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ON RISK MANAGEMENT DETERMINANTS: WHAT REALLY MATTERS?

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ABSTRACT

We investigate the determinants of the risk management decision for an original dataset of North American gold mining firms. We propose explanations based on the firm's financial characteristics, managerial risk aversion and internal corporate governance mechanisms. We develop a theoretical model in which the debt and the hedging decisions are made simultaneously. Our model suggests that more hedging does not always lead to a higher debt capacity when the firm holds a standard debt contract, while hedging is an increasing function of the firm's financial distress costs. We then test the predictions of our model. To estimate our system of simultaneous Tobit equations, we extend, to panel data, the minimum distance estimator proposed by Lee (1995). We obtain that financial distress costs, information asymmetry, separation between the posts of CEO and chairman of the board positions and managerial risk aversion are important determinants of the decision to hedge whereas the composition of the board of directors has no impact in such decision. Also, our results do not support the conclusion that firms hedge in order to increase their debt capacity which seems to confirm our model's prediction.

Keywords: Risk management determinants, corporate hedging, capital structure, managerial risk aversion, gold price, tax incentive, minimum distance estimator, panel data, Tobit, corporate governance.

JEL classification: D80, G10.

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INTRODUCTION

Risk management has received a lot of attention in the financial literature. Several theories have been put forward to explain why and how corporations manage (or should manage) the risks they face [e.g., Stulz (1984); Smith and Stulz (1985); Stulz (1990, 1996); DeMarzo and Duffie (1991); Froot, Scharfstein and Stein (1993); Morellec and Smith (2002), Breeden and Viswanathan (1998) and Carpenter (2000)].

When we look at the different papers that tested empirically the arguments justifying firm's risk management activities, we can classify them into two groups according to the approach used to conduct the tests. A first traditional approach widely adopted consists in a one equation model that considers all other decisions made by the firm as exogenous**.** This approach does not capture the interaction between the different policies adopted within the firm. To overcome this limit, a second approach has been proposed in more recent papers and consists in a system of simultaneous equations that models risk management along with another single decision in the firm. Rogers (2002) and Rajgopal and Shelvin (2002) model the risk management and the CEO risk-taking incentives as simultaneous and provide evidence suggesting that only the hedging decision is affected by the CEO risk-taking incentives tied to options. Based on their evidence, we could claim that these two decisions are not simultaneously set. Graham and Rogers (2002) also apply the simultaneous approach to test the determinants of the risk management decision. Their empirical investigation is motivated by theoretical arguments claiming an endogenous relation between the debt and the risk management policies. Indeed, Smith and Stulz (1985) suggest that the firm's hedge ratio should be an increasing function of the firm's financial distress costs and consequently of its leverage, whereas Stulz (1996) and Leland (1998) suggest that the tax advantage of financing with debt should be greater for firms that manage risk, because risk management can lead to a higher debt capacity. Therefore, one has to model the debt as endogenous when studying the determinants of the risk management decision. Graham and Rogers (2002) and Borokhovich et al (2004) have recently provided empirical support for these hypotheses.

This paper fits into the simultaneous approach framework. We investigate the determinants of the risk management activity under an endogenous debt policy for a sample of North American gold mining firms. Our work differs from that of Graham and Rogers (2002) on four points. First, we conduct our tests using a hand collected panel dataset covering a seven-year period instead of a cross sectional dataset. Our dataset allows us not only to capture differences in risk management policies among firms but also to follow the evolution of this policy over a long period of time. Econometrically speaking, the model we aim to estimate corresponds to two simultaneous Tobit equations with two censored dependent variables and panel data. Estimating such a system is a very challenging task and, to our knowledge, no methodology exists in the literature to do so. We overcome this problem by extending the minimum distance estimator proposed by Lee (1995) to a panel dataset. Such a methodology would be very useful to researchers wishing to estimate different forms of simultaneous equations with panel data.

Second, to measure the firm's hedging activity, we use the delta percentage instead of the value of the net position held by the firm on derivative contracts for non-trading purposes.

The delta percentage, first used by Tufano (1996) and more recently by Dionne and Garand (2003), is defined as the delta of the risk management portfolio held by the firm divided by its expected production. Since a risk management strategy implies decisions concerning both the amount of risk to hedge and the instruments employed to hedge, using the net position as a measure of risk management leads to an information loss regarding the instruments[1]. We think that the delta percentage more suitably describes the firm's risk management activities in the firm because its calculation includes information on both the level of hedging and the types of instruments utilised to hedge.

Third, we propose internal corporate governance characteristics as possible explanations of a firm's risk management policy. We think that corporate governance in general and the composition of the board in particular could explain this policy. Indeed, Borokhovich et al (2004) and Whidbee and Wohar (1999) have reported evidence suggesting that the proportion of unrelated directors is positively related to the firm's use of interest rate derivatives**.** These findings are consistent with hedging in the interests of shareholders. However, we know that at least some of the firm's risk management activity is designed to maximise the manager's utility rather than the firm's value. Tufano (1996) and more recently Pertersen and Thiagarajan (2000) have confirmed this hypothesis for the gold mining industry. Also, the recent scandals reported in the financial press clearly showed that the board of directors is not always the watchdog that it is supposed to be. Since hedging usually involves off-balance operations, manipulating the firm's hedging activities is often easier than manipulating the firm's accounting measures. We are therefore inclined to think that managers who are also chairmen of the board and those facing a weaker board would increase their risk management level if this activity enhanced their utility.

Fourth, we propose a theoretical model where the debt and the risk management decisions are set simultaneously as a background for our empirical investigation. Our model suggests that, under a standard debt contract, hedging is always an increasing function of the firm's financial distress costs but that it does not always lead to a higher debt capacity. Interestingly, our empirical evidence shows that the effect between these two decisions goes in only one direction not as reported in Graham and Rogers (2002) and more recently by Borokhovich et al (2004). This finding partially supports the prediction of our theoretical model.

It is also worth noting that in the case of the gold mining industry there is mixed evidence as to the validity of the theoretical arguments explaining the risk management policies. Indeed, Tufano (1996) claims that firms hedge mainly to increase the manager's utility whereas Dionne and Garand (2003) report evidence validating the maximisation of the firm's value argument. In order to check the robustness of our findings to the debt endogeneity hypothesis, we run regressions for both the single and the simultaneous models.

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[1] The problem with the value of the net position held by the firm on derivative contracts for non-trading purposes is that it does not distinguish between the different derivative contracts and may lead to conclude that a firm having a $90 millions long position in options and a $50 millions short position in futures-a net position of $40 millions- is having the same risk management strategy as a firm having a long position of $40 millions only in the forward markets.

Our results suggest that financial distress costs, informational asymmetry and managerial risk aversion do affect the risk management strategy even when we control for the endogenous relation between the risk management and the debt decisions. This statement does not hold for the tax and size arguments. Also, the composition of the board of directors seems to play no active role in decisions on risk management policy, whereas CEOs who are also chairmen of the board hedge more with financial instruments. These findings are partially consistent with hedging to enhance the manager's utility.

The remainder of the paper is divided into six sections. Section 1 proposes a theoretical model where the debt and the hedging decisions are simultaneously made as well as the hypothesis drawn from the model. Section 2 describes our sample and the different variables we use in the analysis. In section 3, we explain the methodology we propose to estimate our system of simultaneous equations with panel data. Section 4 reports the results of the univariate analysis while section 5 presents the results for the multivariate analysis. We report results for two models: one where the debt is set exogenous and one where the debt is endogenized. Section 6 concludes the paper.

