Does Hedging Reduce the Cost of Delegation?*

Sapnoti K. Eswar †

Job Market Paper

July 2014

Abstract

I incorporate the choice of hedging instrument into a moral hazard model to study the impact of derivatives on a firm's value. A hedging instrument creates value by minimizing the expected costs of distress. In the model, managers who exert effort on their project understand the underlying risk exposure well and, therefore, can choose the optimal instrument to use as a hedge. I show that the optimal hedging instrument maximizes the firm's value but does not reduce the noise in the compensation contract, thereby forcing investors to leave more rents to the manager. When the agency problem is severe, the investor induces the manager to exert low effort and to choose an imperfect hedge, which leads to a drop in the firm's value. I test the model by exploiting an exogenous shock (the Washington Agreement on Gold, 1999) to the cost of hedging in the gold mining industry and find strong support for the model's predictions.

*I am very grateful to Francesca Cornelli for her invaluable advice and guidance. I also thank Ulf Axelson, Andrea Buffa, Joao Cocco, James Dow, Alex Edmans, Julian Franks, Denis Gromb, Christopher Hennessy, Ralph Koijen, Stefan Lewellen, Vojislav Maksimovic, Clemens Otto, Ellen Paulus, Anna Pavlova, Stephen Schaefer, Rik Sen, Henri Servaes, Rui Silva, Lucie Tepla, Vikrant Vig, Paolo Volpin and seminar participants at the LBS and INSEAD seminar series for helpful comments and discussions. I gratefully acknowledge the cooperation of Ted Reeve for sharing the surveys of gold mining firms' risk management practices. Any errors or omissions are the responsibility of the author.

†London Business School, Regent's Park, London NW1 4SA, U.K., Email: seswar@london.edu

I Introduction

Risk management is an important aspect of corporate financial policy. Recent empirical studies find that over 60% of all non-financial firms engage in risk management, most of them with derivatives.[1] In theory, hedging with derivatives can create value in the presence of market frictions such as costs of bankruptcy, information asymmetries, and taxes.[2] The positive impact of hedging on a firm's value has also been documented empirically. Campello et al. (2011) find that hedging lowers the cost of borrowing and investment restrictions in firms' loan agreements. They argue that these favorable financing terms have a positive impact on a firm's value. Perez-Gonzales and Yun (2013) find that the introduction of weather derivatives leads to higher valuations and investments for weather-exposed firms.[3] In this paper, I ask whether hedging with derivatives can be value-destroying.

The traditional arguments in favor of hedging emphasize that hedging reduces the impact of market frictions. I explore an important additional effect that arises when there is an increase in the complexity of hedging instruments. In a moral hazard model with hedging instruments and contracting frictions (due to the complexity of these instruments), I show that the cost of compensation for the manager has to increase to induce him or her to choose the optimal hedge. In this paper, the price of the hedging instrument is endogenized and derivative markets are sufficiently liquid such that the manager has the ability to buy inefficiently large quantities of the hedging instrument. Choice of such a quantity in the model is equivalent to speculation, which destroys firm value. Under these conditions, I find that the manager is more inclined to exert less effort when he or she has hedging instruments at his disposal. Thus, the cost of compensation has to increase to ensure that the manager exerts effort and chooses the optimal hedge.

[1] Lins, Servaes, and Tamayo (2011) conduct a global survey of chief financial officers (CFOs) across 36 countries. They find that 90% of the respondents manage risk with derivatives. Bartram, Brown, and Conrad (2011) find that 60.5% of non-financial companies across 47 countries use atleast one type of derivative for risk management.

[2] Theoretical arguments in favor of hedging are provided by Stulz (1984), Smith and Stulz (1985), Stulz(1990), Froot, Scharfstein, and Stein (1993) and DeMarzo and Duffie (1995) among others.

[3] Other studies report mixed results. Jin and Jorion (2006) document an insignificant impact from hedging on the values of oil and gas producers. Guay and Kothari (2003) question the empirical relevance of hedging for a firm's value.

When I take the increase in compensation cost into account, there are different conclusions for the impact of hedging on the firm's value. I show that there are cases where the increase in the compensation cost can reduce the net benefit from the optimal hedge such that investors do not find the search for the optimal hedge worthwhile. In this situation, investors might induce the manager to exert less effort and to choose an imperfect hedge. Contrary to traditional arguments, the availability of hedging instruments reduces the firm's value. In other cases where the cost of effort is low, the investors leave more rents to the manager and induce the manager to hedge optimally. This strategy leads to an increase in the firm's value with hedging.

I consider a moral hazard model where investors want to induce a risk-neutral manager to exert effort on a project or a portfolio, the payoff of which can take two values. Effort increases the probability of the high payoff. I find that in the absence of derivatives, investors find it optimal to provide financing in the form of debt. The manager holds all the equity in the firm and receives a share of the total payoff only if the firm performs well. He or she has an incentive to exert effort because effort maximizes the probability of the high payoff, a state in which he or she is rewarded. Simultaneously, effort reduces the probability of the low payoff, a state in which he or she is "punished". To this setup, I introduce two new elements - deadweight losses in distress and the derivative. The expected losses in distress can be eliminated or reduced by taking a position in the derivative. The derivative enables the firm to borrow from the states of the world in which the project has a high payoff and get paid in states of the world when the project payoff is low. Hedging with the derivative, thereby, creates value by reducing the variance in the cash flow of the firm.

In this model with derivatives, investors do not fully understand the nature of the derivative as well as the manager does. To capture this idea of complexity, I assume that the optimal quantity of the derivative is not contractible. Investors leave the choice of the optimal derivative and the optimal quantity of that derivative to the manager. In addition, managerial effort has two implications: it increases the probability of a high payoff, and it allows the manager to choose the optimal derivative for the project or portfolio. When managers do not fully understand the risks of their project or portfolio, they are not able to evaluate the suitability of any derivative

as a hedge. In other words, the manager needs to exert effort on the project in order to choose the optimal derivative.

The complexity of financial derivatives can be relevant in a number of industries. For example, the hedging of jet fuel by airline companies can be done using a number of instruments. The CFO or the risk manager needs to evaluate between derivatives based on crude oil, jet fuel and heating oil.[4] In addition, within crude oil derivatives, the manager has to decide between different crude oil indices such as Brent Crude and West Texas Intermediate crude. Also, he or she has to choose between the types of instruments such as swaps, forwards or combinations of options. Another example is in the context of fund managers. The anecdotal evidence suggests that fund managers with equity positions choose among a number of correlated instruments to hedge the risk of low equity prices. The fund managers use foreign exchange or interest rate derivatives as hedges because using equity derivatives can be very expensive. The vast number of available derivatives and the technical and institutional details of derivative contracts makes the optimal quantity effectively not contractible for investors.

The model proceeds in three stages. At the initial stage of the model, the investors choose an incentive contract, and the manager chooses a level of effort. At the interim stage, the manager then approaches a competitive, risk-neutral market-maker and chooses the quantity of the derivative. At the final stage, all of the payoffs are realized, and the contracts settled. I assume that the total cash flow, that is, the sum of the payoffs of the project and the derivative is observable.

The first finding from the model is that when investors induce the manager to implement risk management, there is an increase in the rents to the manager. Consider the manager's choice of the derivative. The market-maker charges a "fair" price given the success probability of the optimal or "effort" project. Thus, in equilibrium, the derivative represents a zero net present value investment for the manager. Now consider the incentives of the manager when he or she is given the same incentive contract as in the model without derivatives, that is, the

[4] A combination of these underlying assets are listed in 10-K filings of North-American airline companies. Most airlines tend to use crude oil derivatives as the market is more liquid. A smaller number use derivatives based on jet fuel or heating oil, or both.

manager owns all the equity in the firm. With low effort, the derivative represents a positive net present value investment to the manager. There is a state of the world in which a mismatch exists between the derivative and the project's payoff. In this state, the project has a low payoff but the derivative does not make up for this loss. Therefore, the firm faces distress costs. Given that the manager holds all the equity in the firm, he or she does not internalize the costs in this state, neither the distress costs nor the price of the derivative. In other words, the limited liability option of the manager becomes valuable and, therefore, the manager has an incentive to deviate and exert low effort. Now consider the choice of the incentive contract at the initial stage: the difference in the manager's payoffs from effort and low effort reduces. In other words, if the market assumes that the manager is exerting effort and hedging optimally, it will price the hedge accordingly. But given such a market price, the manager has an incentive to exert low effort and hedge sub-optimally. Thus, the investors are forced to leave more rents to the manager as compared to the model without the derivative.

The change in rents to the manager can be seen as a combination of three effects. The first effect increases the rents. When the manager can use derivatives, he or she can obtain a high payoff even when the project fails because the derivative provides a payoff. Therefore, the existence of a hedge makes it harder to obtain effort from the manager. This force is akin to the insurance-efficiency trade-off. The second effect comes about when investors contract on the derivative signal. The derivative signal, for example the Brent crude index, provides a noisy signal for the project payoff. The contract on this signal can reduce the rents to the agent. The ability of the manager to speculate brings about the third effect. If the incentive contract of the manager conditions on the total cash flow of the firm (including the project and the derivative) and the derivative signal, then he or she is more likely to speculate. I find that the sum of the two forces that increase rents to the manager dominate.

As a corollary, if the investors induce the manager to hedge but do not increase the managerial incentives at the same time, then there is a negative effect on the firm's value. The manager is more likely to exert low effort because his or her incentive compatibility condition is not satisfied. As a result, there is a reduction in the firm's value when compared to the model without the

derivative.

When faced with an increase in the agency costs and therefore the need to increase the manager's compensation, the investors might optimally choose to request low effort and an imperfect hedge. The investors ensure that the manager receives his or her reservation utility, thereby saving on high rents to the manager. The investors retain the entire equity stake in the firm. And they prefer an imperfect hedge to no hedging because the derivative reduces expected costs of distress.[5] In sum, the value of the investors' claim on the firm increases. However, the inefficient choice of low effort reduces the firm's value and the debt capacity as compared to the un-hedged firm.

I then study the North American gold mining industry and find suggestive evidence in favor of my theory, since I find a reduction in the firm's value when hedging is an effort-intensive task. I identify, from an ex-ante perspective, the firms that are more likely to use derivatives ineffectively. I further test whether these firms are worse off on a number of firm characteristics after an exogenous shock to the costs of hedging.

To empirically test the impact of hedging on firm characteristics, I exploit a natural experiment created by the Washington Agreement on Gold, which exogenously impacts the costs of hedging in the gold mining industry. The Washington Agreement on Gold was signed on September 26, 1999, by the central banks of the European countries. One of the features of the Agreement was that these central banks would freeze their gold lending volumes at existing levels. Because these banks accounted for nearly 50% of the world's official gold holdings,[6] this freeze significantly affected the availability of gold forwards.[7] This setting is appealing for two reasons. First, the motivation behind the passage of these laws centered around the unifying policies of all of the EU member countries. Because this agreement was not passed with the intention of promoting or inhibiting gold forwards, the potential effects on the gold hedging

[5]Although the firm now has no debt, derivatives reduce costs of distress which can occur due to high operational leverage.

[6]This freeze increased to 85% of the total global gold holdings with the United States and Japan announcing that they would follow suit and limit their gold lending.

[7]Because the delta of a forward contract is higher than the delta of a put or call option, the volume of borrowed gold required to create and hedge a forward contract is high compared to options. The volume of gold forwards available reduced after this agreement.

market are an unintended consequence of the agreement. Second, the segregation of the firms based on the exposure of their operations to the price of gold before the shock is possible. This segregation allows me to find firms that have operations that are more "hedge-able" with gold derivatives.

Based on the theory developed in this paper, if the firms' cash flows have a high correlation with the price of gold then such firms are more likely to use derivatives effectively. In the model, these firms are the "effort" firms. The operations of these firms are more closely correlated with the price of gold. After the shock, these firms are able to re-optimize their hedge portfolio more easily. On the other hand, the firms with cash flows that have a lower correlation with the price of gold are more likely to use derivatives ineffectively. Based on the model, these are the "no effort" firms.

I carry out a differences-in-differences analysis and find that the firms with a low correlation between their unhedged cash flows and the price of gold reduce their firm value, debt capacity and investment. The "control" firms in this specification are all of the firm-year observations pre-1999 and high correlation firms post-1999. I control for the time-varying firm-level variables: the size of the company, investment opportunities, and the investment rate. To ensure that the results are robust to other confounding factors, I control for the changes that might affect the firm's financing and investment decisions such as changes in accounting regulations and changes in business prospects because of the credit crisis of 2008 to 2009. These tests provide suggestive evidence that firms differ in their ability to use derivatives and ineffective derivative usage can destroy firm value.

This paper contributes to two streams of literature: corporate risk management and optimal contracts for risk taking. The literature on corporate risk management sets forth a number of benefits. Smith and Stulz (1985) argue that if financial distress is costly, then hedging can be used as a means to increase the firm's debt capacity. If raising external financing is a costly process, then the firms can increase their value by hedging. The argument in a number of papers (Froot, Scharfstein and Stein(1989), Lessard (1990), Stulz (1990)) is the following: without hedging, firms are forced to underinvest in some states of the world where raising external financing is

too costly or indeed impossible. I incorporate this benefit of derivative usage in my model and derive further implications on the incentives for hedging.

Stulz (1984) posits that risk management is the result of the managers' risk aversion when they are unable to hedge their own accounts. If the firm does not hedge, then the risk-averse manager might seek very high rents or refuse to invest in high risk, positive NPV projects. Thus, hedging can increase the firm's value by removing these agency costs. Campbell and Kracaw (1987) derive the optimal incentive contract with corporate insurance. Bessembinder(1991) argues that hedging reduces the agency costs by eliminating the underinvestment problem. In this paper, I argue that hedging can increase the agency costs. The derivative instrument is incorporated as a choice variable in my model. This is the main assumption that drives this increase in agency costs.

A related paper in the area of hedging and hedge accounting highlights a trade-off between the observability of hedge transactions and the choice of an effective hedge by the manager. Duffie, DeMarzo (1995) show that if the underlying risk and the magnitude of the hedge position are unobservable then the manager achieves the efficient hedge level. If the underlying risk is unobservable but the magnitude of the hedge position is observable then the agent over hedges. In this paper, the manager has an additional choice variable, which is the derivative instrument. I find that to ensure that the manager chooses the efficient hedge, more rents need to be shared with the manager.

A number of papers, including Jin and Jorion (2006), Haushalter(2000), and Tufano(1996) find no significant increase in the firm's value from derivative usage. I identify a mechanism to identify firms that are more likely to use derivatives effectively and create value. This mechanism also helps identify the firms that are more likely to lose value when they use derivatives.

This paper is also related to the literature on risk taking. Hellwig (2009) and Biais and Casamatta (1999) derive that the optimal financing of investment projects occurs when managers must exert unobservable effort and can also switch to more riskier ventures. Both papers find that the optimal financial contracts can be implemented by a combination of debt and equity. The key difference in my paper is the result that debt continues to be the optimal financing

contract in the model with derivatives. DeMarzo, Livdan and Tchistyi (2011) consider the optimal contracts in which agents in addition to shirking can divert funds to riskier ventures. They posit that the agency costs increase under such a scenario. I argue that if there is a correlation between the effort decision and the risk decision, then there can also be an increase in the agency costs. In my paper, the mechanism for this increase comes about due to the endogenous pricing of the derivative and the ability of the manager to speculate.

This paper proceeds as follows. Section II introduces the model. In Section III, I analyze a benchmark case without derivatives. Section IV presents the case with derivatives. In Section V, I discuss the empirical identification strategy and the main results of the empirical tests, and section VI concludes. Appendix A contains all of the proofs, figures, and tables.

II The Model

The model has four dates, $t = -1, 0, 1$, and 2, and three economic agents, the principal, the agent, and the derivative market-maker.

