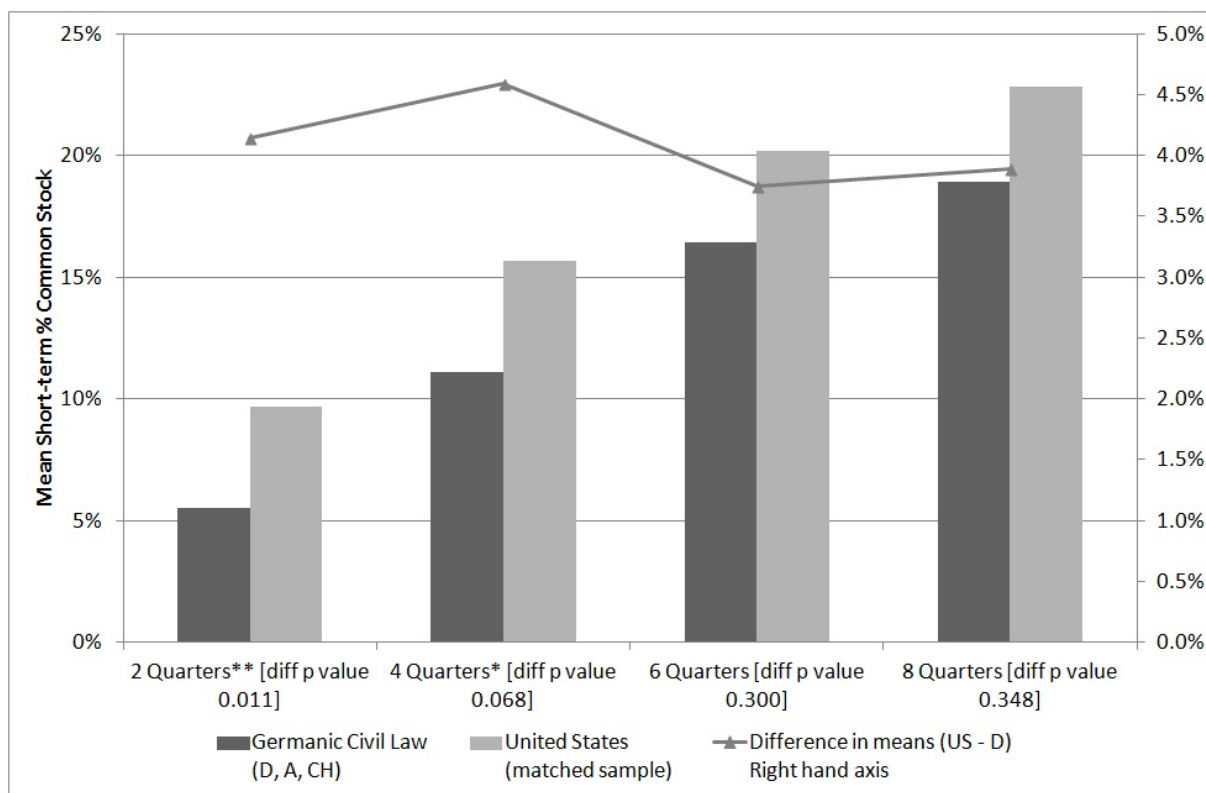


Figure 3: Comparison of Shareholder Short-Termism Between Germanic Civil Law countries and US (Common Law)

Notes: The graph depicts the mean short-termism amongst the top 20 firms in the Germanic civil law countries of Germany, Switzerland and Austria. This is compared against the mean short-termism amongst the matched panel of firms in the leading common law country (United States). Short-termism is measured using construction (29). The data is drawn from CapitalIQ and measures short-termism in the period ending with Q3 2012. The matching is done by 3-digit SIC, followed by firm size. \*\*, \*, denotes difference in mean significant at 5%, 10% level; p values in parentheses. The difference in means is plotted on the right hand axis.

analysis presented above.

## 7.2 Empirical Predictions

The analysis of short-term shareholders yields the following main empirical predictions:

1. A greater proportion of short-term shareholders in an economy, or for an individual firm, raises the cost of capital.
2. The over-allocation of firms to high-risk/high-reward business models is greatest when the elasticity of supply of the input is high and the proportion of short-term shareholders is high.
3. CEO compensation is tilted to short-term performance targets, and away from long-term performance targets, when the proportion of short-term shareholders on the