1. THE ENDOGENOUS RELATION BETWEN RISK MANAGEMENT AND DEBT

Froot, Scharfstein and Stein (1993) argue that (1) if financial distress is costly and (2) if debt provides a fiscal advantage or a reduction in agency costs, risk management can be used to increase the debt capacity. The argument that risk management can affect the debt policy can also be found in Stulz (1996), Leland (1998) and Graham and Rogers (2002). In this section we propose a theoretical model that considers simultaneously the hedging and borrowing decisions. Our model extends the general framework of costly state verification developed by Townsend (1979) and Gale and Hellwig (1985)[2]. Indeed, we consider two random variables along with two decisions variables: F the face value of debt or the amount to be paid to creditors, and h the hedge ratio. Unlike Froot, Scharfstein and Stein (1993), we do not focus on the way investment policy is financed but rather on the simultaneous decision making of the hedging and borrowing policies for a given investment decision. This model will serve as a theoretical background to the empirical tests conducted later in the paper.

A. The model

We focus on linear hedging strategies because they are more popular in hedging commodity risk[3]. We assume that the mining firm produces gold and holds another asset or commodity whose price cannot be hedged by derivative instruments or insurance policies. The firm's revenues will depend mainly on the gold return but also on the return generated by the second asset. We design the model in such a way that both revenues can be correlated. The firm's total revenue *w* is modeled as follow:

[2] This model is also in the spirit of Caillaud, Dionne and Jullien (2000).

[3] The 1998 Wharton survey of financial risk management by US non-financial firms indicates that "options are generally less popular than forwards in the FX area, swaps in the IR area and futures in the CM area…..FX options were the most common, used by 44% of derivatives-using firms, while IR and CM were used by just 28% of derivatives-using firms".

$$w = w_0\left[h + (1-h)x\right] + y \tag{1}$$

where w_0 corresponds to the firm's revenues from gold in certainty, x to the random gold return[4], h to the hedge ratio, and y to the random revenue generated by the second asset in place. To simplify the presentation, we define y as equal to $\alpha x w_0$ where α is a measure of the correlation between both revenues. The firm must choose simultaneously the level of hedging h and the face value of its debt F in order to maximise the following program[5]:

$$\underset{F,h}{Max}\int_{x_F}^{+\infty}\left[w_0\left[h+(1-h)x\right]+\alpha x w_0 - F\right]g(x)dx \tag{2}$$

under the financial constraint:

$$\int_{-\infty}^{x_F}\left[w_0\left[h+(1-h)x\right]+\alpha x w_0 - c\right]g(x)dx + F\left[1-G(x_F)\right] \geq D(1+r) \tag{3}$$

where:

D is the amount of debt contracted by the firm,
c are the audit costs paid by creditors in the bankruptcy states,
r is the interest rate during the period,
$g(x)$ and $G(x)$ are respectively the density and cumulative distribution function of x. To make things simple, we assume that x is distributed normally with a mean of 1 and a standard deviation of σ[6],
x_F is defined such that $w_0\left[h+(1-h)x_F\right]+\alpha x_F w_0 - F = 0$ and corresponds to the minimal value of x that allows the firm to avoid bankruptcy.

The maximization problem in (2) and (3) yields the following first order conditions (See Appendix I for details) with λ corresponding to the Lagrange multiplier for (3):

[4] For a gold mining firm, w_0 corresponds to the current forward price of gold multiplied by the total production of the firm while x corresponds to the ratio of the revenues obtained if the production is sold later on the spot market divided by the revenues obtained if the production is sold at the current forward price.

[5] In this case we consider the amount of debt and not the form of the debt contract as endogenous which means that the firm chooses strategically its hedging ratio and the face value of its debt under a standard debt contract.

[6] This hypothesis was first proposed by Froot, Scharfstein and Stein (1993) to get an analytical expression for h^*. It implies that the expected level of revenues will not be affected by the hedging decision.

$$
\begin{cases}
\lambda = \dfrac{1-G(x_F)}{1-G(x_F)-cg(x_F)\dfrac{1}{w_0(1-h+\alpha)}} \\
\lambda = \dfrac{w_0\sigma^2}{w_0\sigma^2 - c\dfrac{F-w_0(1+\alpha)}{w_0(1-h+\alpha)^2}}
\end{cases} \tag{4}
$$

The first equation in (4) looks familiar; it resembles the condition for a standard debt contract. According to these equations λ will be greater than 1 (a standard result for a debt contract) as long as $1\text{-h}+\alpha > 0$ and $F - w_0(1+\alpha) > 0$. In the following, we limit our analysis to the standard debt contract by assuming that these two conditions are satisfied. Solving for F^* and h^* by equating both equations yields:

$$
\begin{cases}
h^* = 1+\alpha - \dfrac{1}{\sigma^2}\left[\dfrac{1-G(x_f)}{g(x_f)}\right]\left[\dfrac{F^* - w_0(1+\alpha)}{w_0}\right] \\
F^* = w_0\left[1+\alpha+\sigma^2\dfrac{g(x_f)}{1-G(x_f)}(1-h^*+\alpha)\right]
\end{cases} \tag{5}
$$

According to equation (5), the firm's optimal hedge ratio is increasing in σ^2 and in the hazard rate $\dfrac{g(x)}{1-G(x)}$. Let's suppose for the moment that α =0 (the firm generates its revenues only from the selling of gold and therefore has just one source of uncertainty affecting its revenues). In this case, for a given F^*, the optimal hedge ratio h^* will be lower than 1.

This result does not confirm Froot, Scharfstein and Stein (1993) conclusion that the optimal hedge ratio will be equal to one when the firm has a single source of risk. This can easily be explained by the difference in the settings of the two models. Recall that in the Froot, Scharfstein and Stein (1993) the firm captures the total benefit of hedging because it hedges only its internal revenues, whereas, in our model the firm hedges its total revenues and therefore does not fully capture the benefits of hedging. Indeed, the firm hedges both the part of its revenues it keeps and the part it reimburses to the creditors which means that a fraction of the hedging benefits will be captured by the creditors. Therefore, in our case the firm will be less inclined to set its hedge ratio at the maximum (full hedging).

More generally, when $\alpha < 0$ the optimal hedge ratio will be lower than in the $\alpha = 0$ case, meaning that firms having negatively correlated revenues will benefit from a natural hedging that decreases their need for hedging with derivatives. We can also show that when $\alpha > 0$, the optimal hedge ratio will be greater than in the previous two cases and can even be greater than 1.

Equation (5) shows that F^*, the face value of a standard debt contract is increasing in σ^2 and in the hazard rate. Also, for a fixed value of the hazard rate, F^* is a decreasing function of h^*. This means that if the default intensity were independent from the level of hedging and debt, firms that hedge more would be able to reduce the face value of their debt. This result confirms the argument that hedging could increase the firm's debt capacity. However, the default intensity (the hazard rate) is usually not constant and we can even verify that it is increasing in x when the latter is normally distributed. Therefore, the relation between hedging and debt will not be as obvious. Equation A3 in Appendix I shows that under the standard debt contract, a higher hedging level will decrease the firm's face value. However, since firms will be able to contract more debt – because they reimburse less per dollar borrowed- they can end up with a higher default intensity and face value for their debt. This will yield to an indirect second positive effect between hedging and debt making the relation between both variables not obvious.