Principal. The principal is risk-neutral with the utility function $V(\omega) = \omega$ where ω denotes the principal's payoff at $t = 2$. At $t = -1$, the principal is endowed with capital of \$1. The principal employs an agent to implement a risky project, and the per unit return from the project is $\tilde{Y}$, realized at $t = 2$. The return from the risky project can take one of two values: $Y_H > 1$ and $Y_L < 1$. Moreover, the principal can invest in a risk-less asset that provides a zero net return. The principal signs an incentive contract with the agent at $t = -1$.

Agent. The agent is risk-neutral with the utility function $U(w, \psi) = w - \psi$ where w represents the agent's total wealth and ψ represents the agent's personal cost of effort. The agent has zero wealth at $t = -1$ and his or her alternative employment option is normalized to zero. The agent has limited liability.

At $t = 0$, the agent has to exert costly, unobservable effort to improve the cash flow from the risky project. The agent can choose between effort $e = 1$ at a personal cost of $\psi > 0$ and no effort $e = 0$. There are three states of the world: good, medium, and bad with probabilities π_g,

π_m, and $1 - \pi_g - \pi_m$ respectively (with $\pi_m > 0$). If the agent exerts effort, the project returns Y_H in the good and medium states and Y_L in the bad state. In this case, the total probability of a high return Y_H is $\pi_g + \pi_m$. If the agent does not exert effort, then the project returns Y_H in the good state alone and returns Y_L in the medium and bad states. The probability of a high return Y_H is given by π_g. The monotone likelihood ratio property (MLRP) is satisfied because the probability of a high return is greater with effort than with no effort.

Table I shows the payoffs of the project with effort (effort project) and the project with no effort (no-effort project) in the different states. The states of the world are not observable.

If the return from the risky project is below the distress threshold Z_{min}, then the project faces real costs of distress. I assume that this threshold value satisfies the following condition:

$$Y_L < Z_{min} < 1 \tag{1}$$

Froot, Scharfstein and Stein (1994) summarize the fundamental concept of cash-flow hedging as follows: "... risk management lets companies transfer funds from situations in which they have an excess supply to situations in which they have a shortage. In essence, it allows companies to borrow from themselves." Following the same concept, I define the distress threshold based on the level of cash flow within the firm.

When the total payoff is less than the distress threshold, the project faces deadweight losses L. I assume that the deadweight loss is not more than the low payoff of the project Y_L. Further, I assume that the risky project has positive net present value (NPV) if the agent exerts effort.

$$(\pi_g + \pi_m)Y_H + (1 - \pi_g - \pi_m)(Y_L - L) > 1 > \pi_g Y_H + (1 - \pi_g)(Y_L - L) \tag{2}$$

Furthermore, I assume that effort is socially efficient such that the social surplus from effort is

more than the social surplus from no effort.

$$(\pi_g + \pi_m)Y_H + (1 - \pi_g - \pi_m)(Y_L - L) - \psi > \pi_g Y_H + (1 - \pi_g)(Y_L - L)$$
$$\pi_m \Delta Y + \pi_m L \geq \psi \tag{3}$$

where $\Delta Y = Y_H - Y_L$.

Derivative. At $t = 1$, the agent can choose to buy a hedging instrument or a derivative. Two derivatives exist which complete markets. Each of the derivative's payoffs is based on two separate publicly observable and verifiable signals: the public signal, $\tilde{s} \in \{s_H, s_L\}$ and the alternative signal, $\tilde{s}' \in \{s'_H, s'_L\}$.

State	Probability	Effort project	No-effort project	Public signal	Alternative signal
good	π_g	Y_H	Y_H	s_H	s'_H
medium	π_m	Y_H	Y_L	s_H	s'_L
bad	$1 - \pi_g - \pi_m$	Y_L	Y_L	s_L	s'_L
	1	$Y_L + (\pi_g + \pi_m)\Delta Y$	$Y_L + \pi_g \Delta Y$		

Table I: States of the world and risky assets.

I assume that the principal cannot contract on both signals, the public signal and the alternative signal. I further assume that managerial effort improves the performance of the hedge. In other words, the derivative provides a perfect hedge to the effort project.

The table below shows the derivative chosen by the manager given that he or she has exerted effort on the project. The derivative pays a unit payoff in the bad state of the world. A competitive, risk-neutral market-maker sets the price of the derivative. The price of the derivative p is paid by the agent in the good and medium states of the world. Given the price, the agent chooses the quantity of the derivative to buy. At $t = 2$, the signal is observed and all payoffs from the derivative are realized[8].

If the agent exerts effort on the risky project, he or she understands the underlying risks of the project and is able to obtain the best hedge for the project. As a result, the effort project

[8]The derivative has a payoff structure similar to a swap contract. It has zero value when entered and can be an asset or a liability to either party at a future date and/or at maturity.

State	Probability	Effort project	No-effort project	Derivative payoff	Public signal
good	π_g	Y_H	Y_H	$-p$	s_H
medium	π_m	Y_H	Y_L	$-p$	s_H
bad	$1-\pi_g-\pi_m$	Y_L	Y_L	1	s_L
	1	$Y_L+(\pi_g+\pi_m)\Delta Y$	$Y_L+\pi_g\Delta Y$		

Table II: Payoffs of all risky assets.

has zero expected costs of distress in the first-best scenario. If m_e denotes the quantity of the derivative chosen by the agent when he or she exerts effort, then the total payoff is:

$$\tilde{Z} = \begin{cases} Y_H - pm_e & \text{probability } \pi_g + \pi_m \\ Y_L + m_e & \text{probability } 1-(\pi_g+\pi_m) \end{cases}$$

If the agent does not exert effort, then the same derivative provides an incomplete hedge. If m_n denotes the quantity of the derivative chosen by the agent when he or she does not exert effort, then the total payoff is:

$$\tilde{Z} = \begin{cases} Y_H - pm_n & \text{probability } \pi_g \\ Y_L - L - p' & \text{probability } \pi_m \\ Y_L + m_n & \text{probability } 1-(\pi_g+\pi_m) \end{cases}$$

where, $p' = \min\{Y_L - L, pm_n\}$.

However, in the medium state, the no-effort project has a low payoff Y_L. The derivative does not pay in this state of the world, and the firm's total value is less than the distress threshold Z_{min}. Thus, the firm faces costs of distress L. The division of the firm's value between the principal and the market-maker depends on the seniority treatment of the derivative in bankruptcy. I assume that the derivative is senior in bankruptcy (based on the regulations in the US bankruptcy law). Thus, the transfer to the market-maker in the medium state is $Y_L - L$ or pm_n, whichever is lower.

The market-maker also takes into account the project payoff when deciding the maximum quantity of derivatives that he or she is willing to sell m_{alt}. The maximum quantity that the

market-maker is willing to sell satisfies the condition:

$$0 \leq m_{alt} \leq \frac{Y_H}{p} \tag{4}$$

where p is the price of the derivative. The right-hand side of the inequality ensures that the market-maker receives the price of the derivative when the project payoff is Y_H.

Incentive Contract. The incentive contract specifies the fraction of the firm's total value to be paid to the agent b. The firm's total value $\tilde{Z}$ and the public signal $\tilde{s}$ are observable and verifiable. Therefore, the contract conditions on the verifiable information, $b(\tilde{Z}, \tilde{s})$. The contract is consistent with the limited liability of the agent, and thus $b(\tilde{Z}, \tilde{s}) \geq 0$.

The sequence of events is summarized in Figure 1:

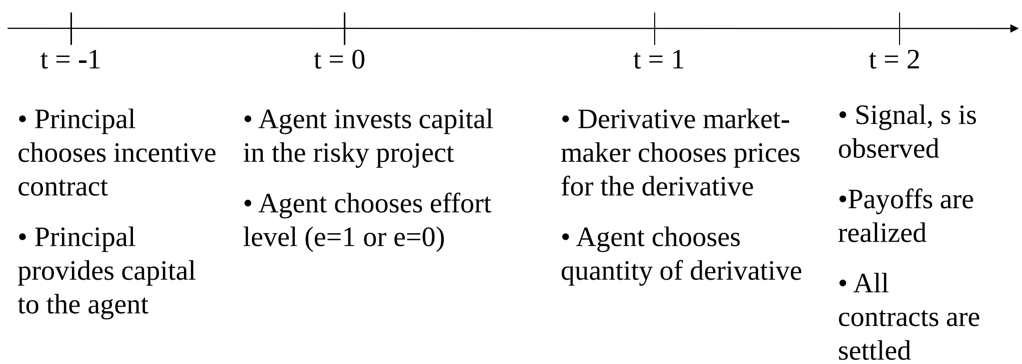

Figure 1: Timeline of events

III The Benchmark Case: The Model without Derivatives

In this section, I analyze the benchmark case where the agent implements the risky project but does not buy the derivative. I derive the optimal incentive contract and the rent paid to the agent to implement effort. The optimal contract is a revenue sharing rule that specifies the fraction of revenue that is paid to the agent. The contract conditions on the payoff of the risky project and the public signal are:

$$b = \begin{cases} b_H & \text{if } \tilde{Z} = Y_H \ , \ \tilde{s} = s_H \\ b_M & \text{if } \tilde{Z} = Y_L \ , \ \tilde{s} = s_H \\ b_L & \text{if } \tilde{Z} = Y_L \ , \ \tilde{s} = s_L \end{cases}$$

In the model, no state exists in which a high cash flow from project Y_H and a low public signal s_L are observed simultaneously. Therefore, this combination is not considered when defining the optimal contract.

The principal's problem is to choose the optimal contract that maximizes his or her expected payoff:

$$\max_b (\pi_g + \pi_m)(1 - b_H)Y_H + (1 - \pi_g - \pi_m)(1 - b_L)(Y_L - L)$$

The payoff is subject to the incentive compatibility (IC thereafter) constraint of the agent:

$$(\pi_g + \pi_m)b_H Y_H + (1 - \pi_g - \pi_m)b_L(Y_L - L) - \psi \geq \pi_g b_H Y_H + \pi_m b_M (Y_L - L) + (1 - \pi_g - \pi_m)b_L(Y_L - L)$$
$$\pi_m b_H Y_H - \psi \geq \pi_m b_M (Y_L - L);$$

and the participation (IR thereafter) constraint of the agent:

$$(\pi_g + \pi_m)b_H Y_H + (\pi_g + \pi_m)b_L(Y_L - L) - \psi \geq 0$$

The participation (PC thereafter) constraint of the principal is satisfied if the principals payoff

at least breaks even.

$$(\pi_g + \pi_m)(1 - b_H)Y_H + (\pi_g + \pi_m)(1 - b_L)(Y_L - L) \geq 1$$

An optimal contract is the function $b(\tilde{Z}, \tilde{s})$ such that the IC and IR constraints of the agent are satisfied. The principal chooses to implement effort if his or her PC constraint is satisfied. To reduce the implementation costs, the principal optimally chooses $b_M = 0$. This choice relaxes the IC constraint and does not impact the IR and PC constraints if the IR and IC constraints are:

$$\pi_m b_H Y_H - \psi \geq 0 \tag{5}$$

$$(\pi_g + \pi_m) b_H Y_H + (1 - \pi_g - \pi_m) b_L (Y_L - L) - \psi \geq 0 \tag{6}$$

Figure 2 illustrates the constraints (5) and (6) in the (b_L, b_H) space. The dotted line is the IR constraint. The constraint binds on the line and is slack to the right of it. The horizontal solid line is the IC constraint. It binds along the line and is slack above it. Therefore, the set of possible transfers that satisfy both constraints lies on and above the solid line (IC constraint). The choice of transfers that minimizes the implementation costs to the principal lies at the intersection of the IC constraint and the Y-axis. The IC constraint binds, and the cheapest transfers to the agent are equal to $(0, \frac{\psi}{\pi_m Y_H})$. Combining the IC constraint with the PC constraint leads to the complete solution. This is summarized in Proposition 1:

Proposition 1. *The first-best solution is attained and the positive NPV project is undertaken under the following condition:*

$$Y_H \geq Y_0 = \frac{1 - (1 - \pi_g - \pi_m)(Y_L - L)}{\pi_g + \pi_m} + \frac{\psi}{\pi_m}$$

The optimal contract to induce the agent to exert effort is:

$$\widehat{b} = \begin{cases} \frac{\psi}{\pi_m Y_H} & \text{if } \tilde{Z} = Y_H \ , \ \tilde{s} = s_H \\ 0 & \text{otherwise} \end{cases}$$

The highest payoff to the principal is achieved when $b = \widehat{b}$. The principal shares a fraction of the firm's payoff with the agent when the firm performs well, that is, the payoff of the project is high. When the firm performs poorly, the principal retains the entire project payoff. This contract provides the agent with incentives to exert effort. He or she receives a high payoff when the project payoff is high (the probability of which is maximized with effort) and is "punished", that is, he or she receives zero payoff when the project payoff is low (the probability of this state is minimized with effort). Thus, the optimal financing contract is a debt contract and the agent holds all the equity in the firm.

$$R_e = \left(1 + \frac{\pi_g}{\pi_m}\right)\psi \qquad\qquad V_e = (\pi_g + \pi_m)Y_H + (1 - \pi_g - \pi_m)(Y_L - L) \tag{7}$$

where R_e is the rent to the agent, and V_e is the expected cash flow from the project or the firm's value.

For the PC constraint to be satisfied, the project needs to have a large positive NPV. If the cash flow from the project in the good state is sufficiently high, then the principal is able to pay the agent and have enough left over to obtain positive profits. As the costs of distress increase, that is, as L increases; more and more positive NPV projects are not financed by the principal. Y_0 (as specified in Proposition 1) increases with the costs of distress L.

IV Model with Derivatives

In this section, I analyze the case where the agent implements the risky project and buys the derivative.

IV.A First-Best Equilibrium

In the case where effort and the quantity of the derivative are observable and contractible, the principal solves

$$\max_m (\pi_g + \pi_m)(Y_H - pm)\mathbf{1}_{\tilde{Z} \geq Z_{min}} + (1 - \pi_g - \pi_m)(Y_L + m)\mathbf{1}_{\tilde{Z} \geq Z_{min}}$$

subject to the agent's and market-maker's participation (PC) constraints.

The first-best quantity of the derivative is that which minimizes the costs of financial distress. From the maximization problem, I obtain the range of derivative quantities m that minimizes the distress costs and maximizes the firm's value:

$$Y_H - pm \geq Z_{min}$$
$$Y_L + m \geq Z_{min}$$

where p is the price of the derivative. Thus, the first-best quantity of the derivative lies within the range of

$$Z_{min} - Y_L \leq m^{FB} \leq \frac{Y_H - Z_{min}}{p} \tag{8}$$

When the quantity of the derivative bought lies within the range specified above (equation 8), the firm is borrowing from itself in the good state of the world. This range of quantity maximizes the firm's value. The PC constraint of the market-maker is binding at the optimum:

$$(\pi_g + \pi_m)p = 1 - (\pi_g + \pi_m)$$
$$p = \frac{1}{\pi_g + \pi_m} - 1 \tag{9}$$

In further sub-sections, I assume that the market-maker draws zero rents in equilibrium. Therefore, in the equilibrium where the agent exerts effort (sub-section IV.C), equation 9 represents

the endogenous price of the derivative. The firm's value with the first-best quantity is:

$$\begin{aligned} V_{FB} &= (\pi_g + \pi_m)(Y_H - p * m) + (1 - \pi_g - \pi_m)(Y_L + m) \\ &= Y_L + (\pi_g + \pi_m)(Y_H - Y_L) \end{aligned}$$

From equation (2), the firm's value with the first-best quantity is always more than one. This equilibrium demonstrates that hedging with the derivative increases the firm's value compared to the benchmark case. In other words, the derivative represents a positive NPV project for the firm. Figure 4 shows the comparison of the social surplus in the first-best equilibrium and the benchmark case. For all levels of cost of effort, the social surplus in the first-best equilibrium is higher than that in the benchmark case. Thus, hedging with the derivative also increases social welfare.