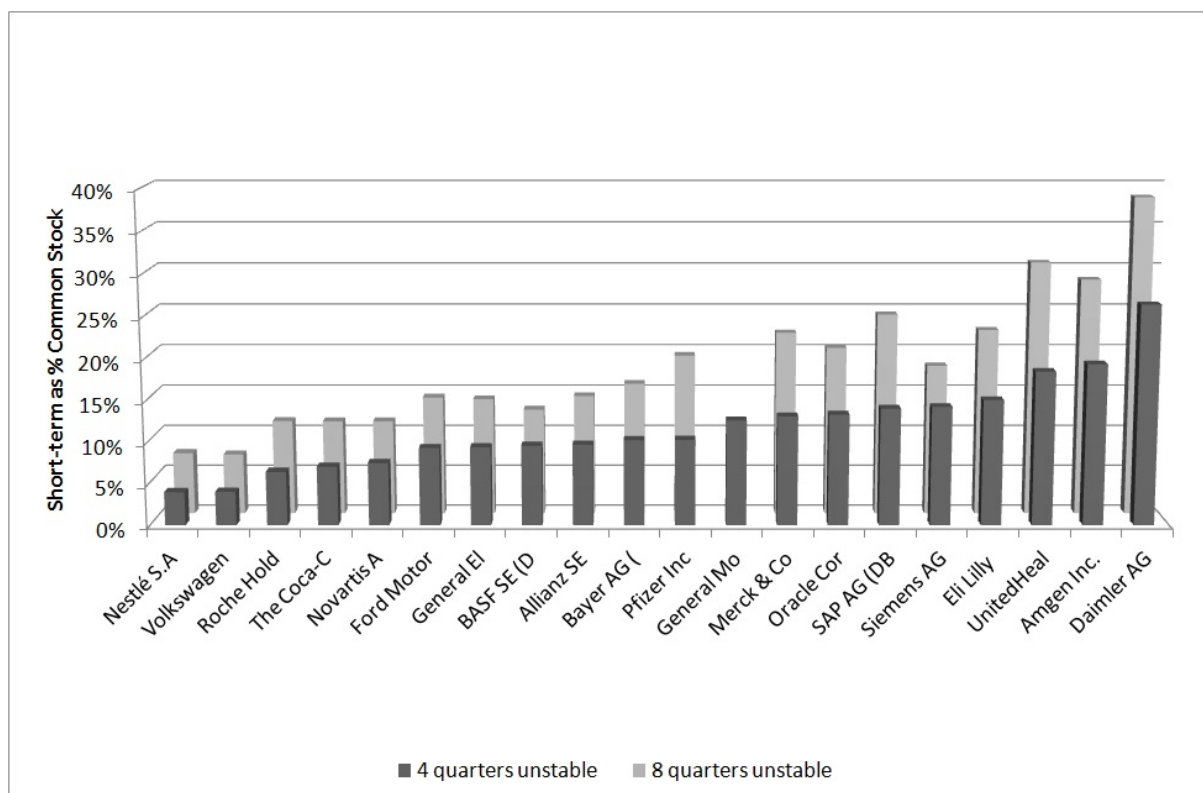


Figure 4: Comparison of Shareholder Short-Termism Between Large Firms in Germanic Civil Law countries and US (Common Law)

Notes: The graph depicts the short-termism amongst the top 10 firms in the Germanic civil law countries of Germany, Switzerland and Austria, and the top 10 matched firms in the leading common law country (United States). Short-termism is measured using construction (29). The data is drawn from CapitalIQ and measures short-termism in the period ending with Q3 2012. The matching is done by 3-digit SIC, followed by firm size.

firm's register is high.

The empirical work linking investor time horizons with corporate behaviour has yet to move significantly beyond looking at investment levels. The resulting paucity of empirical evidence is perhaps partly explained by the difficulties in measuring the time-horizon of investors. Asker, Farre-Mensa, and Ljunqvist (2010) compare listed to unlisted companies, however in this case the lack of data disclosure for unlisted companies limits the questions which can be asked. A second recent development is contained in Gaspar, Massa, and Matos (2005) who construct an average duration of share ownership for named owners. This work is labour intensive and so far the databases have not been applied to the structure of CEO pay or to firm cost of capital. Here we discuss what evidence is available.

The positive link between the cost of capital and the proportion of short-term shareholders is delivered at the industry level by Proposition 6, and at the individual firm level by Propositions 7 and 15. Using conference call transcripts, Brochet, Loumioti and Serafeim (2012) document that firms with a short-term oriented investor base have senior

executives which focus most on the short-term. Further they document that such firms acquire higher betas, and so pay higher costs of capital. Thus this evidence is strongly in support of the analysis here. Further, Attig, Guedhami and Mishra (2008) find that the implied cost of equity capital decreases with the presence of large shareholders who are banks, the state, or family, beyond the controlling owner. It seems likely that such blockholders are in the main long-term shareholders. If so then this evidence is also supportive of my first empirical prediction. Cella (2012) finds that long-term investors improve firms' investment performance which would typically imply reduced costs of capital.

The over-allocation of firms to high-risk/high-reward business models, and the fact that this is exacerbated when the elasticity of supply of the input asset is high is given by Propositions 5 and 9. There is little existing systematic empirical evidence as to this prediction to the best of my knowledge.