Using the conclusions provided by our model we can now enunciate two hypotheses that we will test in the empirical section when the debt is set endogenous:

Hypothesis 1: *The firm's hedging ratio is an increasing function of the firm's default intensity. Since financially distressed firms support higher distress costs we should observe a positive relation between h (the hedge ratio) and the firm's financial distress costs.*

Hypothesis 2: *The firm's hedge ratio has two opposite effects on the debt face value. We will investigate empirically the net effect for the gold mining industry.*

2. SAMPLE CONSTRUCTION AND VARIABLES

A. The delta percentages

The initial data on the delta percentages comes from Dionne and Garand (2003). They document 898 quarter-company risk management observations (the delta percentages) relative to 45 North American gold mining companies over the 1992-1998 period. We first updated their sample by including data relative to the 1999 year. The information used to calculate the delta percentages was gracefully provided by Ted Reeve, a Canadian analyst specializing in the gold mining industry[7]. The delta percentage for a given quarter is the fraction of the planned gold production that is being hedged over the next three years. To obtain the delta percentage for each firm-quarter, we first have to calculate the deltas of each instrument that is used to hedge the production over the next three years. Each delta is then multiplied by the ounces of gold that are covered by the corresponding instrument, so as to obtain what Tufano (1996) calls the delta ounces. Then, we have to take the sum of the different delta ounces in order to obtain the delta of the hedge portfolio held by a firm. Finally, we calculate the delta percentage as the delta of the hedge portfolio divided by the

[7] For a number of years, Ted Reeve published quarterly reports containing detailed three-year information on hedging activities for North American gold mining firms over the future three years.

expected gold production over the same three years that are used for the hedge variable[8]. As Table I shows, the delta percentage is highly dispersed among firms which motivate the analysis of its determinants. Most firms composing our sample have delta percentages ranging between 0 and 50%, which indicates that these firms use derivative hedging mainly to reduce gold price risk rather than to speculate. Table II also suggests that the risk management activity becomes more popular as we approach the end the 1990s. This is probably caused by the growing popularity of the derivatives market over the same period.

(Insert Tables I AND II)

B. The sample

For each firm-quarter observation, we collected data from COMPUSTAT Quarterly on the firm's market value, leverage, liquidity, acquisition expenses, operating income, selling and general expenses, depreciation and amortization as well as on the book value of its property, plant and equipment and sales. The data relative to the firm's operating cash cost and exploration expenditures was hand collected from quarterly reports. Data on directors and officers shareholdings and options holdings, the percentage of shares owned by institutions, the board size and composition were hand collected from the proxy statements and annual reports. Some of the companies in our initial sample had to be dropped because they had been acquired, had filed for bankruptcy or simply because their management was unable to locate the proxy statements or quarterly reports for the fiscal years we requested[9]. Our proxy for taxable income is taxable accounting earnings before extraordinary items and discounted operations. This input is needed to construct the taxsave and the marginal tax rate variables. Our final sample consists of 485 quarter-company observations relative to 36 North American gold mining companies: 25 Canadian and 11 US. It ranges over the period running from January 1993 to December 1999.

C. The Variables in the risk management equation

C.1. Unobservable Imperfections: information asymmetry

Stulz (1990) claims that firms will manage risk to decrease cash flow volatility because it reduces one of the costs related to managerial discretion in the presence of information asymmetry about the managerial actions**.** DeMarzo and Duffie (1991) confirm that a risk management strategy can be profitable for shareholders faced with information asymmetry about the dividend stream. Breeden and Viswanathan (1998) also consider asymmetric information as a determinant of hedging. The asymmetry in their case concerns the competence level of management; here, risk management can reduce the noise in the learning process concerning the managers' capacities. In this case, risk management is a signal of a manager's quality and superior ability. DeMarzo and Duffie (1995) show that even if the information asymmetry concerns the source and magnitude of the risks the firm

[8] For more details concerning the construction of the delta percentage, see Tufano (1996).
[9] We needed data from proxy statements and quarterly reports ranging from January 1991 to December 1999. These documents were unavailable on EDGAR (for US firms) or SEDAR (for Canadian firms) for many cases, especially in SEDAR where data is not available before January 1997. We had to contact the firms and ask them to send us their proxy statements and quarterly reports for the quarters we needed.

faces rather than the manager's ability, risk management does benefit shareholders and increases the value of the firm. As in Graham and Rogers (2002), we measure informational asymmetry by the percentage of shares held by institutions. Indeed, institutions are very exigent shareholders who typically have privileged access to management information and facilitate its processing in the financial markets. Therefore, we expect a negative coefficient for this variable.

C.2. Observable Imperfections

Taxes: The tax argument introduced by Smith and Stulz (1985) suggests that in the presence of a convex tax function, hedging reduces the variability of the firm's pre-tax value and its tax liability because it locks the taxable earnings in a predefined level. This prediction is confirmed by results reported, among others, in Nance, Smith and Smithson (1993).

We measure the tax function's convexity using a modified version of the simulation approach proposed by Graham and Smith (1999)[10]. We expect a positive relation between this variable and the delta percentage when the debt decision is set exogenous. Things will be less obvious when the debt decision is endogenous because debt provides also a tax advantage than can make tax savings generated by hedging less significant. We calculate the tax savings resulting from a five percent reduction in the volatility in order to be consistent with the empirical findings reported in Guay (1999). Unfortunately, it is impossible for us to construct the tax save variable on quarterly basis so we calculate it on an annual basis and suppose that it is constant for the four quarters of the year. For each firm-year t observation, we first collect all available data on taxable incomes from COMPUSTAT annual files for previous years, in order to calculate the drift μ_i and the volatility of the innovations on a rolling historical basis. Next, using the drift and volatility estimates, we generate for each US firm a normal variable ε with 18 realisations (15 years to account for carry forwards and 3 years to account for carry backs). In the United Stated, since late 1998, a net operating loss can be carried back 2 years and forward 20 years. However, because our sample ranges mainly from 1991 to 1998, we use the old legislation that allows firms to carry back losses for 3 years and forward for 15 years. For Canadian firms, we generate a normal variable with only 10 realisations because the Canadian legislation allows firms to carry back net operating losses for 3 years and forward only for 7 years only. Then, we use the normal variables generated to simulate taxable incomes from t+1 to t+18 for US firms and from t+1 to t+10 for Canadian ones. Taxable income for firm i in year t (TI_{it}) is supposed to follow a random walk variable as follows:

$$\Delta TI_{it} = \mu_i + \varepsilon_{it}$$

[10] Graham and Smith (1999) treat Canadian and US firms drawn from COMPUSTAT identically by applying the American legislation and tax code to their whole sample. We think that it is more appropriate to use the legislation of its original country for each firm. Graham and Smith (1999) also repeat the procedure 50 times only, which could be insufficient when dealing with simulations. Therefore, we repeat our simulation 1000 times.

Next, we calculate the tax liability for each firm in each year t using the simulated future taxable incomes and historical taxable incomes for year's t-3, t-2 and t-1. For each firm, we consider the tax plan corresponding to its home country. We then suppose a five-percentage decrease in the volatility calculated in the first step and recalculate the tax liability. The tax save variable is calculated as the difference between the tax liability paid in the full volatility case, and the tax liability paid in the reduced volatility case. We perform this procedure 1000 times for each firm in each year. The expected tax savings are then obtained by averaging the 1000 tax save values calculated. As in Graham and Rogers (2002), we scale the expected tax saving by the sales in the regression analysis.

Financial Distress Costs: Under the financial distress argument first proposed by Smith and Stulz (1985), hedging increases shareholders' wealth because it decreases the expected value of direct bankruptcy costs and the loss of the debt tax shield. As in Tufano (1996), we measure financial distress costs with two variables: cash cost and leverage. Cash costs measures the operating costs of producing one ounce of gold, excluding all non-cash items such as depreciation, amortisation and other financial costs. The second variable used is leverage measured as the book value of the long-term debt divided by the firm's market value. We should observe a positive relation between the delta percentage and both variables measuring the financial distress costs.

Firm size: We use the natural logarithm of the firm's sales revenues to control for firm size. If the risk management costs are proportional to the firm's size as stated in Smith and Stulz (1985), small firms should hedge more and we should obtain a negative coefficient for this variable. However, if the risk management costs are fixed, larger firms might hedge more especially when these costs are substantial.