IV.B Constrained First-Best Equilibrium

I now relax the assumption that effort is observable. In this case, I assume that the derivative is not complex and therefore the investor can contract on the quantity of the derivative bought by the agent. Given that the principal can observe both the quantity and the public signal, he or she can infer the payoff from the risky project.

The optimal contract conditions on all of the observable and verifiable information: the payoff from the risky project and the public signal. The fraction of the risky project's payoff that is paid to the agent is given by:

$$b = \begin{cases} b_H & \text{if } \tilde{Y} = Y_H \;\&\; \tilde{s} = s_H \\ b_M & \text{if } \tilde{Y} = Y_L \;\&\; \tilde{s} = s_H \\ b_L & \text{if } \tilde{Y} = Y_L \;\&\; \tilde{s} = s_L \end{cases}$$

In addition, the principal agrees to pay w if the derivative quantity satisfies equation (8) and zero otherwise. Because the principal expects the agent to always exert effort, he or she can ensure that the firm's total value is always more than the distress threshold Z_{min} by contracting

for the derivative quantity. Thus, the principal solves

$$\max_{b,w}(\pi_g + \pi_m)(1 - b_H)Y_H + (1 - \pi_g - \pi_m)(1 - b_L)Y_L - w$$

subject to the incentive compatibility (IC) and the participation (IR) constraint of the agent.

$$IC : (\pi_g + \pi_m)b_H Y_H + (1 - \pi_g - \pi_m)b_L Y_L + w - \psi \geq \pi_g b_H Y_H + \pi_m b_M(Y_L - L - p') + (1 - \pi_g - \pi_m)b_L Y_L + w$$

$$IR : (\pi_g + \pi_m)b_H Y_H + (1 - \pi_g - \pi_m)b_L Y_L + w - \psi \geq 0$$

where, $p' = \min\{Y_L - L, pm^{FB}\}$, $Z_{min} - Y_L \leq m^{FB} \leq \frac{Y_H - Z_{min}}{p}$ and $p = \frac{1}{\pi_g + \pi_m} - 1$. The principal chooses to implement effort if his or her PC constraint is satisfied:

$$(\pi_g + \pi_m)(1 - b_H)Y_H + (\pi_g + \pi_m)(1 - b_L)Y_L - w \geq 1 \tag{10}$$

In addition, equations (8) and (9) and the limited liability constraints of the agent should be satisfied. Setting $b_M = 0$ is optimal because this value relaxes the IC constraint of the agent and does not impact the IR constraint nor the payoff function of the principal. Similarly, $w = 0$ is optimal. Figure 3 illustrates the constraints in the (b_L, b_H) space. The cheapest contract is the black dot at the intersection of the IC constraint (thick line) and the Y-axis. Combining this contract with the PC constraint of the principal (equation 10) completes the solution. This solution is summarized in Proposition 2.

Proposition 2. *The first-best solution is attained and the positive NPV project is undertaken under the following condition:*

$$Y_H \geq Y_1 = \frac{1 - (1 - \pi_g - \pi_m)Y_L}{\pi_g + \pi_m} + \frac{\psi}{\pi_m}$$

The optimal contract is given by $w = 0$ *and*

$$b = \begin{cases} \frac{\psi}{\pi_m Y_H} & \textit{if } \tilde{Y} = Y_H \ \& \ \tilde{s} = s_H \\ 0 & \textit{otherwise} \end{cases}$$

The proposition states that the return in the good state Y_H must be larger than a minimum level Y_1 for financing to be granted. When derivatives are used, more positive NPV projects receive funding or $Y_1 < Y_0$ (specified in Proposition 1). The derivative reduces the expected costs of distress, and no additional rents are shared with the agent. Therefore, the ex-ante funding capacity of the project increases when compared to the benchmark case. The firm's value in the constrained first-best case is higher than the benchmark case. This increase is due to the choice of the optimal derivative and the optimal choice of quantity of this derivative.

IV.C Effort and Derivative Usage

I now turn to the case where both the effort and the quantity of the derivative are not contractible. The key motivation underlying this assumption is that the principal does not fully understand the nature of the derivative or the derivative is "complex", and is, therefore, unable to contract on the optimal quantity of the derivative. When the agent exerts effort on the project, he or she understands the underlying risk exposure better. In this case, the agent can choose the optimal derivative and the optimal quantity of that derivative. In the model, I assume that when the agent exerts effort, he or she is able to choose the derivative that best matches the project.

Similar to the benchmark case, the optimal contract is a revenue sharing rule that specifies the fraction of revenue that is paid to the agent. The contract conditions on all of the observable and verifiable information: the total payoff and the public signal. I assume that the optimal

contract is linear in cash flow:

$$b = \begin{cases} b_H & \text{if } \tilde{Z} \geq Z_{min} \;\&\; \tilde{s} = s_H \\ b_M & \text{if } \tilde{Z} < Z_{min} \\ b_L & \text{if } \tilde{Z} \geq Z_{min} \;\&\; \tilde{s} = s_L \end{cases}$$

where Z_{min} represents the distress threshold of the firm.

I solve the model with backward induction. At $t = 1$, the derivative market-maker sets the price p in a competitive market. The agent optimally chooses the quantity of the derivative m given the price of the derivative. At $t = 0$, the agent chooses his or her effort level, anticipating his or her expected compensation. At $t = -1$, the principal takes into consideration the equilibrium actions of the derivative market-maker and the agent and optimally chooses the incentive contract: $b(\tilde{Z}, \tilde{s})$.

The agent chooses his or her effort level at $t = 0$. I refer to the agent who exerts effort as the "effort" agent (subscript e) and the agent who chooses no effort as the "no-effort" agent (subscript n). I derive the optimal quantity of the derivative m_x for each agent x where $x \in \{e, n\}$, given price p. I assume that the agent can only buy the derivative (or have no position at all), that is, $m_x \geq 0$ where $x \in \{e, n\}$.

Definition 1. ***Hedge.*** *The agent has a hedging position if m lies within the range of $m \in [Z_{min} - Y_L, \frac{Y_H - Z_{min}}{p}]$. The total payoff in the good and the bad states is weakly greater than the threshold value of Z_{min}.*

Speculation. *The agent has a speculative position with the derivative if $m > \frac{Y_H - Z_{min}}{p}$. The payoff in the good and medium states is less than the threshold value of Z_{min}.*
where $Z_{min} \in (Y_L, 1)$ and $p = \frac{1}{\pi_g + \pi_m} - 1$.

At $t = 1$, the market-maker sets the price that breaks even (equation 9). In other words, the market-maker assumes that the agent has exerted effort and prices the derivative correctly. This price ensures that the market-maker receives zero rents in equilibrium.

In the same spirit as Froot, Scharfstein and Stein (1994), I define a hedging position in the derivative as that which allows the agent to borrow from a state in which the risky project provides a high payoff, that is, the good state of the world. For any choice of the quantity within the aforementioned range, the firm receives the benefit of being above the distress threshold, Z_{min} in all states of the world, conditional on effort. Therefore, if the agent chooses the quantity of the derivative such that it satisfies equation (8), this is akin to cash flow hedging in the model.

It is noteworthy that if the agent exerts no effort then the firm will be in distress in the medium state of the world even with a hedging position in the derivative. The derivative cannot keep the company away from distress in all states of the world. Both managerial effort and a hedging position in the derivative are necessary to minimize deadweight losses in distress and, thereby, maximize firm value.

If the agent buys a quantity of the derivative which is larger than the higher end of the first-best range then this is defined as a speculative position. With such a quantity of the derivative, the total firm cashflow is below the distress threshold when the project payoff is high, that is, in the good state of the world. The firm faces deadweight losses in distress despite the project performing well. Such quantities of the derivative lead to a reduction in firm value. Such inefficiently large quantities of the derivative are, therefore, defined as a speculative position in the derivative.

At $t = 0$, given that the optimal contract ensures a hedging position in the derivative, the effort and the no-effort agents decide the quantities of the derivatives m_e and m_n, respectively, by solving the following maximization problems. The effort agent solves:

$$\begin{aligned} m_e &= \arg\max_m U_e \\ &= \arg\max_m \{(\pi_g + \pi_m) b_H (Y_H - pm)\mathbf{1}_{\tilde{Z} \geq Z_{min}} + (1 - \pi_g - \pi_m) b_L (Y_L + m)\mathbf{1}_{\tilde{Z} \geq Z_{min}} - \psi\} \end{aligned} \tag{11}$$

The no-effort agent solves:

$$
\begin{aligned}
m_n &= \arg\max_m U_n \\
&= \arg\max_m \{\pi_g b_H (Y_H - pm)\mathbf{1}_{\tilde{Z} \geq Z_{min}} + \pi_m b_M (Y_L - L - p') + (1 - \pi_g - \pi_m) b_L (Y_L + m)\mathbf{1}_{\tilde{Z} \geq Z_{min}}\}
\end{aligned} \tag{12}
$$

where, $p' = \min\{Y_L - L, pm\}$

Proposition 3. ***(Derivative quantity)*** *Given that the optimal contract ensures a hedging position in the derivative, the optimal choices of the derivative quantities for the effort and the no-effort agents m_e and m_n, respectively, are given by:*

$$
m_e = \begin{cases} \frac{Y_H - Z_{min}}{p} & \text{if } b_L > b_H \\ \in [Z_{min} - Y_L, \frac{Y_H - Z_{min}}{p}] & \text{if } b_L = b_H \\ Z_{min} - Y_L & \text{if } b_L < b_H \end{cases} \tag{13}
$$

$$
m_n = \begin{cases} m_{alt} & \text{if } b_L \geq \frac{\pi_g}{\pi_g + \pi_m} b_H \ \&\ U_n < U_{sp} \\ \frac{Y_H - Z_{min}}{p} & \text{if } b_L > \frac{\pi_g}{\pi_g + \pi_m} b_H \ \&\ U_n \geq U_{sp} \\ \in [Z_{min} - Y_L, \frac{Y_H - Z_{min}}{p}] & \text{if } b_L = \frac{\pi_g}{\pi_g + \pi_m} b_H \ \&\ U_n \geq U_{sp} \\ Z_{min} - Y_L & \text{if } b_L < \frac{\pi_g}{\pi_g + \pi_m} b_H \ \&\ U_n \geq U_0 \\ 0 & \text{if } b_L < \frac{\pi_g}{\pi_g + \pi_m} b_H \ \&\ U_n < U_0 \end{cases} \tag{14}
$$

The thresholds are given by

$$
\begin{aligned}
U_n &= \pi_g b_H (Y_H - pm_n) + \pi_m b_M (Y_L - L - p') + (1 - \pi_g - \pi_m) b_L (Y_L + m_n) \\
U_{sp} &= \pi_g b_M (Y_H - pm_{alt}) + \pi_m b_M (Y_L - L - \min\{Y_L - L, pm_{alt}\}) + (1 - \pi_g - \pi_m) b_L (Y_L + m_{alt}) \\
U_0 &= \pi_g b_H Y_H + (1 - \pi_g) b_M (Y_L - L)
\end{aligned}
$$

where, $Y_L < Z_{min} < 1$ and $p = \frac{1}{\pi_g + \pi_m} - 1$.

Proof. Please refer to the appendix.

The expected compensation of the effort agent with a hedging position in the derivative is:

$$
\begin{aligned}
U_e &= (\pi_g + \pi_m)b_H(Y_H - pm_e) + (1 - \pi_g - \pi_m)b_L(Y_L + m_e) - \psi \\
&= (\pi_g + \pi_m)b_H Y_H + (1 - \pi_g - \pi_m)b_L Y_L + m_e(1 - \pi_g - \pi_m)(-b_H + b_L) - \psi.
\end{aligned}
$$

If $b_L > b_H$, then the derivative is a positive NPV investment opportunity for the agent. In such a scenario, the effort agent is more likely to speculate and buy a large quantity of the derivative. If the optimal contract ensures a hedging position with the derivative, then the agent chooses the largest possible hedge, that is, $m_e = \frac{Y_H - Z_{min}}{p}$. If $b_L = b_H$, then the derivative is a zero NPV project for the agent; and the agent is indifferent to the quantity choice within the first-best range of(equation 8). If $b_L < b_H$, then the derivative is a negative NPV opportunity when not accounting for the savings in the deadweight losses; and the agent chooses the minimum value within the first-best range of the derivative quantity.

The expected compensation of the no-effort agent with a hedging position in the derivative is:

$$
\begin{aligned}
U_n &= \pi_g b_H(Y_H - pm_n) + \pi_m b_M(Y_L - L - p') + (1 - \pi_g - \pi_m)b_L(Y_L + m_n) \\
&= \pi_g b_H Y_H + \pi_m b_M(Y_L - L - p') + (1 - \pi_g - \pi_m)b_L Y_L + m_n(1 - \pi_g - \pi_m)(-\frac{\pi_g}{\pi_g + \pi_m} b_H + b_L).
\end{aligned}
$$

If $b_L > \frac{\pi_g}{\pi_g + \pi_m} b_H$, then the agent perceives the derivative as a positive NPV project. Therefore, the no-effort agent is more likely to speculate and buy a large quantity of the derivative. If the optimal contract ensures a hedging position for this agent, then the agent chooses the largest hedging position, that is, $m_n = \frac{Y_H - Z_{min}}{p}$.

However, if the choice is $m_n = m_{alt} > \frac{Y_H - Z_{min}}{p}$ and if the derivative markets are sufficiently liquid or m_{alt} is high and the contract provides a higher payoff in the bad state of the world, then the agent benefits from speculating. The firm receives a high payoff from the speculative position, and the agent receives a large fraction of that payoff. Thus, he or she chooses to buy the maximum amount of the derivative available: $m_n = m_{alt}$.

Now consider the range, $m_n = 0 < Z_{min} - Y_L$. If the agent receives low compensation in the bad state and ends up paying the full price for the derivative, the optimal choice of the agent is $m_n = 0$.

In sum, if the optimal contract ensures a hedging position in the derivative, then the effort agent chooses the quantity within the first-best range or $m_e \in [Z_{min} - Y_L, \frac{Y_H - Z_{min}}{p}]$. However, the same contract might not be able to ensure that the no-effort agent has a hedging position in the derivative.

The principal anticipates the actions of the market-maker and the agent and chooses the contract parameters $b(\tilde{Z}, \tilde{s})$ to minimize the implementation costs. I solve for the optimal contract that induces effort and a hedging position in the derivative. The principal's maximization problem is

$$\max_b \Big((\pi_g + \pi_m)(1 - b_H)(Y_H - pm_e)\mathbf{1}_{\tilde{Z} \geq Z_{min}} + (1 - \pi_g - \pi_m)(1 - b_L)(Y_L + m_e)\mathbf{1}_{\tilde{Z} \geq Z_{min}} \Big)$$

subject to the IC constraints of the agent

$$\begin{aligned}
IC_0 \quad &: U_e \geq \pi_g b_H Y_H + (1 - \pi_g) b_M (Y_L - L) \\
IC_{hedge} &: U_e \geq U_n \\
IC_{spec} \quad &: U_e \geq \pi_g b_H (Y_H - pm_{alt})\mathbf{1}_{\tilde{Z} < Z_{min}} + \pi_m b_M (Y_L - L) + (1 - \pi_g - \pi_m) b_L (Y_L + m_{alt})\mathbf{1}_{\tilde{Z} \geq Z_{min}}
\end{aligned}$$

and the PC constraints of the agent

$$\begin{aligned}
IR_0 \quad &: U_e \geq (\pi_g + \pi_m) b_H Y_H + (1 - \pi_g - \pi_m) b_M (Y_L - L) - \psi \\
IR_{spec} &: U_e \geq (\pi_g + \pi_m) b_M (Y_H - pm_{alt})\mathbf{1}_{\tilde{Z} < Z_{min}} + (1 - \pi_g - \pi_m) b_L (Y_L + m_{alt})\mathbf{1}_{\tilde{Z} \geq Z_{min}} - \psi
\end{aligned}$$

where U_e and U_n are defined as in equations (11)and (12) respectively.