The link between reduced levels of CEO deferred pay and short-term shareholders is provided by Corollary 13. A number of empirical papers exist in support of this hypothesis. Shin (2008) classifies short versus long term investors on the basis of their average turnover and breadth of portfolio. He demonstrates that firms with a greater proportion of short-term shareholders cause CEO pay to be more sensitive to current reported results. Dong and Ozkan (2008) document that long-term institutional investors lower short-term CEO pay as proxied by base salary and cash bonus. Further, they document that long-term investors increase the sensitivity of overall pay to ultimate firm performance. Dikolli, Kulp and Sedatole (2009) also argue that transient shareholders lead CEOs to be under pressure to increase current earnings, however they report some evidence that boards try to compensate for this with contracts which underweight quarterly earnings in favour of yearly returns. Cadman and Sunder (2010) also report that CEO contracts when a firm is backed by a venture capital fund have short-term incentives corresponding to the time of anticipated exit of the VC.

## 8 Conclusions

A firm seeks to maximise the wealth of its existing shareholders. As shareholders differ in their investment horizons, this implies that the Board of a firm must be concerned with the path of the share price through time as well as with its final value. As a result having short-term shareholders on the register causes a firm to wish to take actions which pool it with firms of high value. Thus a firm which enters a high-risk/high-reward market will send a signal that the management believe they have a high quality firm which can make profits in this space. This desire to enter markets for the benefits of signalling drives up the price of the inputs needed to enter the market to above their fundamental levels. A bubble is created. Further, as the inputs become more expensive, firms must enter at a smaller scale than they would do otherwise. Market clearing then causes too many firms

to self select into the high-risk/high-reward market. Thus short-term shareholders in an economy lead to bubbles, too many firms in risky markets, and so to a higher cost of capital for the sector.

Faced with some short-term shareholders on the register a Board must structure incentives of the CEO to ensure sufficient attention is paid to the path of the share price. This can be achieved by increasing the weighting on the short-run share price. Incentivising the CEO to exert effort on capability is expensive as the reward is risky, and so the risk averse CEO discounts it. Short-run shareholders gain less from the increase in the capabilities as it will not be factored into the share price in the short run, and yet they bear the costs. Hence as the proportion of short-term shareholders on the register increases, the CEO's incentive contract becomes overly weighted to short-term results, leading to too many firms opting for the high-risk/high-reward industry, with CEOs exerting less effort in making a long run success of the decision.

In principle, if a firm was unable to determine the time-horizon of its owners then the negative outcomes described here would be avoided. Thus, if investors all channeled their funds through a third party, such as a bank, and the bank(s) were the firm's only investors, then arguably the effects described here would not occur. Though the providers of capital may be subject to liquidity shocks, by pooling resources into a bank those liquidity shocks would not impact corporate decision making. Such a model of ownership is similar to the German and Japanese models of corporate control (Froot, Perold, and Stein (1992)). It is well known however that such an approach has its own disadvantages and so can be no panacea to the forces identified in this paper.

## A Omitted Proofs

**Proof of Lemma 1.** Rewrite (4) as  $rP^f = \bar{R}q(bP^f)$ . The left hand side is increasing in  $P^f$ . The right hand side is declining in  $P^f$ . Hence any solution to (4) must be unique. We have  $\lim_{P^f \rightarrow 0} \bar{R}q(bP^f) = \bar{R} > [rP^f]_{P^f=0}$  and  $\lim_{P^f \rightarrow 1/b} \bar{R}q(bP^f) = 0 < [rP^f]_{P^f=1/b}$  hence a fundamental price exists by the Intermediate Value Theorem. ■

**Proof of Lemma 2.** A proportion  $1 - L$  of the shareholders are long term investors. The Board would expect these to receive a payoff of  $\Pi^{\text{risk}}(\tau)$  which will arrive at period  $t = 2$ . The remaining  $L$  of the shareholders will sell at the end of  $t = 1$ . They will receive the price which equals the expected  $t = 2$  payoff conditional on having chosen the risky technology:  $E(\Pi^{\text{risk}}(\tau) | \tau \in T^{\text{risk}})$ . Combining yields (5). ■

**Proof of Lemma 3.** Suppose otherwise that the Board's strategy was not a cut-off type of this form. Then there must exist two firm types  $\tau_1 < \tau_2$  such that a firm of type  $\tau_1$  would strictly prefer to develop the risky technology whilst the firm with higher type

$\tau_2$  would strictly prefer to develop the safe technology. Hence we would have

$$V^{\text{risk}}(\tau_1, L) > r > V^{\text{risk}}(\tau_2, L) \quad (30)$$

However, using Lemma 2 and (1)

$$\begin{aligned} \frac{\partial}{\partial \tau} V^{\text{risk}}(\tau, L) &= \frac{\partial}{\partial \tau} [(1-L)\Pi^{\text{risk}}(\tau) + LE(\Pi^{\text{risk}}(\tau) | \tau \in T^{\text{risk}})] \\ &= (1-L)\bar{R} > 0 \text{ as } L < 1 \end{aligned}$$

A contradiction to (30). Therefore if  $\tau_1$  develops the risky technology so must higher type firms. ■