Investment Opportunities: Froot, Scharfstein and Stein (1993) argue that when external financing is more costly than internal financing, firms with attractive investment opportunities will adopt higher risk management levels to ensure the availability of more internally generated funds. They present the risk management strategy as a tool to reduce the under investment problem. Morellec and Smith (2002) also argue that when managers have control over the financial policy, their incentive to hedge increases with the firm's investment opportunities. In their model, hedging has two opposite effects on manager's risk shifting incentive: (1) first hedging decreases the firm's free cash flow level and therefore constrains the manager's investment policy in the short run, (2) second hedging decreases the firm's financial distress costs and improves its credit risk which leads to an increase in the investment level in the long run. This second effect of hedging tends to dominate the first as the number of investment opportunities increases. Consequently, the manager's incentives to hedge would be positively associated with the number of growth options available in the firm. The positive relation between the firm's investment opportunities and its risk management activities was confirmed by results reported in Nance et al (1993); Géczy et al (1997); Gay and Nam (1999) and Knopf, Nam and Thornton (2002).

Our proxies for the firm's investment opportunities are the exploration expenditures and the acquisitions expenditures both scaled by the firm's market value. In fact, gold mining companies can decide to expand either internally by exploring new mines or externally by acquiring already existing mines. If firms use risk management to ensure internally generated funds to pursue those activities, we should observe a positive relation between the delta percentage and these two variables.

C.3. Managerial Risk Aversion

Stulz (1984) and Smith and Stulz (1985) were among the first to discuss managerial risk aversion as a possible explanation for risk management. According to Smith and Stulz (1985), a manager will hedge less as long as his expected utility is a convex function of the firm value, even if his expected utility is a concave function of his personal wealth. Though, managers with large holdings in options will seek more risk than the ones with no, or small options holdings. On the other hand, compensation packages that lead to a concave function between the manager's expected utility and the firm's value will encourage managers to hedge more. Consequently, managers holding a significant fraction of the firm's shares would search more hedging. Tufano (1996), Rajgopal and Shelvin (2002) and Rogers (2002) show that the hedging level is a decreasing function of managers' options holdings. These results seem to confirm the robustness of the Stulz (1984) and Smith and Stulz (1985) models. However, Carpenter (2000) argues that option compensation does not automatically lead to more risk seeking. Under some conditions, giving risk adverse managers more options incite them to reduce the firm value volatility and thus adopt higher levels of risk management. This prediction is confirmed by results reported in Knopf, Nam and Thornton (2002), and explains the positive relation between option detentions and hedging reported in Géczy et al (1997) and Gay and Nam (1999).

We measure managerial risk aversion by two variables: the value of the common shares owned by directors and officers at the quarter end, and the number of options held by directors and officers[11,12].

C.4. Other control variables

Corporate governance variables: In some cases, managers hedge more, not in order to decrease the firm's financial distress costs, tax liability or underinvestment costs but simply to increase their own utility. This situation is more likely to occur when managers have greater discretionary power to make sub optimal decisions from a shareholder perspective. Unrelated directors and the separation between the CEO and the chairman of the board

[11] Unfortunately, we were unable to get any information on option holdings on a quarterly basis and we just assume that the number of options owned by directors and officers to be constant through over the fiscal year. This hypothesis does not seriously violate the reality since firms usually wait for fiscal year end performance to determine the number of options it will grant to its directors and officers.

[12] We did not use the sensitivities of D&O option portfolio to stock return and stock return volatility (the Delta and Vega of the option portfolio) as proxies for managerial risk aversion because of data limitation. Also, recall that the Core and Guay (2002) method relies on the dividend-adjusted Black & Scholes model to estimate the sensitivities of the D&O option portfolio to stock return and stock return volatility. As stated in Rajgopal and Shevlin (2002), the partial derivatives used to calculate the sensitivities, likely overstates the real values of the ESO risk incentive (Vega) and the ESO wealth effect (Delta). Consequently, we use the value of common shares owned by directors and officers, and the number of options held by directors and officers as proxies for managerial risk aversion. We are aware that those variables have their own limitations but we think they still represent acceptable proxies of managerial risk aversion.

responsibilities are usually adopted as mechanisms to limit the managerial discretion. These mechanisms are supposed to lead to an optimal level of hedging. In this sense, Borokhovich et al (2004) report a positive relation between the number of outside directors on the board and the quantity of interest rate hedging held by the firm. We use two variables as proxies for internal corporate governance mechanisms: the number of unrelated directors as a percentage of the board size and a dummy variable equal to 1 if the CEO is also the chairman of the board[13]. If the coefficients of the two variables proxying for internal corporate governance mechanisms are respectively positive and negative, the evidence would be consistent with corporate hedge in the interest of shareholders.

Financial slack: Derivatives and gold loans are not the only tools firms can employ to manage gold price risk. Indeed, instead of hedging price risk with financial instruments, gold mining firms can simply decide to support themselves the losses caused by an adverse movement in the gold market. Usually, firms that decide to retain their own losses will form liquidity cushions intended to facilitate such retention. Consequently, the existence of the financial slack should be negatively associated with the level of risk management through financial instruments. Nance, Smith and Smithson (1993) and Tufano (1996) have reported empirical results that support such a hypothesis for models where the debt decision is set exogenous. However, this negative relation might disappear in a model where the debt decision is set endogenous particularly if the additional financial slack comes from the firm's credit line. We include the quick ratio in the regression to proxy the firm's financial slack and we expect a negative coefficient for this variable at least when the debt decision is set exogenous. The quick ratio is defined as the value of the cash on hand, short term investments and clients' accounts divided by the short term liabilities.

Finally, we include a dummy variable equal to 1 if the firm is US to control for the firm's nationality.

D. Variables in the debt equation

The dependent variable in the debt specification is leverage measured as the book value of long-term debt divided by the firm's market value. We incorporate the delta percentage as an independent variable. A positive and significant coefficient will confirm Graham and Rogers (2002) findings and indicate that firms hedge in order to increase their debt capacity. However, the results drawn from our theoretical model suggest that hedging will not lead to a higher debt capacity if the second effect (an increase in the default intensity) prevails or is significant enough to neutralize the first one (a decrease of the firm's risk). Therefore, we can not predict a sign for the delta percentage coefficient.

The other independent variables are standard in the literature (e.g., Titman and Wessels (1988)). For example, we use the book value of property, plant and equipment divided by the book value of total assets as a proxy for the *firm's collateral value*, on the grounds that firms with more tangible assets can use them as collateral to contract more debt. Hence, we expect a positive coefficient for this variable. Our proxy for the *non-debt tax shield* is depreciation and amortisation divided by the book value of total assets. We expect a

[13] Refer to Table III for a complete description of how we define a director as unrelated.

negative coefficient for this variable because tax deductions provided by depreciation and amortisation can be substitutes to the tax advantage generated by debt.

The third variable used in the debt equation is the marginal tax rate (MTR)[14]. We expect a positive coefficient for this variable because a higher MTR will mean a higher *tax advantage for financing with debt*. In the debt equation, we also include the exploration and acquisitions expenditures of the firm scaled by its market value as proxies for the *firm's growth opportunities*. We expect a negative coefficient for both variables. According to Titman and Wessels (1988), growth opportunities cannot be collateralised nor will they generate tax deductions, causing firms with important growth opportunities to carry less debt in their capital structure. The variable we incorporate as a proxy for the *firm uniqueness* is its selling, general and administrative expenses divided by its net sales. We expect a negative sign for this variable. Our debt specification also contains a proxy for *size*: the natural logarithm of the firm's sales revenues. Big firms are supposed to be more diversified and therefore less likely to suffer from financial distress. This argument suggests that bigger firms should be more leveraged. Furthermore, larger firms can benefit from economies of scale and issue long-term debt at lower costs than smaller firms. Larger firms should then carry more long-term debt than smaller ones. We also control for the *firm's profitability* because profitable firms generate more internal funds and are supposed to need less external financing by debt or equity. Our proxy for profitability is the firm's operating income divided by the value of its sales. We expect a negative coefficient for this variable. The volatility of the percentage change in the operating income of the firm is also included in the debt specification. This variable is used as a proxy for the *firm's operating risk* and we expect a negative coefficient for it. Firms with a high operating risk are supposed to carry less debt in order to lower their financial risk and keep their total risk at a reasonable level. Finally, we include a dummy variable in the debt equation to control for the *firm's nationality*.