Equation IC_0 ensures that the agent is better off with effort and a hedge as compared to no effort and no derivative position. Equation IC_{hedge} ensures that the agent is better off with effort and a hedge as opposed to no effort and a hedge. Equation IC_{spec} guarantees that the

agent is better off with effort and a hedge as opposed to no effort and a speculative position. Equation IR_0 ensures that the agent exerts effort and hedges as compared to only exerting effort. Equation IR_{spec} ensures that the agent exerts effort and hedges and does not speculate. Similar to the benchmark case, $b_M = 0$ in this setup. I will be using this result throughout this subsection.

It is also worth noting at this point that only one of the two participation constraints dominates. This domination depends on the values of the distress threshold Z_{min} and the maximum quantity of the derivative supplied by the market-maker m_{alt}.

Proposition 4. ***(Effort Equilibrium)*** *The first-best solution is attained, and the positive NPV project is undertaken with the following condition:*

$$Y_H \geq Y_{2e} = \begin{cases} \frac{\pi_m Z_{min}}{(\pi_g+\pi_m)(\pi_m Z_{min}-\psi)} - \frac{(1-\pi_g-\pi_m)Y_L}{\pi_g+\pi_m} & \text{if } m_{alt} \leq M1 \\ \frac{\overline{\pi}Y_H-(1-\overline{\pi})m_{alt}}{\overline{\pi}(\overline{\pi}Y_H-(1-\overline{\pi})m_{alt}-\psi)} - \frac{(1-\overline{\pi})Y_L}{\overline{\pi}} & \text{if } M1 < m_{alt} < \frac{Y_H}{p} \end{cases} \tag{15}$$

The parameters of the optimal contract are given by:

$$b_H = b_L = \begin{cases} \frac{\psi}{\pi_m Z_{min}} & \text{if } m_{alt} \leq M1 \\ \frac{\psi}{(\pi_g+\pi_m)Y_H-(1-\pi_g+\pi_m)m_{alt}} & \text{if } M1 < m_{alt} < \frac{Y_H}{p} \end{cases} \tag{16}$$

And $b_M = 0$. The threshold is given by:

$$M1 = \frac{(\pi_g + \pi_m)Y_H - \pi_m Z_{min}}{1 - \pi_g - \pi_m} \tag{17}$$

where $Y_L < Z_{min} < 1$, $p = \frac{1}{\pi_g+\pi_m} - 1$, and $\overline{\pi} = \pi_g + \pi_m$.

Proof. Please refer to the appendix.

The optimal contract in the second-best equilibrium does not condition on the public signal if the firm's total value is not in distress. For both realizations of the public signal, s_H and s_L, the principal shares the same fraction for the total payoff with the agent: $b_H = b_L$. The principal is not able to pay the agent any less in the good state because less pay leads the

agent to speculation. When speculation occurs, the principal is not able to implement effort. Therefore, the principal does not condition on the derivative signal if the firm is not in distress. The optimal financing contract resembles a debt contract.

The distress threshold is high when $\frac{(1-\pi_g-\pi_m)Y_L}{\pi_m} < Z_{min} < 1$ is satisfied. If the available quantity of the derivative is sufficiently low ($m_{alt} < M1$ in Proposition 4), then the agent is not able to speculate with the derivative. The IC constraint that dominates is IC_{hedge}, or the no-effort agent optimally chooses to hedge with the derivative. As a result, the increase in rent compared to the benchmark case is low. As the derivative markets become more liquid, the agent is able to speculate with the derivative. Therefore, the principal is forced to share more rents to ensure effort and a hedging position in the derivative.

Figure 5 plots the rent to the agent and the utility of the principal as a function of the available derivative quantity. The left panel shows that when the derivative markets are less liquid, the rents to the agent in the effort equilibrium are close to the benchmark case. As the derivative markets become more liquid, the rents to the agent increase. The right panel shows that the principal's utility is a function of the available derivative quantity. As the derivative markets become more liquid or m_{alt} increases, the principal is more likely to be worse off in the effort equilibrium as opposed to the benchmark case.

IV.D No-effort and Derivative Usage

In this subsection, I solve for the equilibrium in which the principal implements no effort. The earlier subsection sets out the conditions under which an equilibrium with effort exists. The principal might find the implementation of effort to be too costly. He or she is faced with a choice between the following options: (1) implement effort without the derivative (benchmark case) and (2) implement no effort and a hedging position in the derivative. Both of these options reduce the cost of compensation.

The principal solves the following maximization problem subject to the participation constraints of the agent and the market-maker :

$$\max_b \left(\pi_g(1-b_H)(Y_H - pm)\mathbf{1}_{\tilde{Z}\geq Z_{min}} + \pi_m(1-b_M)(Y_L - L)\mathbf{1}_{\tilde{Z}<Z_{min}}(1-\pi_g-\pi_m)(1-b_L)(Y_L+m)\mathbf{1}_{\tilde{Z}\geq Z_{min}}\right)$$

Proposition 5. ***(No-effort Equilibrium)*** *When the first-best effort is not attainable, the no-effort project is undertaken with the following condition:*

$$\psi \geq \max\left[\frac{\pi_m}{\pi_g+\pi_m}\left(\pi_m\Delta Y - (1-\pi_g-2\pi_m)\Delta Y\right), \pi_m Z_{min}\frac{\pi_m(\Delta Y - L)}{Y_L + (\pi_g+\pi_m)\Delta Y}\right] \tag{18}$$

The parameters of the optimal contract are $b_H = b_M = b_L = 0$. And the price of the derivative is:

$$p = \begin{cases} \frac{1-\pi_g-\pi_m}{\pi_g} - \frac{\pi_m(Y_L-L)}{\pi_g m} & \text{if } m \geq \frac{(Y_L-L)(\pi_g+\pi_m)}{1-\pi_g-\pi_m} \\ \frac{1}{\pi_g+\pi_m} - 1 & \text{if } m < \frac{(Y_L-L)\overline{\pi}}{1-\overline{\pi}} \end{cases} \tag{19}$$

where, $Y_L < Z_{min} < 1$.

Proof. Please refer to the appendix.

The no-effort equilibrium is the optimal choice for the principal when he or she faces a high moral hazard (as given by equation 18). The effort equilibrium is not implemented because the cost of compensation increases with hedging. The principal is left worse off with hedging and chooses between two options: choose effort and no derivative or choose no-effort and an ineffective derivative. If the firm faces a high cost of managerial effort ψ, then the no-effort equilibrium is the optimal choice for the principal. He or she benefits from a reduction in the expected distress costs from the ineffective derivative. He or she also saves on paying high rents to the agent.

The market-maker adjusts the price to reflect the actions of the principal and the agent. The price of the derivative in the no-effort equilibrium is weakly higher than the price in the effort equilibrium. The market-maker anticipates that he or she will not receive any payment

from the agent in the medium state (because of the mismatch between the project's cash flow and the derivative's signal). He or she then increases the price in anticipation.

Figure 9 plots the utility of the principal and the social surplus in the no-effort equilibrium. The left panel of Figure 9 shows the zone where the agent is better off without effort ($L_1 < L < L_2$). He or she saves by not paying high rents to the agent but has to face a higher expected deadweight loss compared to the first-best equilibrium. However, the privately optimal choice of the principal leads to a socially suboptimal outcome. The social surplus is lower than the benchmark case. This is shown in the right panel of Figure 9. The socially suboptimal choice of effort and an ineffective hedge reduces the surplus. Thus, even after using derivatives, the firm may face a reduction in funding or a reduction in firm value.

IV.E Effort and the "Wrong" Derivative

In this section, I solve the model without the assumption that managerial effort increases the performance of the hedge.

In the earlier sections, I have shown that if effort choice and derivative choice are correlated then, the cost of compensating the agent for effort increases. Also, under the same assumptions an equilibrium exists in which the principal induces the manager to exert low effort and choose a suboptimal hedge. In this section, I assume that after exerting effort on the project, the manager chooses a derivative which is not the "best" hedge for the project. To capture this idea in the model, I assume that the derivative chosen by the manager who has not exerted effort is the "best" hedge for his or her project.

The table below shows the payoffs of the risky project and the alternative derivative, the payoff of which is based on the alternative signal, $\tilde{s}' \in \{s'_H, s'_L\}$. This alternative derivative matches the no-effort project and provides a complete hedge.

The optimal contract conditions on all observable and verifiable information: the payoff from the risky project and the alternative signal. The fraction of the risky project's payoff that is

State	Probability	Effort project	No-effort project	Derivative payoff	Alternative signal
good	π_g	Y_H	Y_H	$-p'$	s'_H
medium	π_m	Y_H	Y_L	1	s'_L
bad	$1-\pi_g-\pi_m$	Y_L	Y_L	1	s'_L
	1	$Y_L+(\pi_g+\pi_m)\Delta Y$	$Y_L+\pi_g\Delta Y$		

Table III: Payoffs of the risky project and the alternative derivative.

paid to the agent is given by:

$$b = \begin{cases} b_H & \text{if } \tilde{Z} \geq Z_{min} \;\&\; \tilde{s}' = s'_H \\ b_M & \text{if } \tilde{Z} < Z_{min} \\ b_L & \text{if } \tilde{Z} \geq Z_{min} \;\&\; \tilde{s}' = s'_L \end{cases}$$

The principal's maximization problem is

$$\max_b \Big(\pi_g(1-b_H)(Y_H - pm_e)\mathbf{1}_{\tilde{Z}\geq Z_{min}} + \pi_m(1-b_L)(Y_H+m_e)\mathbf{1}_{\tilde{Z}\geq Z_{min}} + (1-\pi_g-\pi_m)(1-b_L)(Y_L+m_e)\mathbf{1}_{\tilde{Z}\geq Z_{min}}\Big)$$

subject to the IC constraints of the agent

$$\begin{aligned} IC_0 \quad &: U'_e \geq \pi_g b_H Y_H + (1-\pi_g)b_M(Y_L - L) \\ IC_{hedge} &: U'_e \geq U'_n \\ IC_{spec} \quad &: U'_e \geq \pi_g b_M(Y_H - pm_{alt})\mathbf{1}_{\tilde{Z}<Z_{min}} + (1-\pi_g)b_L(Y_L+m_{alt})\mathbf{1}_{\tilde{Z}\geq Z_{min}} \end{aligned}$$

and the PC constraints of the agent

$$\begin{aligned} IR_0 \quad &: U'_e \geq \pi_g b_H Y_H + \pi_m b_L Y_H + (1-\pi_g-\pi_m)b_M Y_L - \psi \\ IR_{spec} &: U'_e \geq \pi_g b_M(Y_H - pm_{alt})\mathbf{1}_{\tilde{Z}<Z_{min}} + \pi_m b_L(Y_H+m_{alt})\mathbf{1}_{\tilde{Z}\geq Z_{min}} + (1-\pi_g-\pi_m)b_L(Y_L+m_{alt})\mathbf{1}_{\tilde{Z}\geq Z_{min}} - \psi \end{aligned}$$

where $U'_e = \pi_g b_H Y_H + \pi_m b_L Y_H + (1-\pi_g-\pi_m)b_L Y_L + (1-\pi_g)m'_e(-b_H+b_L)$ and $U'_n = \pi_g b_H Y_H + (1-\pi_g)b_L Y_L + (1-\pi_g)m'_n(-b_H+b_L)$.

U'_e denotes the payoff to the effort agent when he or she chooses a hedging position in the

derivative and U_n' denotes the payoff to the no-effort agent when he or she chooses a hedging position in the derivative. Equations IC_0, IC_{hedge}, IC_spec, IR_0 and IR_{hedge} have the same definitions as before. Similar to the benchmark case, $b_M = 0$ is the optimal choice in this case.

Proposition 6. ***(Alternative Equilibrium)*** *The first-best solution is attained, and the positive NPV project is undertaken with the following condition:*

$$Y_H \geq Y_{2alt} = \begin{cases} \frac{\pi_m Z_{min}}{(\pi_g+\pi_m)(\pi_m Z_{min}-\psi)} - \frac{(1-\pi_g-\pi_m)Y_L}{\pi_g+\pi_m} & \text{if } m_{alt} \leq M1 \\ \frac{\overline{\pi}Y_H-(1-\overline{\pi})m_{alt}}{\overline{\pi}(\overline{\pi}Y_H-(1-\overline{\pi})m_{alt}-\psi)} - \frac{(1-\overline{\pi})Y_L}{\overline{\pi}} & \text{if } M1 < m_{alt} < \frac{Y_H}{p} \end{cases} \tag{20}$$

The parameters of the optimal contract are given by:

$$b_H = \begin{cases} 0 & \text{if } m_{alt} \leq \frac{Y_H-Z_{min}}{p'} \\ \frac{\psi}{\pi_m \Delta Y} \cdot \frac{p' m_{alt}-Y_H+Z_{min}}{Z_{min}} & \text{if } \frac{Y_H-Z_{min}}{p'} < m_{alt} < \frac{Y_H}{p'} \end{cases} \tag{21}$$

And $b_L = \frac{\psi}{\pi_m \Delta Y}$, $b_M = 0$*; where* $Y_L < Z_{min} < 1$, $\Delta Y = Y_H - Y_L$ *and* $p' = \frac{1}{\pi_g} - 1$.

Proof. Please refer to the appendix.

Unlike the case in the Effort Equilibrium (shown in Proposition 4), the optimal contract in the Alternative Equilibrium does condition on the signal when the firm out of distress, $b_H \neq b_L$. This contractual form ensures that the agent exerts effort and stays away from speculating with the derivative.

Figure 7 shows the rents to the agent in the Benchmark Case, the Second-best Equilibrium (Effort Equilibrium) and the Alternative Equilibrium. When the liquidity of the derivative markets is low or m_{alt} is low, the total rents to the agent in the Alternative Equilibrium is lower than the Benchmark Case. Under these conditions, the no-effort equilibrium does not exist. This analysis shows that the main result of the paper - a reduction in firm value with hedging - comes about only when the assumption of managerial effort affecting derivative choice holds.

V Empirical Evidence

This section briefly lays out suggestive empirical evidence of the impact of hedging on firm value. In the previous sections, I have described the existence of the "Effort" equilibrium and the "No-effort" equilibrium in the presence of hedging. In this section, I use data from the gold-mining industry and find evidence in favour of the theory. First, I lay out the methodology and hypotheses. Then I briefly describe the data and test results.

V.A Empirical Strategy and Predictions

To empirically test the impact of hedging on firm value, I use a natural experiment that exogenously impacted the costs of hedging in the gold-mining industry. The Washington Agreement on Gold[9] was signed on 26 September 1999 by the European Central Bank and all central banks of EU member states for a period of five years[10]. The Agreement declared that they would not expand their gold lending and their use of gold futures. Since the participating banks held nearly 50% of the world's official gold holdings, this affected the costs of hedging for gold mining firms.

This setting is appealing for a number of reasons. First, the motivation behind the passage of this Agreement centered around unifying the policies of EU member countries. The Agreement was not passed with the intention of promoting or inhibiting hedging in the gold mining industry. The potential effects on the gold hedging market are an unintended consequence. Second, the increase in the costs of hedging was different across different derivative products. This differential increase made hedging effort-intensive. Therefore, my model, which assumes that hedging requires managerial effort, becomes applicable in the post-Agreement years. In this setting, I can test whether some firms are worse off with hedging.

In order to explain the differential increase in costs of hedging across different products, I provide a brief overview of the institutional setting of the gold hedging market.[11] Commercial

[9]Brief overview and press release available on www.gold.org.