**Proof of Proposition 4.** For market clearing (3), and using the cut-off property of Lemma 3, firms with type  $\tau \in [q(bP), 1]$  will develop the risky technology. Each firm will buy  $1/P$  units of the input asset. Applying Bayes rule, the expected value at end  $t = 1$  of a firm which develops the risky technology is

$$\begin{aligned} E(\Pi^{\text{risk}}(\tau) | \tau \in [q(bP), 1]) &= \int_{\tau=q(bP)}^1 \frac{\bar{R}\tau}{P} \cdot \frac{1}{bP} g(\tau) d\tau \\ &= \frac{\bar{R}}{bP^2} \left\{ q(bP)bP + \int_{\tau=q(bP)}^1 1 - G(\tau) d\tau \right\} \end{aligned} \quad (31)$$

The last line follows by integration by parts. Market clearing requires that the firm of type  $\tau = q(bP)$  to be indifferent between developing the risky technology and the safe technology. If the firm develops the safe technology then both long and short-term shareholders will secure  $r$ . Using Lemma 2 and (31) we require:

$$r = \left[ (1-L) \frac{\bar{R}\tau}{P} + L \frac{\bar{R}}{bP^2} \left\{ q(bP)bP + \int_{\tau=q(bP)}^1 1 - G(\tau) d\tau \right\} \right]_{\tau=q(bP)}$$

This can be simplified to yield (7). To show that we have a bubble, suppose for a contradiction that  $P \leq P^f$ . Then using (4),  $\bar{R}q(bP)/P \geq r$  as  $q(bP)/P$  is declining in  $P$ . Hence we must have the integral term in (7) being weakly negative which is a contradiction if  $L > 0$ . Hence  $P > P^f$ . Existence and uniqueness follow by multiplying (7) through by  $P$  and applying the Intermediate Value Theorem on prices  $P \in \{0, 1/b\}$ , and using assumption (2).

For the final result note that firms of type  $\tau \in [q(bP), 1]$  develop the risky technology, and as  $P > P^f$  we have  $q(bP) < q(bP^f)$ . Hence an inefficiently large number of firms develop the risky technology. ■

**Proof of Proposition 5.** Define the function  $W(P)$  equal to the right hand side of (7), so at equilibrium  $r = W(P)$ . Hence the sensitivity of the market price to the proportion of short-term shareholders is  $dP/dL = -(\partial W/\partial L)/(\partial W/\partial P)$ . By inspection we see that

$\partial W/\partial L > 0$ . For the denominator we explicitly find

$$\frac{\partial W}{\partial P} = q'(bP) b \frac{\bar{R}}{P} (1-L) - \bar{R} \frac{q(bP)}{P^2} - 2L \frac{\bar{R}}{bP^3} \int_{\tau=q(bP)}^1 (1-G(\tau)) d\tau < 0$$

The inequality follows as  $q'(\cdot) < 0$ . Hence  $dP/dL > 0$ , and we have the first result.

For the second result market clearing has firms with type  $\tau \in [q(bP), 1]$  developing the risky asset, and this range expands with the proportion of short-term shareholders. For the final result the expected payoff of a firm exploiting the risky technology is given by  $\bar{R}\tau/P$ . Hence the average such expected payoff conditional on developing the risky technology is  $\int_{\tau=q(bP)}^1 \frac{\bar{R}\tau}{P} \frac{1}{bP} g(\tau) d\tau$ . We can rewrite this as

$$\text{Average payoff from risky technology} = \frac{\bar{R}}{P} \cdot \frac{\int_{\tau=q(bP)}^1 \tau g(\tau) d\tau}{\int_{\tau=q(bP)}^1 g(\tau) d\tau} \quad (32)$$

Now note that

$$\begin{aligned} & \frac{d}{dP} \left\{ \frac{\int_{\tau=q(bP)}^1 \tau g(\tau) d\tau}{\int_{\tau=q(bP)}^1 g(\tau) d\tau} \right\} \\ &= \text{sign} \underbrace{-q'(bP) bg(q(bP))}_{+ve} \left\{ q(bP) \int_{\tau=q(bP)}^1 g(\tau) d\tau - \int_{\tau=q(bP)}^1 \tau g(\tau) d\tau \right\} \\ &= \text{sign} \int_{\tau=q(bP)}^1 (q(bP) - 1) g(\tau) d\tau < 0 \end{aligned}$$

As  $dP/dL > 0$ , it follows from (32) that the average payoff from the risky technology falls with the price of the input asset. Hence we have the final result. ■

**Proof of Proposition 6.** The expected value of a firm of unknown type to long term or short-term shareholders (6) is  $V = \int_{\tau=0}^{q(bP)} r g(\tau) d\tau + \int_{\tau=q(bP)}^1 \frac{\bar{R}}{P} \tau g(\tau) d\tau$ . Hence implicit differentiation yields:

$$\frac{dV}{dL} = \frac{dP}{dL} \cdot \left\{ q'(bP) bg(q(bP)) \left[ r - \frac{\bar{R}}{P} q(bP) \right] - \int_{\tau=q(bP)}^1 \frac{\bar{R}}{P^2} \tau g(\tau) d\tau \right\}$$

By Proposition 4  $P > P^f$ , and so from (4)  $r > \bar{R}q(bP)/P$ . As  $q'(\cdot) < 0$  and  $dP/dL > 0$  (Proposition 5), we have  $dV/dL < 0$  as required. Hence a greater proportion of short-term shareholders raises the firm cost of capital. ■

**Proof of Proposition 7.** Suppose  $P$  for the input asset is fixed by the market. Given a firm with  $L$  short-term shareholders on its register, the market infer some type  $\tilde{\tau}$  will be marginal. Hence the  $t = 1$  market value from selecting the risky technology, following (31) is  $\int_{\tilde{\tau}}^1 \frac{\bar{R}}{P} \tau \frac{g(\tau)}{1-G(\tilde{\tau})} d\tau$ . The critical type  $\tilde{\tau}$  must be indifferent between the two technologies.