Table III summarizes the different variables used in the regression analysis.

(Insert Table III)

3. METHODOLOGY

We use a Tobit model to estimate the single equation model in order to account for the censoring of the dependent variable. Moreover, our sample consists of panel data and we had to choose between a random effect and a fixed effect specification. We opted for a random firm effect model because the fixed effect specification suffers from the incidental parameters problem described by Neyman and Scott (1948). Indeed, Greene (2002) shows that the incidental parameters problem does not lead to biased estimates of the slope in the

[14] Graham (1996) defines the marginal tax rate as the expected value of additional taxes paid on an additional dollar of income earned today. We construct the marginal tax rates for the firms in our sample with a procedure similar to the one we used for the tax save variable. In this case, we do not reduce volatility by 5 percent to calculate the new tax bill, we simply add 1 dollar to the taxable income of year t for which we want to compute the MTR, we then calculate the new tax bill. The MTR is defined as the difference between the new and the old tax bill.

case of a Tobit specification, but does cause a downward bias in the estimated standard deviations. Such problem might lead to erroneous conclusions concerning the statistical significance of the variables used in the regressions. Since we are more interested in testing the significance rather than the economic impact of each theory, we opted for the random firm effect Tobit specification.

The estimation of the model where the debt is set endogenous does however present some econometric challenges. In fact, the system consists of two simultaneous equations with two censored dependent variables. Also, recall that our sample consists of panel data. Unfortunately, we were unable to find in the literature an estimation procedure for a system similar to ours. We propose to use the minimum distance estimation technique (MDE hereafter) originally proposed by Amemiya (1978) because, in our case, it is a suitable technique that provides unbiased and consistent estimates of the system structural form coefficients when the error terms in the equations might be correlated. Lee (1995) applies the MDE to a system of three simultaneous equations with respectively a censored, a dichotomous and a regular dependent variable. However, his procedure can only be applied to cross sectional data. We extended Lee's reasoning to develop our methodology and obtain estimates of the coefficients for the two equations of our system.

Econometrically speaking, the system structural form (SF) can be written as:

$$\begin{cases} y_{1it}^{*} = \alpha_{12} y_{2it}^{*} + X'_{1it}\beta_1 + u_{1i} + e_{1it} \\ y_{2it}^{*} = \alpha_{21} y_{1it}^{*} + X'_{2it}\beta_2 + u_{2i} + e_{2it} \end{cases} \tag{6}$$

where y_{1it}^{*} and y_{2it}^{*} are respectively the risk management level and the long-term debt level targeted by the firm, X_{1it} and X_{2it} are ($k_1 \times 1$) and ($k_2 \times 1$) vectors of exogenous variables (including a constant term) supposed to affect respectively the risk management and the debt decisions. The terms u and e correspond respectively to the random firm effect and error components. α's and β are parameters to be estimated. Only maximum (y_{1it}^{*},0), maximum (y_{2it}^{*},0), X_{1it} and X_{2it} are observed. We assume that (u_{1i}, u_{2i}) and (e_{1it}, e_{2it}) are respectively jointly normally distributed with a zero mean and that $\alpha_{12} \times \alpha_{21} \neq 1$.

The system reduced form (RF) can be derived as (see Appendix II for details):

$$\begin{cases} y_{1it}^{*} = X'_{it}\eta_1 + l_{1i} + \gamma_{1it} \\ y_{2it}^{*} = X'_{it}\eta_2 + l_{2i} + \gamma_{2it} \end{cases} \tag{7}$$

where X'_{it} is a vector containing all the exogenous variables in the system such that $X'_{it} = [X'_{1it}, X'_{2it}]$, η_1 and η_2 are the reduced form parameters vectors, l_{1t} and l_{2t} are the reduced form random firm effects; and γ_{1it} and γ_{2it} are the error terms. Let's define $\Delta = 1 - \alpha_{12} \times \alpha_{21}$. We can show that: $\eta_1 = \begin{bmatrix} \beta_1 / \Delta \\ \beta_2 \alpha_{12} / \Delta \end{bmatrix}$, $\eta_2 = \begin{bmatrix} \beta_1 \alpha_{21} / \Delta \\ \beta_2 / \Delta \end{bmatrix}$, and

$$\begin{cases} l_{1i} = \frac{1}{\Delta} u_{1i} + \frac{\alpha_{12}}{\Delta} u_{2i} \quad ; \quad l_{1i} \sim N(0, \theta_1^2) \\ l_{2i} = \frac{\alpha_{21}}{\Delta} u_{1i} + \frac{1}{\Delta} u_{2i} \quad ; \quad l_{2i} \sim N(0, \theta_2^2) \\ \gamma_{1it} = \frac{1}{\Delta} e_{1it} + \frac{\alpha_{12}}{\Delta} e_{2it} \quad ; \quad \lambda_{1it} \sim N(0, \sigma_1^2) \\ \gamma_{2it} = \frac{\alpha_{21}}{\Delta} e_{1it} + \frac{1}{\Delta} e_{2it} \quad ; \quad \lambda_{2it} \sim N(0, \sigma_2^2) \end{cases}$$

The first step of the MDE procedure consists in estimating the reduced form parameters. In our case, each equation in the reduced form corresponds to a random firm effect Tobit model. We estimate the equations by the Maximum Likelihood method. This step provides us with estimates of etas (η), thetas (θ) and sigmas (σ). Next, the relationships between the reduced form and the structural form parameters are used to formulate the following restrictions:

$$\begin{cases} \eta_1 = \alpha_{11} \eta_2 + J_1 \beta_1 \\ \eta_2 = \alpha_{21} \eta_1 + J_2 \beta_3 \end{cases} \tag{8}$$

where J_1 and J_2 are the exclusion matrices constructed such as: $X'_{it} J_1 = X'_{1it}$ and $X'_{it} J_2 = X'_{2it}$. These restrictions are used to recover consistent but inefficient estimates of the structural form parameters. To do so, we replace η_1 and η_2 by $\hat{\eta}_1$ and $\hat{\eta}_2$ obtained from step one, add an error term ω_k (k=1,2) to each equation in (8) and then apply OLS. The last step of the procedure consists in calculating a variance-covariance matrix based upon the effective scores for ETAs from each reduced form equation, and use it as a weighting matrix to get efficient estimates of the structural form parameters. Lee (1995) defines the effective score for ETAs as the residual of regressing the score for the ETA on the score of the error term standard deviation. In our case, the score for the error term standard deviation will be a matrix with two elements: one is corresponding to the score for θ (the standard deviation of the random firm effect) and one is corresponding to the score for σ (the standard deviation of the error term). The effective score calculation requires the computation of the log likelihood derivatives w.r.t η, θ and σ which could be a very long and difficult task to achieve. To overcome this problem, we first construct the log likelihood function corresponding to a random firm effect Tobit model and then evaluate the derivatives numerically using the derivative definition. Numerical integration is done using the Gauss-Hermite quadrature rule. The log likelihood function of a random firm effect Tobit model is presented in Appendix III. The effective scores for ETAs are then multiplied by the inverted information matrix and used, along with the inefficient estimates of the structural form parameters obtained from the previous step, as inputs to calculate the variance covariance matrix. Finally we estimate the whole system by a procedure analogous to a SURE method.