[10]The Agreement has been reviewed twice and similar terms have been agreed. The third Central Bank Gold Agreement is in force till 26 September 2014.

[11]A more detailed discussion of the functioning of gold derivatives markets can be found in Neuberger (2001).

banks, such as Citibank and Morgan Guaranty, act as intermediaries between central banks (lenders of gold) and gold mining firms (borrowers of gold). Most central banks are willing to lend gold only on three-month contracts. Gold mining firms typically seek derivative hedges with one to five-year maturities. Commercial banks act as intermediaries - they create these long-term derivative contracts and hedge their positions by borrowing gold from the central banks. They borrow gold on short term contracts and roll-over the gold loans every three months. As a result of the maturity mis-match, the commercial banks face the risk that gold borrowing rates (or gold lease rates) may increase during the term of the derivative contract. They charge a premium to compensate for the risk of increase in gold lease rates.

Historically, gold lease rates offered by central banks have been low (between 1% and 4%) and stable. This has helped maintain large volumes of trading in gold derivatives. After 26 September 1999, the gold lease rates increased from an average of 1.5% to 10%. The rates remained at high levels of 4-5% for three to four weeks. Because of the freeze in gold lending volumes by the European central banks, there was greater uncertainty in the expected gold lease rates. As a result, the premium charged for long-term derivative contracts increased. This increase depended on the volume of gold required to hedge each contract. Therefore, forwards became comparatively more expensive than options after the Agreement.[12]

The Agreement affected the ability of gold mining companies to use forwards to hedge their gold price exposure. Since options are more complex instruments, my model predictions apply in the years after the Agreement. My model states that when hedging is effort-intensive some firms will choose sub-optimal projects and sub-optimal hedges. Thereby, these firms will face a drop in firm value compared to the first-best scenario. I argue that firms with un-hedged operating profits less correlated with gold price will be less able to hedge their exposure as compared to firms which have operating profits highly correlated to gold price. One possible mechanism is the following: given that the business operations of low-correlation firms are less “hedge-able”, their

[12]In the case of forwards, the delta of the contract is one. Delta being defined as the change in price of the derivative as a fraction of the change in price of the underlying or gold. The delta of option contracts is weakly lower than one. The higher the delta, the higher is the volume of gold required to hedge the derivative contract. Therefore, forwards and option portfolios with a delta of one face a higher risk of increasing lease rates. The premium charged for such contracts increases more than that for derivatives with delta less than one.

optimal portfolio is more difficult to identify when hedging with more complex instruments. When forwards becomes less attractive compared to options, the managerial effort required to find an alternative, optimal hedging strategy is high. Companies with low correlation to gold will hedge less effectively when faced with the same shock. Using difference-in-differences specifications, I exploit this variation in correlation to identify the impact of hedging on a variety of firm outcomes.

Using quarterly cash flow data of gold mining companies from COMPUSTAT, I run the following regression:

$$\Delta ln(opin/assets)_{it} = a + b_i * \Delta ln(gold)_t + d_i * \Delta ln(gold)_{t-1} + \epsilon_{it} \tag{22}$$

where, $\Delta ln(opin/assets)_{it}$ is the change in the level of unhedged cash flow from operations to total assets of firm i in quarter t, $\Delta ln(gold)_t$ is the change in the spot price of gold. The coefficient, b_i captures the sensitivity of cash flows to variation in spot price of gold. I refer to these as the "gold betas". I divide firms into two groups based on the statistical significance of b_i. If the firm has a statistically insignificant coefficient, b_i then I categorize them as "group1" firms else as "group2" firms. The low exposure or "group1" companies are less likely to use derivatives effectively and increase firm value when faced with an exogenous shock to the costs of hedging. On the other hand, firms with a significant coefficient, b_i are more likely to use derivatives effectively.

The following hypothesis summarize the predictions: Hypothesis 1: A shock to the gold forwards market leads to an decrease in the debt capacity of firms which have low exposure to gold prices.

To test Hypothesis 1, I use a differences-in-differences approach:

$$y_{it} = \alpha + \beta_1 * group1_i * post + n_x X_{it} + \gamma_i + \lambda_t + e_{it}$$

where, $group1_i$ is an indicator variable that takes the value one if the firm is classified as "group1" or as a firm with low correlation with gold price. This is a proxy for the ineffectiveness

of hedges entered into by the firm. *post* is an indicator variable that takes the value one for all observations after 1999, γ_i are firm fixed effects, λ_t are year fixed effects and X_{it} are firm-level control variables. I do not include $group1_i$ as a variable in this specification because firm fixed effects are included. Removing firm fixed effects and including $group1_i$ will lead to similar intuition and results. I expect a negative and significant coefficient to β_1.

V.B Data and Main results

I use data from COMPUSTAT firms which are engaged in mining and refining of gold. Given that I need to obtain a measure of exposure of unhedged cash flows to gold price, I focus on North American firms with quarterly unhedged cash flow data for atleast five years prior to 1999. I arrive at a sample of 15 firms with 552 firm-year observations between 1999 and 2012.

Summary statistics are presented in Table IV, Panel A. The average total assets is $980 million and average revenue is $349 million. The average market-to-book ratio is 1.94 with a standard deviation of 1.55. The average book leverage is 0.169 and the average CAPEX/assets is 0.109. The data on use of financial derivatives is obtained from Haliburton Mineral Services Inc., a precious metals advisory company. This data has been compiled by Ted Reeve, a Canadian equity analyst who started compiling producer hedging data in 1990. More details related to this data set can be obtained in Tufano (1996)[13]. Table IV, Panel B presents summary statistics related to hedging activities. The average fraction of next year's production hedged is 27.59%.

Table V shows the results of the regression (Equation 22) for each firm in the sample and a measure of the significance of the "gold beta" of each firm. The gold betas are estimated using pre-1999 quarterly data on un-hedged cash flows. I use detailed hedge portfolio data from Haliburton Mineral Services to calculate the cash flows from hedging activities for each firm-quarter observation. I obtain the unhedged cash flows by removing cash flows from hedging activities from the operating profits. In unreported results, I carry out a similar regression on a number of different dependent variables including unhedged cash flows and ratio of total costs (including amortisation and financing costs) to total assets. Table V provides evidence that

[13] The data has been used in a number of empirical research papers: Adam, Fernando (2006), Adam, Fernando, Salas (2012) and Tufano(1996)

exposure to gold prices varies widely within the mining industry. All the firms in the sample are gold mining firms with around 80% to 90% of net revenues from gold sales. This is reflected in the fact that all the gold betas are positive. Nevertheless, the business operations of these firms are sufficiently different with respect to their exposure to gold price. Petersen and Thiagarajan (2000) elaborate on the operational reasons behind this difference. Firms such as Homestake Mining are able to respond by changing their operations in response to a change in gold price. This ability is due to the fact that such firms can re-allocate resources and close or open gold mines more effectively. Such firms have a statitically significant and positive gold beta. The most significant coefficient has a t-statistic of 4.6911. The least significant coefficient has a t-statistic of 0.2161. Firms are divided into two groups based on the size of the coefficient, b_i. Firms which have positive, insignificant coefficients are classified as "group1" firms. The other set of firms is classified as "group2" firms.

First, I test the impact of the exposure of gold price on gold-mining firms pre-1999. Given that price exposure variables are time-invariant, I use firm-level controls to account for firm heterogeneity. Table VI shows that firms with high exposure to gold price are similar to the firms with low exposure to gold price before 1999. The firms with low exposure to gold price, "group1" firms have insignificant differences in debt ratios compared to "group2" firms. The firms with low exposure to gold prices or "group1" firms have 0.2% to 0.5% higher *CAPEX / assets*. However, this difference is not significant. The differences between *Net debt/assets* and *Book leverage* is not significant between the two groups of firms. Overall these results provide empirical support to the idea that firms exposed to gold price were not significantly better off compared to less-exposed firms due to their ability to use derivatives. I now test whether this changed after the shock to the gold forwards market.

Tables VII and VIII present the main results of the paper. I expect "group1" firms to reduce in firm value after 1999. Table VII, columns (1) and (2) show that group1 firms decreased in firm value (as measured with market-to-book ratios) by 0.62% to 0.63%. These coefficients are significant at the 5% level. In further columns, I test the impact on firm financing policies. A reduction in firm financing and investment will provide indirect evidence of a reduction in firm

value. Columns (3) to (6) show the impact of the shock on the debt capacity of the firms. These firms reduce their book leverage and their net debt to assets ratio in response to the shock. Columns (3) and (4) show that *group*1 firms reduce their net debt by 12.8% to 23.3% post-1999. In addition, columns (5) and (6) show that group1 firms reduce their book leverage by 11.0% to 15.8% post-1999. These coefficients are significant at the 1% level. In unreported results, I add *group*1 as a variable and remove firm fixed effects. All the results go through in this alternative specification.

Table VIII presents the results of firm investment policies. Columns (1) and (2) show that firms with low correlation reduce their investment post-1999 by 0.5% to 0.6%. The coefficients are significant at the 10%level. Columns (3) and (4) show that firms which have low exposure increase their cash to assets ratio by 1.8% to 7.5% in response to the shock. The coefficients are significant at the 10% level.

One concern with DID specifications is that they may not adequately control for time-varying omitted variables that can differentially affect firms. To address this concern, I report all results using lagged M-B ratios as an independent variable. The inferences may be affected by significant changes such as changes in accounting regulations affecting hedging disclosure and changing business prospects due to the credit crisis of 2008-09. I control for these events in all the specifications. In unreported results, I also check the robustness of the results to a shorter window. I include three years before and after 1999 and find no difference in the sign and significance of the test results.

One alternative hypothesis to explain a reduction in firm value and book leverage is that *group*1 firms may be hedging less or may stop hedging completely post-1999. The reduction or elimination of hedging will affect the debt capacity of these firms and firm value. In order to test this hypothesis, I test for differences in hedging policies across these firms. Table IX presents the results of the impact of the Agreement on firm hedging policies. Columns (1) and (2) show that *group*1 firms, or firms with low gold betas, do not have a different hedging policy compared to high gold beta firms post-1999. The *group*1 firms have a delta of their derivatives portfolio which is higher by 3.91% to 10.24% compared to high gold beta firms. However, these coefficients are

not significant. These tests suggest that low gold beta firms have a hedge portfolio which looks similar to that of high gold beta firms post-1999. I find no evidence in favour of the alternative hypothesis. There is an aggregate reduction in the delta of derivatives portfolios but there is no relative change between these two groups of firms (low gold beta and high gold beta firms). The similarity in hedging policies of these firms shows that although $group1$ firms continue to hedge, these firms face worsening debt capacity and a reduction in firm value. These results provide further evidence in favour of the hypothesis that these firms hedge ineffectively post-1999.

The aim behind this limited empirical analysis was to show the existence of the "No-effort" equilibrium proposed in this paper. The empirical results described above show that some firms reduce their debt capacity and investment in response to an exogenous shock to hedging opportunities. This is despite the fact that they continue to hedge using other available hedging instruments. This is evidence in favour of the theory that hedging may reduce debt capacity and social surplus. A detailed analysis of the mechanism behind the empirical findings is left for further research.

VI Conclusion

Can hedging with derivatives be value-destroying for firms? This paper studies the impact of hedging on the firm's value in a setting in which a manager with limited liability has to undertake two actions - exert unobservable, costly effort to pick the optimal project, and choose the quantity of a hedging security. Under the assumption that managers who work hard to identify the optimal project are able to find identify the optimal derivative, I derive the contract that implements the level of the first-best effort. With the optimal contract, there is an increase in the agency costs when the manager invests in the derivative. This increase in rent occurs due to the interaction of three key elements of the model: the unobservability of the underlying risk, the choice of the derivative by the manager and the ability of the manager to speculate with the derivative. The increase in the agent's rents can make the investor worse off with the optimal derivative. This finding has an important economic implication. The firms that face

a severe moral hazard problem will choose a suboptimal project. This inefficient choice of the project leads to a reduction in the firm's value when hedging as compared with the un-hedged firm. Thus, I see suboptimal project choices, ineffective derivatives, and a high probability of bankruptcy in equilibrium.

I use a natural experiment in the gold mining industry to provide evidence of the negative impact of hedging on firm characteristics. The Washington Agreement in 1999 negatively affected the ability of firms to use gold forwards. However, all of the firms were not affected in the same way. I categorize firms into two groups based on the ex-ante exposure of their operations to the price of gold. I find that the firms with a low correlation with the price of gold reduce their investment and leverage in response to the shock. On the other hand, the firms with a high correlation with the price of gold increase their investment and leverage in response to the shock. This differential impact in response to the shock provides suggestive evidence in favor of my theory.

References

[1] Adam, Tim, 2009, "Capital Expenditures, Financial Constgraints and the Use of Options", *Journal of Financial Economics* 92,238-251.

[2] ________, Sudipto Dasgupta and Sheridan Titman, 2007, "Financial Constraints, Competition and Hedging in Industry Equilibrium", *Journal of Finance* 62, 2445-2473.

[3] ________and Chitru Fernando, 2006, "Hedging, Speculation and Shareholder Value", *Journal of Financial Economics* 81, 283-309.

[4] Bartram, Sohnke M., Gregory R. Brown and Frank R. Fehle, 2009, "International Evidence on Financial Derivatives Usage", *Financial Management* 185-206.

[5] Bartram, Sohnke M., Gregory R. Brown and Jennifer Conrad, 2011, "The Effect of Derivatives on Firm Risk and Value", *Journal of Financial and Quantitative Analysis* 46, 967-999.

[6] Biais, Bruno, Florian Heider and Maria Hoerova, 2011, "Risk Sharing or Risk Taking? Financial Innovation, Margin Requirements and Incentives ", mimeo.

[7] ________and Catherine Casamatta, 1999, "Optimal Leverage and Aggregate Investment", *Journal of Finance* 54, 1291 - 1323.

[8] Bisin, Alberto, Adriano A. Rampini and Piero Gottardi, 2008, "Managerial Hedging and Portfolio Monitoring", *Journal of European Economic Association* 6, 158-209.

[9] Bodnar, Gordon M., Gregory S. Hyat and Richard C. Marston, 1995, "1995 Wharton Survey of Derivatives Usage by Non-Financial Firms", *Financial Management* 25,113-133.

[10] Bodnar, Gordon M., Gregory S. Hyat and Richard C. Marston, 1998, "1998 Wharton Survey of Derivatives Usage by Non-Financial Firms", *Financial Management* 27, 70-91.

[11] Breeden, Douglas and S. Viswanathan, 1998, "Why Do Firms Hedge? An Asymmetric Information Model", working paper, Duke University.

[12] Brown, George W., 2001, "Managing Foreign Exchange Risk with Derivatives", *Journal of Financial Economics* 60, 401-448.

[13] Brown, George W. and Klaus B. Toft, 2002, "How Firms Should Hedge", *The Review of Financial Studies* 15, 1283-1324.

[14] Campbell, Tim S. and William A. Kracaw, 1987, "Optimal Managerial Incentive Contracts and the Value of Corporate Insurance", *Journal of Financial and Quantitative Analysis* 22, 315-328.

[15] Campello, Murillo, Chen Lin, Yue Ma and Hong Zou, 2011, "The Real and Financial Implications of Corporate Hedging", *Journal of Finance* 64, 1615-1647.

[16] Carter, David A., Daniel A. Rogers and Betty J. Simkins, 2006, "Does Hedging Affect Firm Value? Evidence from the US Airline Industry", *Financial Management*, 53-86.

[17] Chang, Chun, 1997, "Does Hedging Aggravate or Alleviate Agency Problems? A Managerial Theory of Risk Management", working paper, University of Minnesota.

[18] DeMarzo, Peter M. and Darrell Duffie, 1991, "Corporate Financial Hedging with Proprietary Information" *Journal of Economic Theory* 53, 261-286.

[19] ——————, 1995, "Corporate Incentives for Hedging and Hedge Accounting" *Review of Financial Studies* 8, 743-771.