This yields the analogue of (7) for this partial equilibrium context:

$$r = \frac{\bar{R}}{P}\tilde{\tau} + L\frac{\bar{R}}{P}\int_{\tau=\tilde{\tau}}^1 \frac{1-G(\tau)}{1-G(\tilde{\tau})}d\tau \quad (33)$$

Differentiating with respect to  $L$  yields

$$\frac{\bar{R}}{P}\int_{\tau=\tilde{\tau}}^1 \frac{1-G(\tau)}{1-G(\tilde{\tau})}d\tau + \frac{d\tilde{\tau}}{dL}\left\{\frac{\bar{R}}{P}(1-L) + L\frac{\bar{R}}{P}\frac{g(\tilde{\tau})}{1-G(\tilde{\tau})}\int_{\tau=\tilde{\tau}}^1 \frac{1-G(\tau)}{1-G(\tilde{\tau})}d\tau\right\} = 0$$

This implies  $d\tilde{\tau}/dL < 0$  and so delivers the first result. For the second result the ex-ante value of this firm is  $V = \int_{\tau=0}^{\tilde{\tau}} rg(\tau)d\tau + \int_{\tau=\tilde{\tau}}^1 \frac{\bar{R}}{P}\tau g(\tau)d\tau$ . Differentiating with respect to  $L$ , and using the fact that  $r > \bar{R}\tilde{\tau}/P$  (24) we have  $dV/dL =_{\text{sign}}(d\tilde{\tau}/dL) < 0$ . This delivers the second result. ■

**Proof of Lemma 8.** If the price of the input is  $P$  then market clearing with supply function (8) implies that the critical firm type satisfies

$$\int_{\tilde{\tau}}^1 \frac{1}{P}g(\tau)d\tau = S(P) \Rightarrow \tilde{\tau} = q(P \cdot S(P)) = q\left(bP\left(\frac{P}{P^f}\right)^\zeta\right) \quad (34)$$

Yielding (11). The  $t = 1$  price of the firm which pursues the risky technology will be given by

$$E(\Pi^{\text{risk}} | \tau \in [\tilde{\tau}, 1]) = \int_{\tau=\tilde{\tau}}^1 \frac{\bar{R}\tau}{P} \frac{g(\tau)}{1-G(\tilde{\tau})}d\tau$$

Using an integration by parts and setting the critical firm type to be indifferent between the risky and safe payoffs we have

$$r = \frac{\bar{R}\tilde{\tau}}{P} + \frac{\bar{R}}{P}\frac{L}{1-G(\tilde{\tau})}\int_{\tilde{\tau}}^1 1-G(\tau)d\tau$$

From (34) we have  $G(\tilde{\tau}) = 1 - bP(P/P^f)^\zeta$ . Using this to substitute for  $P$  yields (10).

The critical type  $\tilde{\tau}$  exists by applying the intermediate value theorem to (10) at  $\tilde{\tau} \in \{0, 1\}$  and using (9). For uniqueness note that the left hand side of (10) is decreasing in  $\tilde{\tau}$ . Differentiation confirms that the right hand side is increasing in  $\tilde{\tau}$ . ■

**Proof of Proposition 9.** The critical firm type  $\tilde{\tau}(\zeta, L)$  is given by (10). Differentiating with respect to  $\zeta$ :

$$-\frac{r}{\bar{R}}P^f\left[\frac{1-G(\tilde{\tau})}{bP^f}\right]^{\frac{1}{1+\zeta}}\frac{1}{(1+\zeta)^2}\ln\left[\frac{1-G(\tilde{\tau})}{bP^f}\right] = \frac{\partial\tilde{\tau}(\zeta, L)}{\partial\zeta}\left\{\begin{array}{l} \frac{r}{\bar{R}}\frac{1}{1+\zeta}P^f\left[\frac{1-G(\tilde{\tau})}{bP^f}\right]^{\frac{1}{1+\zeta}}\frac{g(\tilde{\tau})}{1-G(\tilde{\tau})} + (1-L) \\ + L\frac{g(\tilde{\tau})}{[1-G(\tilde{\tau})]^2}\int_{\tau=\tilde{\tau}}^1 1-G(\tau)d\tau \end{array}\right\}$$