4. UNIVARIATE ANALYSIS

Tables IV and V report the descriptive statistics for the main independent variables used in the regression analysis as well as some statistical tests. We break the sample down into three groups according to the level of the risk management adopted by the firm. The first group uses no risk management (delta percentage equal to 0%), the second group uses moderately risk management (delta percentage between 0^{+}% and 50%) and the third group uses extensively risk management (more than 50%). The last four columns in Table V report the p-values corresponding to the t-test of the differences in means between the groups (column 10 and 11), and the significance level of the non parametric Wilcoxon rank sum test for differences between the median of the groups (12 and 13). The p-values reported in column (10) of Table V, show that firms using an extensive level of risk management are very different from those with no risk management activities. Indeed, the firms in the extensive level group have higher financial distress costs measured both by leverage and cash cost, carry less liquidity and have lower institutional shareholding than those using no risk management. They are also twice as large in terms of sales revenues and three times as large in terms of market value. And, the managers of the extensive risk management group have a larger equity stake value in the firm and hold more options. This is possibly due to the larger size of these firms. In fact, larger firms are more likely to suffer from agency costs generated by conflicts of interests between managers and shareholders, because their activities are more complex to monitor. Therefore, larger firms have a greater incentive to offer their managers compensation packages containing stocks and options in order to align their interests with those of the shareholders. Another possible explanation is that larger firms are more difficult to manage and consequently their managers deserve higher compensations. Interestingly, despite their large size, the firms in the extensive group, compared to those in the no-risk management group, do not seem to spend significantly more money on acquisition and exploration activities. The Wilcoxon rank sum test results reported in column (12) confirm the conclusions drawn for the financial distress costs, liquidity, institutional shareholding and managerial shareholding and options holdings. However, the median differences between the two variables measuring size are not significant suggesting that an important risk management program is not exclusive to large firms.

An inspection of the second column of p-values reported in Table V (column 11) suggests that firms using extensive levels of risk management have higher cash cost, are larger in terms of market value and sales revenues and carry less liquidity than the firms using moderately risk management. As predicted, the managers of the firms in the extensive risk management group have a greater equity stake value in the firm, fewer unrelated directors on their board and less institutional shareholding. Interestingly, managers in the extensive group hold more options which would confirm the prediction of Carpenter's (2000) model that managers holding more options do not necessarily hedge less. The results of the non parametric Wilcoxon rank sum test reported in column (13) suggest that firms managing extensively risk might be less efficient at the operational level (higher cash cost is), might explore more and might carry less liquidity (as predicted). The conclusion concerning the manager's stake value and options holdings, the composition of the board and the institutional shareholding remain unchanged. One interesting result shown with this test is that firms that would enjoy a greater tax advantage from hedging do not necessarily hedge more.

(Insert Tables IV and V)

Overall, the results reported in Table V suggest that firms in the three groups exhibit different characteristics. The risk management level adopted by a firm seems to be affected by the managerial risk aversion measured both by the value of common shares and the number of options held by managers. The existence of financial slack also seems to lead to less risk management by financial instruments. And, some financial characteristics, such as size and financial distress costs, seem to affect the risk management decision. Finally, taxes do not seem to affect the hedging decision. Since the results reported in Table V have a univariate aspect and do not control for other potential determinants, we conduct a multivariate analysis in the next section

5. MULTIVARIATE ANALYSIS

A. Results for the single equation model

Empirical evidence reported in Tufano (1996) shows little support for financial theories that view the maximization of the firm's value as a rationale for risk management. However, his evidence supports theories that link managerial risk aversion to the hedging decision. In this section, we report the regression results for a single equation model. As in Tufano (1996), we investigate the determinants of the risk management decision for a dataset of North American gold mining firms. However, we employ quarterly rather than annual data over a longer period of time (seven years instead of three). Using quarterly data allows a greater number of observations and produces results that suffer less from problems related to small sample size. Also, such data make it possible to capture more adequately the dynamic aspect of the risk management decision. We also report results for a Tobit model in order to gauge the impact of the estimation method and compare our results with Tufano's (1996)[15]. This section will allows us to check the validity of the theoretical arguments presented in the literature without imposing any hypothesis on the debt decision.

The results obtained with a Tobit model are reported in column A of Table VI. Both variables used as a proxy for managerial risk aversion have the predicted sign and are respectively significant at the five and ten percent level. This result confirms Tufano's (1996) conclusion that managerial risk aversion is an important determinant of the risk management decision, and Smith and Stulz's (1985) prediction that, paying managers with

[15] We also tried to run regressions with a random effect Tobit model using only the end-of the year hedge ratios in annual tests. Unfortunately, given the small sample size in this case, the random effect model does not converge.

shares will push them to manage more risks whereas paying them with options will lead them to seek more risk. However, according to the reported results, the only argument related to the maximisation of the firm's value that affects the risk management decision is the reduction of the financial distress costs. Thus, firms do not manage risk in order to reduce their tax liability nor to ensure more internally generated cash flows for investment purposes. Neither does size seem also to have any effect on such decision. Moreover, according to the coefficients and p-values reported in column A of Table VI, firms carrying financial slack do less hedging with financial instruments whereas those suffering from serious informational asymmetry will be more active in managing the risks they face.

Overall, the results reported in column A support Tufano's (1996) conclusions and suggest that risk management activities are in large part adopted to maximize the manager's utility.

Column B of Table VI reports results obtained using the same model, but with a random firm effect Tobit specification. This specification is more appropriate for our dataset. Unlike the results reported in Column A, the variables proxying the tax advantage of hedging and size are significant at the ten and five percent level respectively, suggesting that firms manage risk in order to decrease their tax liability, and are more willing to do so when they are large. The positive coefficient observed for the natural logarithm of the firm's sales confirms Haushalter (2000) findings that larger firms hedge more. The high costs of risk management can explain why larger firms hedge more. Recall that risk management involves hiring financial specialists to implement strategies and handle sophisticated financial instruments. These activities are usually very expensive and small firms might not be able to afford them. In a consistent fashion, the variables relative to the managerial risk aversion have the predicted sign and are both significant at the five percent level as in Tufano (1996). This result confirms that managerial risk aversion does have a considerable effect on risk management decisions. The institutional shareholding variable has a negative and significant coefficient at the five percent level confirming that reducing information asymmetry costs is also a motive for managing risk. The results reported in column B of Table VI also confirm that firms with large financial slack hedge less with financial instruments.

Both variables used as proxies for internal corporate governance mechanisms have an insignificant coefficient. These results suggest that combining the CEO and the chairman of the board positions has no effect on a firm's risk management activities and this contradicts Borokhovich et al (2001) conclusion that the board of directors plays an active role in the decision making of such policy. These findings are very interesting especially in light of the growing debate concerning how effective corporate governance mechanisms are in solving the agency problem in public firms. Thus far, we have reported evidence showing that risk management increases the firm's value through different mechanisms. Consequently, one would expect firms with more efficient boards (boards with many unrelated directors) to have higher levels of risk management, since it is to the advantage of shareholders. The insignificant coefficient we report for the board variable suggest that unrelated directors are not acting in the benefit of the shareholders because they do not try to increase the firm's value through risk management. A plausible explanation for the observed passivity of unrelated directors is that they lack the background needed to understand the risk management activities in the firm and have less information about such policies than inside directors. Consequently, the presence of unrelated directors on the board would not affect the risk management policy, not because unrelated directors are unwilling to act for the benefit of shareholders but because they are simply unable to understand this complicated activity. This argument is supported by the findings of Buckley and Van Der Nat (2003) who report a disturbing level of ignorance concerning risk management activities among unrelated directors. Finally, the two variable proxying the financial distress costs have a positive and significant coefficient at the five percent level suggesting that firms manage risk to reduce costs resulting from operational and financial efficiencies.