[20] DeMarzo, Peter M., Dimtry Livdan and Alexei Tchistyi, "Risking Other People's Money: Gambling, Limited Liability and Optimal Incentives" working paper.

[21] Dodd, Randall, 2009, "Exotic Derivatives Losses in Emerging Markets: Questions for Suitability, Concerns for Stability", IMF working paper.

[22] Duffee, Gregory R. and Chungsheng Zhou, 2001, "Credit Derivatives in Banking: Useful Tools for Managing Risk ", *Journal of Monetary Economics* 48, 25-54.

[23] Duffie, Darrell and D. A. Skeel, 2012, "A Dialogue on the Costs and Benefits of Automatic Stays for Derivatives and Repurchase Agreements ", Working Paper, Stanford University.

[24] Fauver, Larry and Andy Naranjo, 2010, “Derivative Usage and Firm Value: The Influence of Agency Costs and Monitoring Problems”, *Journal of Corporate Finance* 16, 719-735.

[25] Fehle, Frank and Sergey Tsyplakov, 2005, “Dynamic Risk Management: Theory and Evidence”, *Journal of Financial Economics* 78, 3-47.

[26] Froot, Kenneth A., David S. Scharfstein and Jeremy C. Stein, 1989,“LDC Debt: Forgiveness, Indexation and Investment Incentives”, *Journal of Finance* 44, 1335-1350.

[27] ________________, 1993,“Risk Management: Coordinating Corporate Investment and Financing Policies ”, *Journal of Finance* 48, 1629-1658.

[28] Fudenberg, Drew and Jean Tirole, 1990, “Moral Hazard and Renegotiation in Agency Contracts ”, *Econometrica* 58, 1279-1319.

[29] Gao, Huasheng, 2010, “1995 Optimal Compensation Contracts When Managers Can Hedge”, *Journal of Financial Economics* 97, 218-238.

[30] Geczy, Christopher, Bernadette A. Minton and Cahterine Schrand, 1997, “Why Firms Use Currency Derivatives”, *Journal of Finance* 52, 1323-1354.

[31] Geczy, Christopher C., Bernadette A. Minton and Cahterine Schrand, 2007, “ Taking a View: Corporate Speculation, Governanace and Compensation””, *Journal of Finance* 62, 2405-2444.

[32] Haushalter, G. David, 2000, “Financing Policy, Basis Risk and Corporate Hedging: Evidence from the Oil and Gas Producers, *Journal of Finance* 55, 107-152.

[33] Jin, Yanbo and Philip Jorion, 2006, “Firm Value and Hedging: Evidence from U.S. Oil and Gas Producers”, *Journal of Finance* 61, 813-919.

[34] Lessard, Don, 1990, “Global Competition and Corporate Finance in the 1990s”, *Journal of Applied Corporate Finance* 1, 59-72.

[35] Lins, Karl V., Henri Servaes and Ann Tamayo, 2011, “Does Fair Value Reporting Affect Risk Management: International Survey Evidence”, *Financial Management* 525-551.

[36] Nance, Deana R., Clifford W. Smith Jr. and Charles W. Smithson, 1993, "On the Determinants of Corporate Hedging", *Journal of Finance* 48, 267-284.

[37] Neuberger, Anthony, 2001, "Gold Derivatives: The Market Impact", Center for Public Policy Studies, World Gold Council.

[38] Perez-Gonzales, Francisco and Hayong Yun, 2013,"Risk Management and Firm Value: Evidence from Weather Derivatives", *Journal of Finance* 68, 2143-2176.

[39] Petersen, Mitchell A. and Ramu S. Thiagarajan, 2000, "Risk Measurement and Hedging: With and Without Derivatives", *Financial Management* 5-30.

[40] Rampini, Adriano A. and S. Viswanathan, 2010, "Collateral, Risk Management and the Distribution of Debt Capacity", *Journal of Finance* 65, 2293-2322 .

[41] Raposo, Clara C., 1997, "Corporate Risk Management and Optimal Hedging Disclosure", working paper.

[42] Smith, Clifford W. and Rene M. Stulz, 1985, "The Determinants of Firms' Hedging Policies", *Journal of Financial and Quantitative Analysis* 20, 391-405.

[43] Stulz, Rene M., 1984, "Optimal Hedging Policies ", *Journal of Financial and Quantitative Analysis* 19, 127-140.

[44] ———, 1990, "Managerial Discretion and Optimal Financing Policies ", *Journal of Financial Economics* 26, 3-27.

[45] ———, 2003, "Risk Management and Derivatives ", Southwestern College Publishing, Cincinnati, OH.

[46] Tufano, Peter, 1996, "Who Manages Risk? An Empirical Examination of Risk Management Practices in the Gold Mining Industry", *Journal of Finance* 51, 1097-1137.

[47] Tufano, Peter, 1998, "Agency Costs of Corporate Risk Management", *Financial Management* 27, 67-77.

APPENDIX

Proof of Proposition 3

I begin by finding the optimal quantity of derivative bought by the agent given his effort decision is $e = 1$. Given that the contract implements a hedging position in the derivative, the agent maximizes his expected compensation.

$$\begin{aligned} m_e &= \arg\max_m \{(\pi_g + \pi_m)b_H(Y_H - pm)\mathbf{1}_{\tilde{Z}\geq Z_{min}} + (1 - \pi_g - \pi_m)b_L(Y_L + m)\mathbf{1}_{\tilde{Z}\geq Z_{min}} - \psi\} \\ &= \arg\max_m \{(\pi_g + \pi_m)b_H Y_H + (1 - \pi_g - \pi_m)b_L Y_L + m_e(1 - \pi_g - \pi_m)(b_L - b_H) - \psi\} \quad \text{(A.1)} \end{aligned}$$

From the above expression, it follows that the agent will choose the lowest hedging quantity, $m_e = Z_{min} - Y_L$ if the expression $b_L - b_H < 0$. If $b_L = b_H$, the effort agent will be indifferent between derivative quantities within the first-best range $m_e \in \{Z_{min} - Y_L, \frac{Y_H - Z_{min}}{p}\}$ (Refer equation 8). It follows that the agent will choose, $m_e = \frac{Y_H - Z_{min}}{p}$, the upper bound of the first-best range if $b_L - b_H > 0$.

The optimal quantity of derivative for the agent given no effort is obtained by maximizing his total expected compensation. I have used a result from Proposition 4, $b_M = 0$ in order to simplify the exposition of the proof.

$$U_n = \begin{cases} \pi_g b_H Y_H + (1 - \pi_g - \pi_m)b_L Y_L + m_n(1 - \pi_g - \pi_m)(b_L - \frac{\pi_g}{\pi_g + \pi_m} b_H) & \text{if } m_n \in m^{FB} \\ U_{sp} = (1 - \pi_g - \pi_m)b_L(Y_L + m_{alt}) & \text{if } m_n = m_{alt} \\ U_0 = \pi_g b_H Y_H & \text{if } m_n = 0 \end{cases} \quad \text{(A.2)}$$

If $b_L = \frac{\pi_g}{\pi_g + \pi_m} b_H$, then the no-effort agent perceives the derivative as a zero NPV project. The choice $m_n = 0$ is dominated by either of the remaining two choices. Therefore , the no-effort agent will speculate or choose $m_n = m_{alt}$ if m_{alt} is high and $m_n = m^{FB}$ if not. If $b_L < \frac{\pi_g}{\pi_g + \pi_m} b_H$ then the no-effort agent perceives the derivative as a negative NPV project. Therefore, he will choose to either hedge $m_n = m^{FB}$ or not buy the derivative at all $m_n = 0$. If $b_L > \frac{\pi_g}{\pi_g + \pi_m} b_H$

then the no-effort agent will choose to either hedge with the derivative or speculate. He will choose $m_n = m^{FB}$ if m_{alt} is low and will choose $m_n = m_{alt}$ if m_{alt} is high.

Proof of Proposition 4

The proof proceeds in three steps. First I solve for the optimal contract when IR_0 dominates. Second, I solve for the optimal contract when IR_{spec} dominates. Third, I find the cheapest cost contract within the set of optimal contracts.

I begin by noting that $b_M = 0$ is optimal. This relaxes all three constraints and the two IR constraints and does not affect the payoff function of the principal.

Case A: $\frac{1-\pi_g-\pi_m}{\pi_m} < Z_{min} < 1$

First I show that IR_0 and IR_{spec} are slack when IR_0 dominates. IR_0 will dominate under the following condition:

$$(\pi_g + \pi_m)b_H Y_H - \psi \geq (1 - \pi_g - \pi_m)b_L(Y_L + m_{alt}) - \psi$$
$$m_{alt} < \frac{Y_H}{p}.\frac{b_H}{b_L} - Y_L \tag{A.3}$$

Assume that IR_0 is not slack. This leads to the equation, $\frac{b_L}{b_H} = \frac{m_e}{m_e+Y_L}$. This implies $b_H > b_L$. From Proposition 3, we know that $m_e = Z_{min} - Y_L$. This result, equation (A.3) and equation (4) imply that $Z_{min} \geq \frac{(\pi_g+\pi_m)Y_H}{1-\pi_g-\pi_m} + Y_L$. This is a contradiction due to equation (1). Thus, IR_0 is slack.

IR_0 is satisfied if $b_H \leq b_L$. Now, I solve for the optimal contract assuming $b_H = b_L$. The optimal choice of derivative quantity for effort agent is $m_e \in [Z_{min} - Y_L, \frac{Y_H - Z_{min}}{p}]$ (Proposition 3, equation 13). The following condition ensures that IC_{spec} is slack

$$(1 - \pi_g - \pi_m)b_H m_{alt} \leq \pi_g b_H Y_H + \frac{\pi_m}{\pi_g + \pi_m}(1 - \pi_g - \pi_m)m_n b_H$$
$$m_{alt} \leq \frac{(\pi_g + \pi_m)Y_H - \pi_m Z_{min}}{1 - \pi_g - \pi_m} \tag{A.4}$$

When m_{alt} is low such that equations (A.3) and (A.4) are satisfied, IC_{hedge} is binding which

minimizes implementation costs. The optimal choice of the no-effort agent is $m_n = \frac{Y_H - Z_{min}}{p}$. The binding IC constraint is as below:

$$\begin{aligned} (\pi_g + \pi_m)b_H(Y_H - pm_e) &= \pi_g b_H(Y_H - p * m_n) \\ +(1 - \pi_g - \pi_m)b_L(Y_L + m_e) - \psi & \quad +(1 - \pi_g - \pi_m)b_L(Y_L + m_n) \\ b_H &= \frac{\psi}{\pi_m Z_{min}} \end{aligned} \tag{A.5}$$

This derives the optimal contract $b_H = b_L = \frac{\psi}{\pi_m Z_{min}}$. When equation (A.4) is not satisfied, IC_{spec} is binding. The optimal choice of the no-effort agent is $m_n = m_{alt}$. The binding IC constraint is as below:

$$\begin{aligned} (\pi_g + \pi_m)b_H(Y_H - pm_e) &= (1 - \pi_g - \pi_m)b_L(Y_L + m_{alt}) \\ +(1 - \pi_g - \pi_m)b_L(Y_L + m_e) - \psi & \\ b_H &= \frac{\psi}{(\pi_g + \pi_m)Y_H - (1 - \pi_g - \pi_m)m_{alt}} \end{aligned} \tag{A.6}$$

This yields the optimal contract $b_H = b_L = \frac{\psi}{(\pi_g+\pi_m)Y_H-(1-\pi_g-\pi_m)m_{alt}}$.

I solve for the optimal contract when IR_{spec} dominates. When $\frac{Y_H}{p}.\frac{b_H}{b_L} - Y_L < m_{alt} < \frac{Y_H}{p}$, equation (A.3) is not satisfied and IR_{spec} dominates. By the condition on $\frac{1-\pi_g-\pi_m}{\pi_m} < Z_{min}$ and $\frac{Y_H}{p}.\frac{b_H}{b_L} - Y_L < m_{alt}$, IC_{spec} is binding and IC_{hedge} is slack. The optimal choice of the effort agent is $m_e \in [Z_{min} - Y_L, \frac{Y_H - Z_{min}}{p}]$ (From Proposition 3, equation 13). The optimal choice of the no-effort agent is $m_n = m_{alt}$. Equation (A.6) yields the optimal contract $b_H = b_L = \frac{\psi}{(\pi_g+\pi_m)Y_H-(1-\pi_g-\pi_m)m_{alt}}$.

Now, I consider the case when $b_H < b_L$. We know that IR_0 is slack under this condition. Keeping IR_{spec} binding to minimize implementation costs, yields the ratio

$$\frac{b_H}{b_L} = \frac{m_{alt} - m_e}{\frac{Y_H}{p} - m_e} \tag{A.7}$$

From equation (4) we know that the above is strictly less than one. Under this condition, IC_{spec} dominates. I derive this using the above equation (A.7) and the optimal choice of quantity of

the effort agent, $m_e = \frac{Y_H - Z_{min}}{p}$ and the no-effort agent, $m_n = m_{alt}$. Consider the IC constraint, IC_{spec}

$$\begin{aligned}(\pi_g + \pi_m)b_H(Y_H - pm_e) &\geq (1 - \pi_g - \pi_m)b_L(Y_L + m_{alt}) \\ +(1 - \pi_g - \pi_m)b_L(Y_L + m_e) - \psi & \\ (1 - \pi_g - \pi_m)b_H\left(\frac{Y_H}{p} - m_e\right) - \psi &\geq (1 - \pi_g - \pi_m)b_L(m_{alt} - m_e) \qquad \text{(A.8)}\end{aligned}$$

Using equation (A.7), I note that effort cannot be implemented as the above inequality cannot be satisfied. The optimal contract is summarized below:

$$b_H = b_L = \begin{cases} \frac{\psi}{\pi_m Z_{min}} & \text{if } m_{alt} \leq M1 \\ \frac{\psi}{(\pi_g + \pi_m)Y_H - (1 - \pi_g + \pi_m)m_{alt}} & \text{if } M1 < m_{alt} < \frac{Y_H}{p} \end{cases}$$

where, $M1 = \frac{(\pi_g + \pi_m)Y_H - \pi_m Z_{min}}{1 - \pi_g - \pi_m}$.

Proof of Proposition 5

I begin by noting that the principal implements no-effort but the choice of derivative quantity remains with the agent. Thus, the relevant IR constraint of the agent depends on the liquidity of the derivative market. Consider the two participation constraints of the agent:

$$U_n \geq \pi_m b_H Y_H + (1 - \pi_m)b_M(Y_L - L) \qquad \text{(A.9)}$$

$$U_n \geq \pi_m b_M(Y_H - pm_{alt}) + (1 - \pi_g - \pi_m)b_L(Y_L + m_{alt}) \qquad \text{(A.10)}$$

where, $U_n = \pi_g b_H(Y_H - pm) + \pi_m b_M(Y_L - L - pm)\mathbf{1}_{Y_L - L > pm} + (1 - \pi_g - \pi_m)b_L(Y_L + m)$

Consider the case when $Y_L - L \leq pm$. The price of the derivative is obtained by the binding participation constraint of the market-maker.

$$pm\pi_g + \pi_m(Y_L - L) = (1 - \pi_g - \pi_m)m$$

Equations (A.9) and (A.10) can be rewritten as

$$\pi_g b_H(Y_H - pm) + (1 - \pi_g - \pi_m)b_L(Y_L + m) \geq \pi_g b_H Y_H + (1 - \pi_m)b_M(Y_L - L)$$
$$\pi_g b_H(Y_H - pm) + (1 - \pi_g - \pi_m)b_L(Y_L + m) \geq \pi_m b_M(Y_H - pm_{alt}) + (1 - \pi_g - \pi_m)b_L(Y_L + m_{alt})$$

$b_M = 0$ relaxes both constraints and does not affect the principal's payoff when $Y_L - L \leq pm$ is satisfied. Now, consider the participation constraints of the agent. Equation A.9 dominates when $m_{alt} \leq \frac{\pi_g Y_H}{1-\pi_g-\pi_m} - Y_L$. The cheapest cost constraint is $b_H = b_L = 0$. The principal chooses this equilibrium under the following conditions:

$$V \geq \left[1 - \frac{\psi}{\pi_m Z_{min}}\right](Y_L + (\pi_g + \pi_m)\Delta Y)$$
$$V \geq Y_L + (\pi_g + \pi_m)\Delta Y - (1 - \pi_g - \pi_m)L - \frac{(\pi_g + \pi_m)\psi}{\pi_m}$$

The above conditions simplify to

$$\psi \geq \max\left[\frac{\pi_m}{\pi_g + \pi_m}(\pi_m \Delta Y - (1 - \pi_g - 2\pi_m)\Delta Y), \pi_m Z_{min}\frac{\pi_m(\Delta Y - L)}{Y_L + (\pi_g + \pi_m)\Delta Y}\right]$$

where, $\Delta Y = Y_H - Y_L$.