It follows that

$$\frac{\partial \tilde{\tau}(\zeta, L)}{\partial \zeta} =_{\text{sign}} - \ln \left[ \frac{1 - G(\tilde{\tau})}{bP^f} \right] =_{(34)} - \ln \left[ \left( \frac{P}{P^f} \right)^{\zeta+1} \right] < 0$$

As  $P > P^f$  (Proposition 4). Similar working yields  $\partial \tilde{\tau}(\zeta, L) / \partial L < 0$ . ■

**Proof of Lemma 11.** Substituting (16) into (15) delivers the CEO's utility from pursuing the risky technology as

$$U^{\text{risk}}(f, b, v) = f + bX_1^{\text{risk}} + v \frac{\bar{R}\tau}{P} + \frac{1}{2} \left( \frac{\bar{R}}{P} \right)^2 \frac{v^2}{\kappa} - \frac{\rho}{2} v^2 \sigma^2 \quad (35)$$

If the CEO decides to invest in the safe technology then, as CEO effort on the risky technology does not increase the safe payoff, the CEO would select  $\eta = 0$ . Hence the CEO expected utility would be

$$U^{\text{safe}}(f, b, v) = f + bX_1^{\text{safe}} + vr \quad (36)$$

Comparing (35) to (36) yields (17).

The participation constraint for the CEO is that the expected utility, (35), exceeds  $u$ . This delivers (18). ■

**Proof of Proposition 12.** The fixed fee can be lowered until (18) is satisfied with equality. This yields (21). Using (16) and substituting into the Board's objective function (19) yields

$$V^{\text{risk}}(\tau) = LX_1^{\text{risk}} + (1-L) \frac{v}{\kappa} \left( \frac{\bar{R}}{P} \right)^2 + (1-L) \frac{\bar{R}}{P} \tau - \frac{v^2}{2} \left[ \frac{1}{\kappa} \left( \frac{\bar{R}}{P} \right)^2 + \rho \sigma^2 \right] - u \quad (37)$$

This must be solved subject to the incentive compatibility constraint (17). Equation (37) is a negative quadratic in  $v$  and is independent of  $b$ . Hence  $b$  can be chosen to satisfy (17) and the participation constraint satisfied by appropriately selecting  $f$ . Therefore optimising (37) with respect to  $v$ , the Board, if they choose the risky technology, will select the long-term incentive (20). The CEO will therefore improve the firm's type by  $\eta^*$ , given by (16) and yielding (22). ■

**Proof of Corollary 13.** For a CEO running a firm of type  $\tau$ , expected deferred pay will be  $v(\bar{R}/P)[\tau + \eta^*]$ , using (22) and (20) yields

$$[\text{Expected deferred pay}] = \left[ (1-L)\tau + (1-L)^2 \frac{\frac{1}{\kappa^2} \left( \frac{\bar{R}}{P} \right)^3}{\left[ \frac{1}{\kappa} \left( \frac{\bar{R}}{P} \right)^2 + \rho \sigma^2 \right]} \right] \frac{\frac{1}{\kappa} \left( \frac{\bar{R}}{P} \right)^3}{\left[ \frac{1}{\kappa} \left( \frac{\bar{R}}{P} \right)^2 + \rho \sigma^2 \right]}$$

As  $L \in [0, 1]$  expected deferred pay is declining in  $L$ .

The expected short run pay is given by (21), and differentiating with respect to  $L$  yields

$$\frac{d}{dL} [f + bX_1^{\text{risk}}] = \frac{dv}{dL} \cdot \left[ -\frac{\bar{R}}{P}\tau - v(L) \left[ \frac{1}{\kappa} \left( \frac{\bar{R}}{P} \right)^2 - \rho\sigma^2 \right] \right]$$

By assumption (13) the square bracket is negative, and by (20)  $dv/dL$  is also negative yielding that short-run pay is increasing in  $L$ .

For part three write the expected deferred pay in terms of the deferred bonus as  $v(\bar{R}/P)\tau + (v^2/\kappa)(\bar{R}/P)^2$  and add to the expected short run pay given in (21) to yield (23). As  $dv/dL < 0$  we have the required result. ■

**Proof of Proposition 14.** If a firm of type  $\tau$  develops the risky technology then the Board's value is given by (37). Substituting in for the optimal deferred payment, this can be written

$$V^{\text{risk}}(\tau) = LX_1^{\text{risk}} + (1-L) \left[ \frac{1}{2}(1-L) \frac{\frac{1}{\kappa^2} \left( \frac{\bar{R}}{P} \right)^4}{\left[ \frac{1}{\kappa} \left( \frac{\bar{R}}{P} \right)^2 + \rho\sigma^2 \right]} + \frac{\bar{R}}{P}\tau \right] - u$$

If instead the Board decides to develop the safe technology then they would offer a different contract and their value will be given by  $V^{\text{safe}}(\tau) = LX_1^{\text{safe}} + (1-L)r - [f + bX_1^{\text{safe}} + vr]$ . The participation constraint implies  $f + bX_1^{\text{safe}} + vr = u$ . The value of a Board pursuing the safe technology is therefore  $V^{\text{safe}}(\tau) = LX_1^{\text{safe}} + (1-L)r - u$ . Combining, the Board is indifferent between the two technologies at type  $\tilde{\tau}$  if (24) holds.