Roughly speaking, the results presented in column B show that, when we take into account the panel aspect of the data, some variables relative to the maximization of the firm’s value argument do become statistically significant. The results suggest that managers hedge, not only to maximise their utility, but also to maximize the firm’s value by reducing its financial distress costs, its tax liability and costs related to informational asymmetry. A firm’s risk management activity also appears to be positively related to its size confirming the cost argument already mentioned by Stulz (1996). Our results also support the conclusion Dionne and Garand (2003) draw concerning the relevance of maximization the firm’s value argument in explaining risk management activities.

(Insert Table VI)

B. The results with an endogenous debt decision

Table VII reports the results for the simultaneous equations system. Column (A) contains the estimated coefficients for the hedging equation. Interestingly, both leverage and cash cost maintain a positive and significant coefficient at the five percent level suggesting that, even when we control for the endogenous relation between debt and risk management, firms hedge in order to reduce their financial distress costs. This result confirms the first hypothesis provided by our theoretical model. The managerial risk aversion argument proposed by Smith and Stulz (1985) is also supported since the coefficients of the two variables used to proxy it have the predicted sign and are significant at the five percent level. Besides this, the results in Table VII suggest that firms manage risk in order to reduce the costs of informational asymmetry. Risk management activities seem also to be more important in firms where the CEO is also the chairman of the board. This last finding is consistent with the argument that risk management can lead to an increase in the manager’s utility. As in Tufano (1996), one of the variables proxying the firm’s investment opportunities (acquisition in our case) is negatively related to risk management. This finding is apparently counterintuitive and contradicts the hypothesis that firms set up risk management programs to ensure more internally generated funds for investment purposes. However, this result is not surprising if we take into account the negative relation that might exist between the acquisition activities and the gold price. Indeed, gold mining firms would find it less profitable to acquire new mines when the price of gold is not high enough to cover the acquisition costs. Therefore, acquisition expenditures would be lower in periods of a bearish gold market, while firms would be more tempted to hedge in this kind of market. Unfortunately, the weak significance level of this variable and the insignificant coefficient reported for the exploration variable provide little support for this argument. Also, when we endogenize the debt decision, the board of directors has no active role in setting the risk management policy; hence, the tax and size arguments loose their explanatory power. The coefficient of the quick ratio is positive and significant suggesting that risk management with financial instruments and liquidity cushions are not necessarily substitutes when the debt is set endogenous. Finally, risk management seems to be more popular among US than Canadian firms. This might be caused by the greater liquidity of the gold derivatives market in the US[16]. Indeed, it is obvious that corporate hedging would be more important in liquid markets with a wide choice of instruments and a lower cost of hedging.

(Insert Table VII)

The estimated coefficients for the debt equation are shown in column B of Table VII. First, the coefficient of the delta percentage is positive but not significant indicating that firms do not necessarily hedge to increase their debt capacity as reported in Graham and Rogers (2002). In comparison with the results from the risk management equation, it seems that the relation between debt and risk management goes mainly in the direction of firms hedging in order to decrease the financial distress costs caused by leverage, rather than firms managing risk in order to increase their debt capacity. This result also provides some support for the second hypothesis drawn from our theoretical model (Equation A3 in Appendix I). Indeed, out model shows that hedging has two opposite effects on the firm's debt level and we were unable to determine which effect actually prevails. In the gold mining industry, it would seem that both effects are equivalent and almost neutralize each other resulting in an insignificant effect of hedging on the debt level.

Second, the debt level is negatively related to the firm's uniqueness supporting the hypothesis that unique firms are more difficult to evaluate and consequently are less able to get debt financing. Also, the coefficient obtained for the firm's operating income suggests that the firm's profitability does not automatically lead it to reduce its financing with debt. Indeed, a firm can increase its debt level even if it has important funds generated from its operations because of the several advantages provided by this source of financing i.e. the tax advantage, the reduction of internal agency costs and the additional control imposed to managers…etc. This situation is more likely to occur when the firm has low leverage, which is the case in our sample. The results also show that debt is positively related to the firm's exploration expenditures, whereas the coefficient for the book value of property, plant and equipment is not significant. This might indicate that financial markets reply more on the cash flows from exploration activities than on physical assets, when lending money to gold mining firms. Also, the debt level in gold mining firms seems to be positively related to the riskiness of their operational activities. Finally, the results suggest that US firms are more highly leveraged than their Canadian counterparts.

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[16] For example, according to the triennial Central Bank Survey of Foreign Exchange and Derivatives Market Activity published by the BIS, the total notional value of gold derivatives outstanding in Canada as of March 1995 is 4.6 billions of USD while the corresponding amount for the US is 34.1billions of USD. Unfortunately, the figures for the commodity derivatives were not available in the 1998 survey. Instead, we report the average daily turnover reported for the OTC derivatives market as of April 1998: 33.6 billions of USD for Canada and 293.8 billions of USD for the US.

Overall, the results presented in this section show that even when we control for the endogenous relation between the risk management and the debt decisions, firms hedge in order to reduce their financial distress and informational asymmetry costs, and to increase their manager's utility. The tax and size arguments loose their explanatory power. When we endogenize the debt decision, the board of directors has no active role in the risk management decision whereas having the CEO and the chairman of the board positions filled by the same person does lead to a higher risk management level. Furthermore, Graham and Rogers' (2002) findings that risk management increases the firm's debt capacity are not supported for the gold mining industry.

6. CONCLUSION

Recent empirical work by Grahams and Rogers (2002) and Borokhovich et al (2004) combined with theoretical models already proposed by Stulz (1996) and Leland (1998) show the need to model the debt as endogenous when studying risk management determinants.

This paper extends this literature. We first propose a theoretical model where the debt and the risk management decisions are set simultaneously as a background for our empirical tests. Our model suggests that, under a standard debt contract, hedging has two opposite effects on the firm's debt level which means that it will not always lead to a higher debt capacity.

We then run empirical tests to investigate risk management determinants. We construct a database that contains detailed quarterly information on risk management operations, as well as financial and managerial characteristics for a sample of 36 North American gold mining firms over a seven years period. We also use the simulation procedure proposed by Graham and Smith (1999) to construct a variable that captures adequately the tax incentive to hedge for both US and Canadian firms. In fact, Graham and Smith (1999) apply the American fiscal code to both US and Canadian firms in COMPUSTAT, which would provide inadequate estimates of the tax incentive to hedge for Canadian firms. We overcome this problem by constructing for each firm a tax save variable that uses the legislation of its home country.

We first run regressions for a single equation model in order to compare our results to previous work within the gold mining industry and to isolate how they are related to the debt endogeneity hypothesis. In this case, we provide evidence confirming Tufano's conclusion that managerial risk aversion is an important determinant of the risk management strategy. Moreover, our evidence shows that the financial distress costs, the information asymmetry costs, size and taxes are also important determinants of the decision to hedge. Unlike Tufano (1996), our findings suggest that risk management is an activity that not only maximizes the managerial utility but also the firm's value as stated in Dionne and Garand (2003). However, hedging to finance investment opportunities seems to be irrelevant as a motive. The reported results also support the argument proposed by Stulz (1996) alleging that risk management is an expensive activity that small firms might not be able to afford. Interestingly, the composition of the board of directors seems to have no impact on the decision to hedge, no more than does not separating between the CEO and the chairman of the board positions.

In a second step, we test empirically the predictions of our theoretical model. To do so, we use a simultaneous equations system and extend the minimum distance estimator proposed by Lee (1995). Our conclusions remain unchanged for the arguments related to information asymmetry, financial distress costs and managerial risk aversion. However, when we endogenize the debt decision, taxes and size no longer constitute motives for the firm to hedge, and the non separation between the CEO and the chairman of the board positions does seem to have some impact on setting risk management policies. An important implication of our empirical evidence is that firms do not use hedging to increase their debt capacity as stated in Graham and Rogers (2002) but mainly to reduce their financial distress costs.