Now, consider the case when $Y_L - L > pm$. The price of the derivative is obtained by the binding participation constraint of the market-maker.

$$pm(\pi_g + \pi_m) = (1 - \pi_g - \pi_m)m$$
$$p = \frac{1}{\pi_g + \pi_m} - 1$$

All other conditions are identical to the equilibrium when price satisfies $Y_L - L \leq pm$.

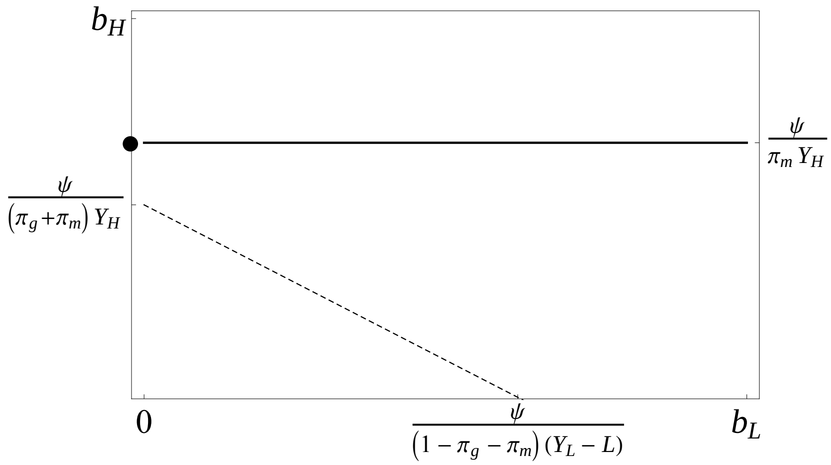

Figure 2: **Illustration of the proof of Proposition 1.** The plot is shown on the (b_L, b_H) plane. The IR constraint is shown by the dashed line. The constraint is satisfied everywhere to the right of the line. The IC constraint is shown by the thick line. Both constraints are satisfied everywhere above this line. The cheapest incentive compatible contract is shown by the black circle at the intersection of the IC constraint and the Y-axis.

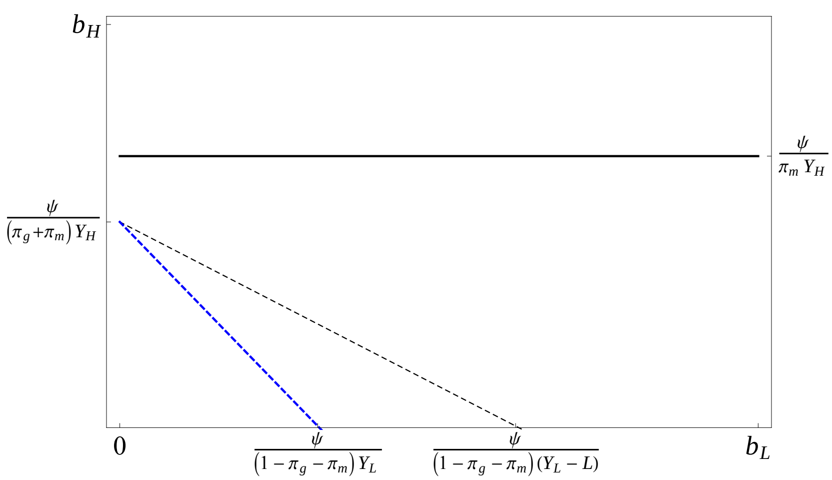

Figure 3: **Illustration of the proof of Proposition 2.** The plot is shown on the (b_L, b_H) plane. The IR constraint is shown by the blue, dashed line. The IC constraint is shown by the thick line. The cheapest incentive compatible contract is shown by the black circle at the intersection of the IC constraint and the Y-axis.

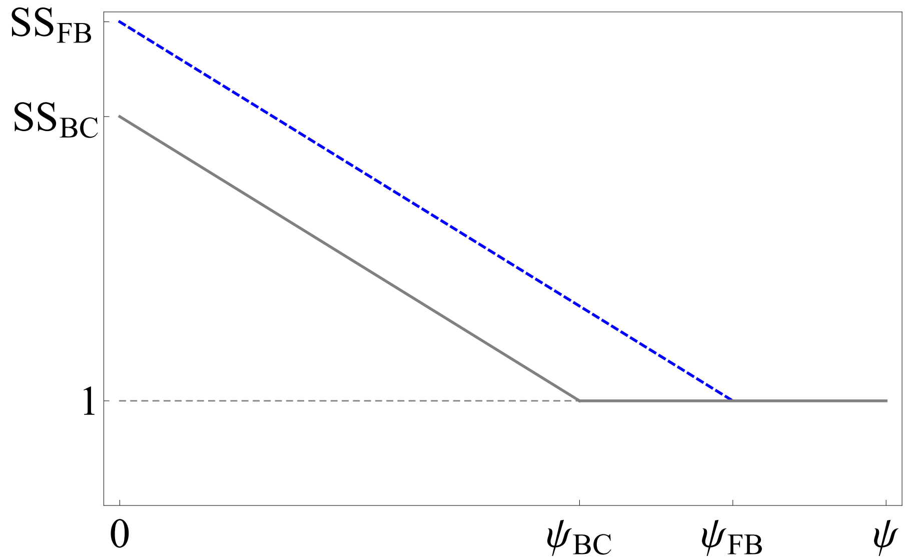

Figure 4: **Plot of social surplus as a function of cost of effort.** The panel plots the social surplus in the Benchmark Case, when the agent does not buy the derivative and the First-Best Case, when the agent buys the derivative and effort and quantity are observable and verifiable; Benchmark Case - Grey Line; First-Best equilibrium - Blue, dashed line; $SS_{FB} = (\pi_g + \pi_m)Y_H + (1 - \pi_g - \pi_m)Y_L$, $SS_{BC} = (\pi_g + \pi_m)Y_H + (1 - \pi_g - \pi_m)(Y_L - L)$.

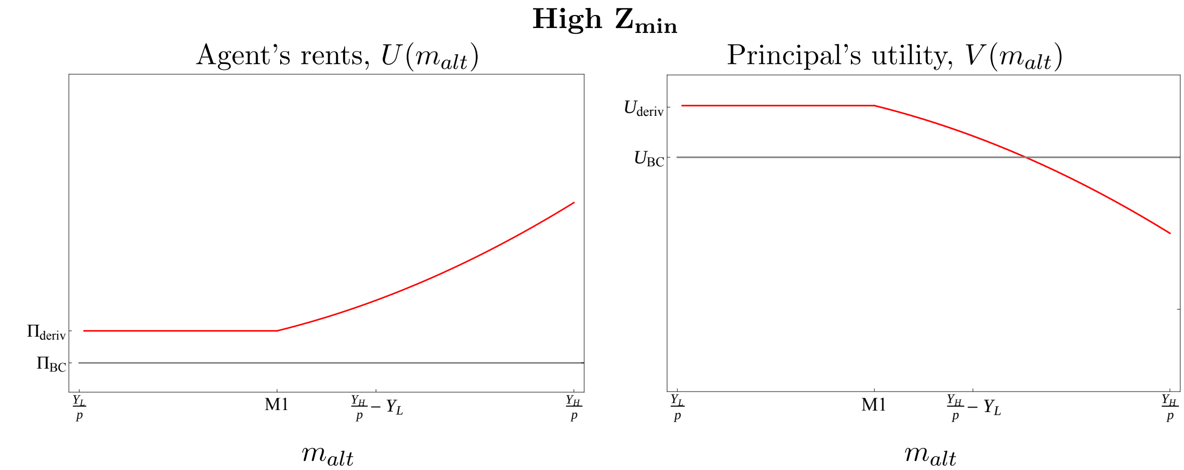

Figure 5: **Plot of agent's rent and principal's utility.** The left panel plots the rent to the agent and the right panel plots the utility of the principal in the second-best equilibrium; Benchmark Case - Grey Line; Second-Best equilibrium - Red Line; $M1 = \frac{(\pi_g+\pi_m)Y_H - \pi_m Z_{min}}{1-\pi_g-\pi_m}$, $\frac{(1-\bar{\pi})Y_L}{\Delta\pi} \leq Z_{min} < 1$, $U_{BC} = Y_L + (\pi_g + \pi_m)\Delta Y - (1-\pi_g)L - \left(1 + \frac{\pi_g}{\pi_m}\right)\psi$, $\Pi_{BC} = \left(1 + \frac{\pi_g}{\pi_m}\right)\psi$, $\Pi_{deriv} = \frac{\psi}{\pi_m Z_{min}}(Y_L + (\pi_g + \pi_m)\Delta Y)$.

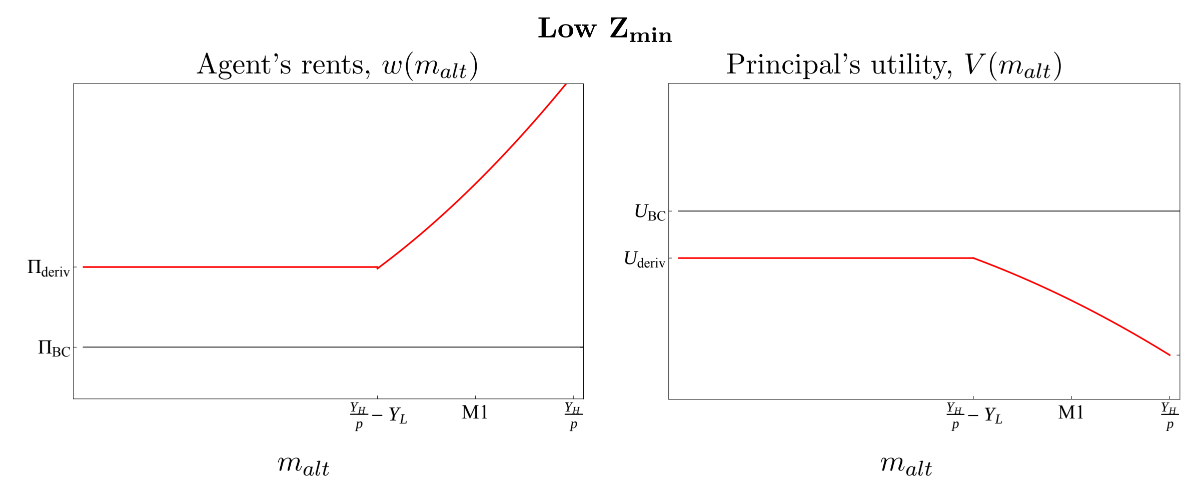

Figure 6: **Plot of agent's rent and principal's utility.** The left panel plots the rent to the agent and the right panel plots the utility of the principal in the second-best equilibrium; Benchmark Case - Grey Line; Second-Best equilibrium - Red Line; $M1 = \frac{(\pi_g+\pi_m)Y_H - \pi_m Z_{min}}{1-\pi_g-\pi_m}$, $Y_L < Z_{min} < \frac{(1-\bar{\pi})Y_L}{\Delta\pi}$, $U_{BC} = Y_L + (\pi_g + \pi_m)\Delta Y - (1-\pi_g)L - \left(1 + \frac{\pi_g}{\pi_m}\right)\psi$, $\Pi_{BC} = \left(1 + \frac{\pi_g}{\pi_m}\right)\psi$, $\Pi_{deriv} = \frac{\psi}{\pi_m Z_{min}}(Y_L + (\pi_g + \pi_m)\Delta Y)$.

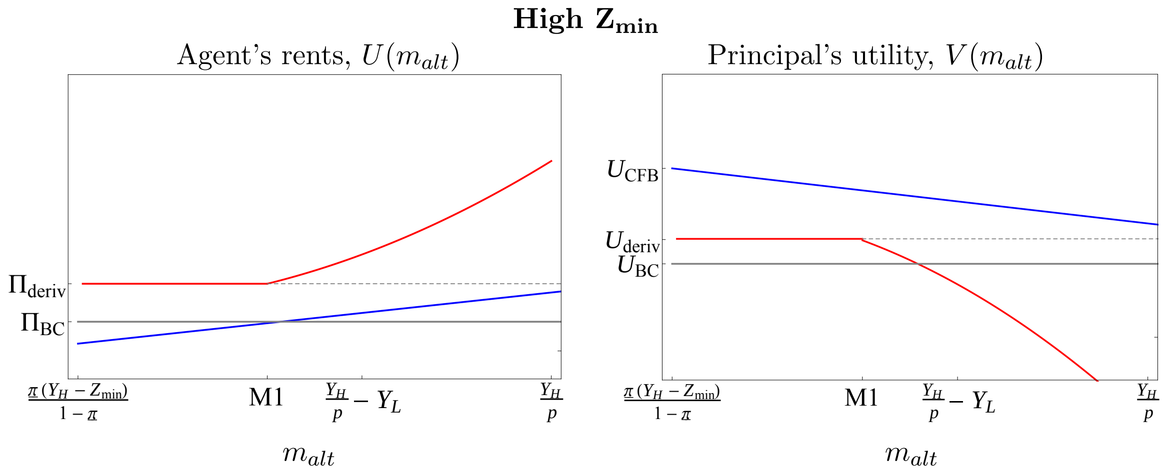

Figure 7: **Plot of agent's rent and principal's utility.** The left panel plots the rent to the agent and the right panel plots the utility of the principal in the second-best equilibrium; Benchmark Case - Grey Line; Second-Best equilibrium - Red Line; $M1 = \frac{(\pi_g+\pi_m)Y_H - \pi_m Z_{min}}{1-\pi_g-\pi_m}$, $\frac{(1-\overline{\pi})Y_L}{\Delta\pi} \leq Z_{min} < 1$, $U_{BC} = Y_L + (\pi_g + \pi_m)\Delta Y - (1-\pi_g)L - \left(1 + \frac{\pi_g}{\pi_m}\right)\psi$, $\Pi_{BC} = \left(1 + \frac{\pi_g}{\pi_m}\right)\psi$, $\Pi_{deriv} = \frac{\psi}{\pi_m Z_{min}}(Y_L + (\pi_g + \pi_m)\Delta Y)$.