From (14) the  $t = 1$  market value conditional on the risky technology,  $X_1^{\text{risk}}$ , is the expected payoff less the expected payment to the CEO. The CEO's expected payment from the optimal contract which incentivises the risky technology is determined as (23). Further, as all firms which develop the risky technology improve their type by  $\eta^*(L)$ , we have  $\Gamma(T) = G(T - \eta^*) / (1 - G(\tilde{\tau}))$  with  $T \in [\tilde{\tau} + \eta^*, \infty)$ . Hence substituting for  $\eta^*$  from (22) we can simplify to yield

$$X_1^{\text{risk}} = \int_{\tau=\tilde{\tau}}^{\infty} \frac{\bar{R}}{P}\tau \frac{g(\tau)}{1 - G(\tilde{\tau})} d\tau - u + \frac{1}{2}(1-L^2) \frac{\frac{1}{\kappa^2} \left( \frac{\bar{R}}{P} \right)^4}{\left[ \frac{1}{\kappa} \left( \frac{\bar{R}}{P} \right)^2 + \rho\sigma^2 \right]} \quad (38)$$

Analogously  $X_1^{\text{safe}} = r - u$ . Combining yields (25). For uniqueness note that substituting (25) into the top line of (24) implies that the left hand side of (24) is monotonically increasing in  $\tilde{\tau}$  as the expected value of  $\tau$  conditional on  $\tau$  lying in  $[\tilde{\tau}, \infty)$  must be increasing in  $\tilde{\tau}$ . Hence (24) must have a unique solution.

For the final result right, using  $Q$  to represent the quotient  $\frac{1}{\kappa^2} \left( \frac{\bar{R}}{P} \right)^4 / \left[ \frac{1}{\kappa} \left( \frac{\bar{R}}{P} \right)^2 + \rho\sigma^2 \right]$

we have

$$\begin{aligned}
X_1^{\text{risk}} &= \int_{\tau=\tilde{\tau}}^{\infty} \frac{\bar{R}}{P} \tau \frac{g(\tau)}{1-G(\tilde{\tau})} d\tau - u + \frac{1}{2} (1-L^2) Q \\
&> L \int_{\tau=\tilde{\tau}}^{\infty} \frac{\bar{R}}{P} \tau \frac{g(\tau)}{1-G(\tilde{\tau})} d\tau + (1-L) \frac{\bar{R}}{P} \tilde{\tau} - u + \frac{1}{2} (1-L^2) Q \\
&= r - u - L \frac{1}{2} (1-L^2) Q - \frac{1}{2} (1-L)^2 Q + \frac{1}{2} (1-L^2) Q \text{ (using (24))} \\
&= X_1^{\text{safe}} + \frac{1}{2} (1-L) Q L (1-L) \geq X_1^{\text{safe}}
\end{aligned}$$

■

**Proof of Proposition 15.** For part 1, the critical firm type is given implicitly by  $\tilde{\tau}(L)$  in (24). Implicitly differentiating with respect to  $L$ , and using (24) we have

$$[X_1^{\text{risk}} - X_1^{\text{safe}}] - \left[ \frac{1}{2} (1-L) Q + \frac{\bar{R}}{P} \tilde{\tau} - r \right] + (1-L) \frac{\bar{R}}{P} \frac{d\tilde{\tau}}{dL} + L \frac{d}{dL} [X_1^{\text{risk}} - X_1^{\text{safe}}] = 0$$

using (24) this simplifies down to

$$\frac{1}{1-L} [X_1^{\text{risk}} - X_1^{\text{safe}}] + (1-L) \frac{\bar{R}}{P} \frac{d\tilde{\tau}}{dL} + L \frac{d}{dL} [X_1^{\text{risk}} - X_1^{\text{safe}}] = 0$$

Substituting in using (25) we have

$$\begin{aligned}
0 &= \frac{1}{1-L} \left[ \int_{\tau=\tilde{\tau}}^{\infty} \frac{\bar{R}}{P} \tau \frac{g(\tau)}{1-G(\tilde{\tau})} d\tau - r + \frac{1}{2} (1-L^2) Q \right] - LQ \\
&\quad + \frac{d\tilde{\tau}}{dL} \left[ (1-L) \frac{\bar{R}}{P} + L \frac{g(\tilde{\tau})}{1-G(\tilde{\tau})} \left( \int_{\tau=\tilde{\tau}}^{\infty} \frac{\bar{R}}{P} \tau \frac{g(\tau)}{1-G(\tilde{\tau})} d\tau - \frac{\bar{R}}{P} \tilde{\tau} \right) \right]
\end{aligned} \tag{39}$$

The coefficient of  $d\tilde{\tau}/dL$  is positive. Hence, using (25)

$$\frac{d\tilde{\tau}}{dL} =_{\text{sign}} - [X_1^{\text{risk}} - X_1^{\text{safe}}] + L(1-L) Q$$