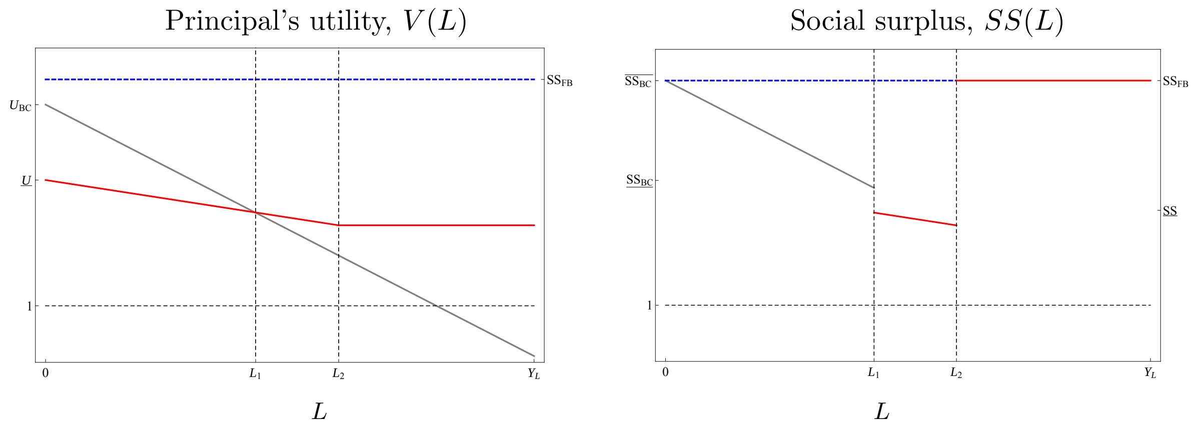

Figure 8: **Plot of principal's utility and social surplus.** The left panel plots the utility of the principal and the right panel plots the social surplus in the no-effort equilibrium; Benchmark Case - Grey Line; First-Best equilibrium: Blue, dashed line; No-effort equilibrium - Red Line; $U_{BC} = \overline{\pi}Y_H + (1-\overline{\pi})Y_L - \frac{\overline{\pi}\psi}{\Delta\pi}$, $\underline{U} = \underline{\pi}Y_H + (1-\underline{\pi})Y_L$, $SS_{FB} = \overline{\pi}Y_H + (1-\overline{\pi})Y_L$.

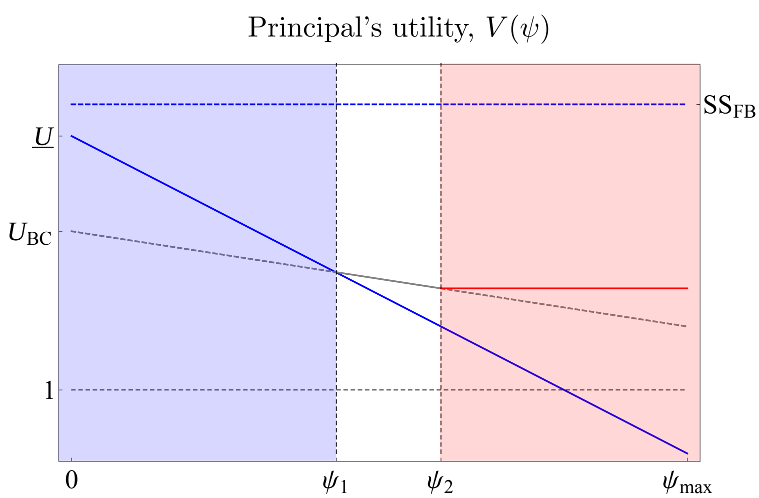

Figure 9: **Plot of principal's utility as a function of cost of effort.** The panel plots the utility of the principal. The blue zone represents the Effort equilibrium and the red zone represents the No-effort equilibrium; Benchmark Case - Grey Line; First-Best equilibrium: Blue, dashed line; No-effort equilibrium - Red Line; $U_{BC} = (\pi_g = \pi_m)Y_H + (1 - \pi_g - \pi_m)Y_L - \left(1 + \frac{\pi_g}{\pi_m}\right)\psi$, $\underline{U} = \underline{\pi}Y_H + (1-\underline{\pi})Y_L$, $SS_{FB} = \overline{\pi}Y_H + (1-\overline{\pi})Y_L$.

Table IV: Sample overview

This table shows summary statistics for 15 North American gold mining companies with (a) financial information for atleast five years prior to 1990 and (b) hedging data from the analyst reports of Haliburton Minerals (www.virtualmetals.co.uk). Panel A presents financial variables. *OROA* is the ratio of operating income before depreciation to assets. *Book leverage* is the ratio of the sum of long-term debt plus existing debt in current liabilities to total assets. *Market leverage* is the the sum of long-term debt plus existing debt in current liabilities divided by the sum of long-term debt and existing debt in current liabilities and the market value of common equity. *M-B ratio or market-to-book ratio* is the ratio of the book value of assets plus the market value of equity minus the book value of common equity and deferred taxes to total assets. *Net debt / assets* is the ratio of book leverage minus cash and marketable securities to total assets. *CAPEX / assets* is the ratio of capital expenditure to total assets. *Investment rate* is the growth rate of total assets. *Net worth* is the book value of assets plus the market value of equity minus the book value of common equity and deferred taxes and long-term debt. *Net Worth / assets* is the ratio of *Net worth* and total assets. *Delta* is the ratio of the change in value of the hedging portfolio over the next three years to the change in value of the expected production over the same time period.

Panel A: Financial Information

Variables	Number of obs.	Mean	Std Dev.	p10	Median	p90
Total assets	522	980	3110	14	118	1982
Revenue	522	349	1049	4	49	726
OROA	522	0.073	0.236	-0.062	0.089	0.236
Book leverage	522	0.169	0.243	0.000	0.124	0.373
Market leverage	397	0.165	0.183	0.000	0.108	0.435
M-B ratio	337	1.935	1.551	0.868	1.606	3.106
Net debt / assets	522	-0.010	0.335	-0.406	0.011	0.301
CAPEX / assets	522	0.109	0.099	0.018	0.085	0.227
Investment rate	522	0.169	0.504	-0.152	0.071	0.519
Net worth	337	2,554	6,806	23	288	7,543
Net worth / assets	337	1.553	1.565	0.408	1.254	2.844

Panel B: Hedging Information

Percentage of production hedged						
One-year forward	432	29.504	53.106	0.000	4.621	93.800
Two-years forward	432	15.641	26.515	0.000	0.000	53.800
Delta	432	18.078	25.863	0.000	6.856	49.045

Table V: Measure of Gold price exposure pre-1999

This table shows the gold price exposure measures. The years over which the firm survives and is present in the sample is provided in the second and third column. The gold price exposure is measured using the regression: $\Delta ln(opin/assets)_{it} = a + b_i * \Delta ln(gold)_t + d_i * \Delta ln(gold)_{t-1} + \epsilon_{it}$ where $opin/assets$ is the ratio of unhedged cash flow from operations to total assets for firm i in quarter t, $\Delta ln(opin/assets)_{it}$ is the change in $opin/assets$ for firm i in quarter t, $gold_t$ is the end-of-quarter spot price of gold and $gold_{t-1}$ is gold price in the quarter preceding quarter t. The sample of firms is divided into two groups based on the magnitude of the coefficient, b_i. The variable $group1$ takes the value one if the coefficient, b_i is not statistically significant.

	First year	Last year	Gold exposure (b_i)	t-stat	group1
ATLAS MINERALS INC	1963	2003	0.6954	4.6911	0
BARRICK GOLD CORP	1983	2012	0.6842	3.8672	0
PLACER DOME INC	1962	2004	0.0963	3.5640	0
HOMESTAKE MINING	1950	2000	0.2458	3.0558	0
HECLA MINING CO	1960	2012	0.3986	1.8477	0
NORTHGATE MINERALS CORP	1966	2010	0.1048	1.6175	1
KINROSS GOLD CORP	1982	2012	0.1153	1.5381	1
CAMPBELL RESOURCES INC	1960	2007	0.1728	1.3973	1
GIANT YELLOWKNIFE MINES LTD	1950	1990	0.1833	1.3088	1
ALTA GOLD CO	1973	1998	0.3979	1.2661	1
AGNICO EAGLE MINES LTD	1973	2012	0.522	0.5652	1
PEGASUS GOLD INC	1982	1997	0.0647	0.2726	1
USMX INC	1980	1996	0.0362	0.2453	1
NEWMONT MINING CORP	1961	2012	0.0006	0.2449	1
ECHO BAY MINES LTD	1982	2001	0.0006	0.2161	1

Table VI: Financing and Investment Policy: Pre-1999

This table examines the impact of gold price exposure on investment and financing policies before the Washington Agreement of 1999. With this agreement, the central banks, which hold close to 85% of the total reserves of gold, agreed not to lend gold or sell gold on the spot market. The dependent variables are (a) *CAPEX / assets* is the ratio of capital expenditure to total assets, (b) *Net debt / assets* is the ratio of book leverage minus cash and marketable securities to total assets and (c) *Book leverage* is the ratio of the sum of long-term debt plus existing debt in current liabilities to total assets. *group2* measures the sensitivity of the firm revenues to gold price. This is an indicator variable which takes the value one if the gold price exposure of the firm is not significant. *Investment rate* is the growth rate of total assets. *Net worth* is the book value of assets plus the market value of equity minus the book value of common equity and deferred taxes and long-term debt. *Ln assets* is the lagged value of total assets. *OROA* is the lagged value of the ratio of operating income before depreciation to total assets. *M-B ratio* is the lagged value of market-to-book ratio. Each regression includes year dummies as controls. Standard errors are clustered at the firm level and are shown in parentheses.

Dependent variables	CAPEX / Assets		Net Debt / Assets		Book Leverage	
	(1)	(2)	(3)	(4)	(5)	(6)
group1	0.0045	0.002	0.012	0.081	0.013	0.006
	(0.017)	(0.016)	(0.092)	(0.072)	(0.038)	(0.035)
Ln assets	-0.006	-0.012**	0.062*	0.017	0.024	0.009
	(0.004)	(0.004)	(0.034)	(0.029)	(0.017)	(0.020)
OROA	0.108	0.058***	-0.339*	-0.096	-0.196	-0.163
	(0.025)	(0.018)	(0.188)	(0.105_	(0.107)	(0.110)
Investment rate	0.060**		0.039		0.005	
	(0.028)		(0.069)		(0.045)	
M-B ratio		0.005		-0.029**		-0.008
		(0.004)		(0.013)		(0.009)
Year controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	402	243	412	244	412	244
R-squared	0.360	0.276	0.190	0.077	0.132	0.186

Table VII: Firm Value and Financing Policy: Around 1999

This table examines the impact of gold price exposure on firm value and financing policies around the Washington Agreement of 1999. With this agreement, the central banks, which hold close to 85% of the total reserves of gold, agreed not to lend gold or sell gold on the spot market. The dependent variables are (a) *M-B ratio* is the ratio of the book value of assets plus the market value of equity minus the book value of common equity and deferred taxes to total assets, (b) *Net debt / assets* is the ratio of book leverage minus cash and marketable securities to total assets and (c) *Book leverage* is the ratio of the sum of long-term debt plus existing debt in current liabilities to total assets. *group1*post* is an indicator variable which takes the value one for all firms with low exposure to gold price and for years after 1999 and zero otherwise. *group1* is an indicator variable which takes the value one for all firms with low exposure to gold price. *Investment rate* is the growth rate of total assets. *Ln assets* is the lagged value of total assets. *OROA* is the lagged value of the ratio of operating income before depreciation to total assets. *M-B lag* is the lagged value of market-to-book ratio. Each regression includes year dummies as controls. Standard errors are clustered at the firm level and are shown in parentheses.

Dependent variables	M-B ratio		Net Debt / assets		Book leverage	
	(1)	(2)	(3)	(4)	(5)	(6)
group1* post	-0.063**	-0.062**	-0.233***	-0.128**	-0.158***	-0.110***
	(0.297)	(0.015)	(0.049)	(0.015)	(0.029)	(0.025)
group1		0.165		0.251		0.869
		(0.096)		(0.363)		(0.655)
Ln assets	-0.249*	-0.009	0.017	0.137	0.002	0.002
	(0.141)	(0.027)	(0.025)	(0.026)	(0.017)	(0.138)
OROA	1.007	-0.003	-0.149*	-0.061	-0.232	-0.075
	(0.677)	(0.148)	(0.069)	(0.187)	(0.140)	(0.129)
Investment rate	-0.148	0.140	0.002	0.011	0.018	-0.013
	(0.122)	(0.140)	(0.053)	(0.096)	(0.038)	(0.077)
M-B lag		0.685***		-0.057***		-0.032*
		(0.006)		(0.014)		(0.007)
Firm controls	Yes	No	Yes	No	Yes	No
Year controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	355	344	518	348	518	348
R-squared	0.315	0.512	0.222	0.082	0.041	0.053

Table VIII: Investment Policy: Around 1999

This table examines the impact of gold price exposure on investment and financing policies around the Washington Agreement of 1999. With this agreement, the central banks, which hold close to 85% of the total reserves of gold, agreed not to lend gold or sell gold on the spot market. The dependent variables are (a) *CAPEX / assets* is the ratio of capital expenditure to total assets and (b) *Cash/assets* is the ratio of cash and short-term securities to total assets. *group1*post* is an indicator variable which takes the value one for all firms with low exposure to gold price and for years after 1999 and zero otherwise. *group1* is an indicator variable which takes the value one for all firms with low exposure to gold price. *Investment rate* is the growth rate of total assets. *Ln assets* is the lagged value of total assets. *OROA* is the lagged value of the ratio of operating income before depreciation to total assets. *M-B lag* is the lagged value of market-to-book ratio. Each regression includes year dummies as controls. Standard errors are clustered at the firm level and are shown in parentheses.

Dependent variables	Capex/assets		Cash / assets	
	(1)	(2)	(3)	(4)
group1* post	-0.005**	-0.006*	0.075**	0.018
	(0.002)	(0.004)	(0.034)	(0.042)
group1		0.002		0.024
		(0.423)		(0.044)
Ln assets	-0.005	-0.009**	-0.015	-0.012
	(0.007)	(0.004)	(0.017)	(0.017)
OROA	0.033**	0.034**	-0.083	-0.014
	(0.015)	(0.015)	(0.074)	(0.085)
Investment rate	0.008*	0.016**	0.017	-0.024
	(0.005)	(0.006)	(0.019)	(0.022)
M-B lag		0.008		0.025*
		(0.006)		(0.013)
Firm controls	Yes	No	Yes	No
Year controls	Yes	Yes	Yes	Yes
Observations	511	347	518	348
R-squared	0.246	0.149	0.352	0.045

Table IX: Hedging Policy: Around 1999

This table examines the impact of gold price exposure on hedging policies around the Washington Agreement of 1999. With this agreement, the central banks, which hold close to 85% of the total reserves of gold, agreed not to lend gold or sell gold on the spot market. The dependent variables are (a) *Delta* is delta of the derivatives portfolio over the next three years divided by the expected gold production over the next three years and (b) *Delta-forwards* is the delta of all forwards and forward-like contracts in the derivatives portfolio over the next three years divided by the expected gold production over the next three years. *group1*post* is an indicator variable which takes the value one for all firms with low exposure to gold price and for years after 1999 and zero otherwise. *Investment rate* is the growth rate of total assets. *Ln assets* is the value of total assets. *OROA* is the value of the ratio of operating income before depreciation to total assets. *Net worth/assets* is the ratio of net worth to total assets where net worth is defined as book value of assets plus the market value of equity minus the book value of common equity and deferred taxes and long-term debt. Each regression includes year dummies and firm dummies as controls. Standard errors are clustered at the firm level and are shown in parentheses.

Dependent variables	Delta		Delta-forwards	
	(1)	(2)	(3)	(4)
group1* post	3.909	10.241	15.042	20.845
	(9.307)	(9.438)	(14.610)	(17.685)
Ln assets	9.645*	10.006*	10.426*	12.542
	(4.725)	(5.021)	(5.75)	(9.099)
OROA	-2.59		11.867	
	(11.51)		(18.211)	
Investment rate	0.178	0.504	-2.001	-2.022
	(2.303)	(2.855)	(3.136)	(3.955)
Net worth / assets		-2.148		1.291
		(3.977)		(4.819)
Firm FE	Yes	Yes	Yes	Yes
Year controls	Yes	Yes	Yes	Yes
Observations	310	310	310	310
R-squared	0.631	0.657	0.488	0.486