This yields the result that for  $X_1^{\text{risk}} \gg X_1^{\text{safe}}$  increasing  $L$  enlarges the range of types which take the risky technology. For the sufficient condition, direct from (39)

$$\frac{d\tilde{\tau}}{dL} =_{\text{sign}} - \left[ \int_{\tau=\tilde{\tau}}^{\infty} \frac{\bar{R}}{P} \tau \frac{g(\tau)}{1-G(\tilde{\tau})} d\tau - r \right] < - \left[ \frac{\bar{R}}{P} E(\tau) - r \right]$$

The inequality follows as  $E(\tau | \tau \geq \tilde{\tau}) \geq E(\tau)$ . This yields the result that given (26), increasing  $L$  lowers the type of firm for which the Board will incentivise the risky technology. Finally, the cost of capital result is then an immediate corollary as the firm seeks the risky technology for inefficiently too many types, and incentivises the firm to improve less. ■

**Proof of Proposition 16.** Consider first short-term shareholders. If the Board pursue the risky technology then the expected market price will be  $X_1$  as given in (27), otherwise the market price will be  $r$ . We first show that the market price at end  $t = 1$  is higher if the Board pursue the risky technology. We have

$$X_1 = \int_{\tau=\tilde{\tau}}^1 \frac{\bar{R}\tau}{P} \frac{g(\tau)}{1-G(\tilde{\tau})} d\tau > \frac{\bar{R}\tilde{\tau}}{P} \cdot \int_{\tau=\tilde{\tau}}^1 \frac{g(\tau)}{1-G(\tilde{\tau})} d\tau = \frac{\bar{R}\tilde{\tau}}{P}$$

So  $X_1 > \tilde{\alpha} \int_{\tau=\tilde{\tau}}^1 \frac{\bar{R}}{P} \tau \frac{g(\tau)}{1-G(\tilde{\tau})} d\tau + (1 - \tilde{\alpha}) \bar{R}\tilde{\tau}/P = r$ , where the final equality is (28). It follows that short-term shareholders will vote for the action which increases the likelihood of the risky technology being pursued.

We now confirm that voting for short-term value maximisation makes the Board more likely to pursue the risky technology. Given market beliefs  $\tilde{\alpha}$  and  $\tilde{\tau}$ , the Board in receipt of  $\alpha$  votes for short-term value maximisation will pursue the risky technology if its type lies in  $[\tau(\alpha), 1]$  where

$$r = \alpha \underbrace{\int_{\tau=\tilde{\tau}}^1 \frac{\bar{R}}{P} \tau \frac{g(\tau)}{1-G(\tilde{\tau})} d\tau}_{X_1} + (1 - \alpha) \underbrace{\bar{R}\tau(\alpha)/P}_{X_2(\tau(\alpha))} \quad (40)$$

To evaluate how extra votes for short-termism would affect the critical firm type  $\tau(\alpha)$ , differentiate (40) with respect to  $\alpha$  and evaluate at  $\alpha = \tilde{\alpha}$ . We establish that

$$\begin{aligned} 0 &= \int_{\tau=\tilde{\tau}}^1 \frac{\bar{R}}{P} \tau \frac{g(\tau)}{1-G(\tilde{\tau})} d\tau - \frac{\bar{R}}{P} \tilde{\tau} + \tau'(\tilde{\alpha}) (1 - \tilde{\alpha}) \frac{\bar{R}}{P} \\ &= \frac{1}{\tilde{\alpha}} \left[ r - \frac{\bar{R}\tilde{\tau}}{P} \right] + \tau'(\tilde{\alpha}) (1 - \tilde{\alpha}) \frac{\bar{R}}{P} \text{ using (28)}. \end{aligned}$$

It follows that  $\tau'(\tilde{\alpha}) < 0$  as  $r > \bar{R}\tilde{\tau}/P$  from (28). Combining short-term shareholders wish the firm to pursue the risky technology, and the probability of this occurring increases if the short-term shareholders vote for short-term share price maximisation.

Now consider long-term shareholders. If the Board pursue the risky technology then the profits realised will be  $\bar{R}\tau/P$  which depend upon the true type of the firm. If the Board pursue the safe technology then the profits realised will be  $r$ . If the shareholders vote in proportion  $\alpha$  for the short-term share price then types  $[\tau(\alpha), 1]$  will develop the risky technology. Hence the long term shareholders will secure value  $G(\tau(\alpha))r + \int_{\tau=\tau(\alpha)}^1 \frac{\bar{R}}{P} \tau g(\tau) d\tau$ . The marginal firm type is given by (40). We established above that  $\tau'(\tilde{\alpha}) < 0$ . Hence increasing  $\alpha$  above its expected level lowers the long-term shareholders value as  $r > \frac{\bar{R}}{P} \tilde{\tau}$  from (28). This demonstrates that long-term shareholders will vote for long-term value maximisation.

In equilibrium the market must correctly anticipate the shareholders' votes. Hence  $\alpha = \tilde{\alpha} = L$ . ■

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