TABLE I: DESCRIPTIVE STATISTICS FOR THE DELTA PERCENTAGE

The delta % is the fraction of the gold production that is hedged over the next three years. It is our measure of the firm's risk management activity. This table reports the descriptive statistics of the delta percentage.

Delta % (1993-1999)	Number of observations
Exactly 0	88
0 - 0.1	125
0.1- 0.2	89
0.2-0.3	59
0.3-0.4	32
0.4-0.5	23
0.5-0.6	29
0.6-0.7	16
0.7-0.8	12
0.8-0.9	6
Over 0.9	29
Number: 508 **Mean:** 0.2451 **Median:** 0.1381 **Standard deviation:** 0.2808	

TABLE II: DISTRIBUTION OF THE DELTA PERCENTAGE OVER THE SAMPLE PERIOD

This table reports the distribution of the delta percentage over the years as well as the descriptive statistics for each year.

Year Delta%	Number of observations	Mean	Median	Standard deviation
1993	16	0.0233	0.0000	0.0448
1994	50	0.1992	0.0777	0.3003
1995	52	0.1632	0.0754	0.2618
1996	55	0.1886	0.1076	0.2446
1997	108	0.2374	0.1692	0.2342
1998	123	0.3068	0.2309	0.2864
1999	105	0.3058	0.1854	0.3209

TABLE III: SUMMARY OF THE VARIABLES USED IN THE ANALYSIS

What we want to measure	How we measure it
The risk management activity	The delta of the risk management portfolio held by the firm divided by its expected gold production.
The financial distress costs	The book value of the firm's long term debt divided by its market value.
	The operating cost of producing one ounce of gold, excluding all non-cash items such as depreciation, amortization and other financial costs
The Informational asymmetry	Percentage of shares held by institutions
The tax advantage of hedging	The tax savings resulting from a five percent reduction in the volatility of the taxable income. This variable is constructed using a modified version of the Graham and Smith (1999) approach
Size	The natural logarithm of the firm's sales revenues
The firm's market value	The number of common shares multiplied by their unit market price plus the number of preferred shares multiplied by their value at par plus the book value of debt.
The firm's investment opportunities	The firm's exploration expenditures scaled by the firm's market value
	The firm's acquisitions expenditures scaled by the firm's market value
Managerial risk aversion	The number of common shares held by D&O multiplied by their market price
	The number of options held by D&O
Independence of the board	The number of unrelated directors as a percentage of the board size and a dummy equal one if the CEO is also the COB. A director is defined as unrelated if he is independent of the firm's management and free from any interest and any business or relationship that could be perceived to affect its ability to act as a director with a view to the best interests of the firm, other than interests arising from shareholdings. A director who is a former employee of the firm is defined as related.

The firm’s liquidity	The quick ratio defined as the value of cash on hand, short term investments and client’s accounts divided by the short term liabilities.
The firm’s collateral value	The book value of property, plant and equipment divided by the book value of total assets.
The non debt tax shield	Depreciation and amortization divided by the book value of total assets.
The tax advantage of debt	The firm’s marginal tax rate defined as the additional taxes paid on an additional $ of income.
The firm’s uniqueness	Selling, general and administrative expenses divided by the net sales.
The firm’s profitability	Operating income scaled by the firm’s sales
The firm’s operational risk	The volatility of the % change in the operating income.
Nationality	A dummy equal 1 if the firm is US, 0 if it is Canadian.

TABLE IV: DESCRIPTIVE STATISTICS FOR THE INDEPENDENT VARIABLES

In this table, Tax save is the fiscal benefit from reducing the firm earnings volatility by five percent, scaled by the firm sales revenues; Leverage is the book value of the long term debt divided by the firm's market value; Cash cost is the operating cost of producing an ounce of gold, excluding all non cash items such as depreciation, amortisation and other financial costs; Sales are the firm's sales at the end of the quarter; VM is the firm's market value defined as the number of common shares multiplied by their price at the end of quarter plus the number of preferred shares issued multiplied by their value at par plus the book value of debt; Exploration and Acquisition are respectively the exploration and acquisition expenditures during the quarter both scaled by the firm's market value; the quick ratio is the value of the cash on hand, short term investments and clients accounts divided by the short term liabilities; Institutional shareholding is the percentage of shares held by institutions; D&O CS Value is the value of the common shares owned by the firm's directors and officers and is calculated by multiplying the number of CS they hold by the share price at the quarter end; D&O nber of options is the number of options held by directors and officers at the quarter end; % of unrelated is the number of unrelated directors divided by the board size. BV of pp&eq is the book value of property, plant and equipment scaled by the book value of total assets; Dep&Amt is depreciation and amortisation during the quarter scaled by the book value of total assets at the quarter end; MTR is the simulated marginal tax rate; Sgl&Adm is the Selling, general and administrative expenses during the quarter divided by the net sales of the firm during the same quarter; Operating income is the Operating income during the quarter scaled by the firm sales; Volatility of % change in OI is the volatility of the percentage change in the quarterly operating income.

Variable	*N*	*Mean*	*Median*	*Standard-deviation*
Cash cost	516	247	239	61.7266
Tax save	494	0.1381	0.0371	0.2822
Leverage	506	0.1186	0.0842	0.1271
Ln (Sales)	513	3.3220	3.1247	1.3674
Acquisition	517	0.0119	0.0000	0.0774
Exploration	517	0.0037	0.0022	0.0088
Quick ratio	517	3.1937	2.2022	3.0946
Institutional shareholding	517	0.1766	0.0000	0.2536
D&O CS Value	517	16.9145	2.3021	46.8042
D&O nber of options	517	0.8844	0.4715	1.4494
% of unrelated	517	0.7018	0.7143	0.1580
Operating income	513	-0.0761	0.1797	1.1046
Sgl&Adm	513	0.1483	0.1105	0.1854
Volatility of % change in OI	485	12.9680	2.1128	125.3759
Dep & Amt	516	0.0181	0.0152	0.0176
BV of pp&eq	516	0.6187	0.6463	0.1713
MTR	497	0.1578	0.1625	0.1248

TABLE V: UNIVARIATE ANALYSIS

This table reports univariate analysis for the variables proposed to explain the risk management decision. The sample is segmented according to the risk management level adopted by the firm. The first group uses no risk management, the second group uses moderately risk management and the third group uses extensively risk management. The last four columns report p-values corresponding to the t-test of the differences of means between the groups and the significance level of the non parametric Wilcoxon rank sum test. The significant values at the 95% level are in bold. All independent variables are measured one quarter prior to the quarter in which the risk management information is available. In the Table, delta % is the fraction of the gold production that is hedged for the three future years; Tax save is the fiscal benefit from reducing the firm earnings volatility by five percent, scaled by the firm sales revenues; Leverage is the book value of the long term debt divided by the firm's market value; Cash cost is the operating cost of producing an ounce of gold, excluding all non cash items such as depreciation, amortisation and other financial costs; Sales are the firm's sales at the end of the quarter; VM is the firm's market value defined as the number of common shares multiplied by their price at the end of quarter plus the number of preferred shares issued multiplied by their value at par plus the book value of debt; Exploration and acquisition are respectively the exploration and acquisition expenditures during the quarter both scaled by the firm's market value; the quick ratio is the value of the cash on hand, short term investments and clients accounts divided by the short term liabilities; Institutional shareholding is the percentage of shares held by institutions; D&O CS Value is the value of the common shares owned by the firm's directors and officers and is calculated by multiplying the number of CS they hold by the share price at the quarter end; D&O nber of options is the number of options held by directors and officers at the quarter end; % of unrelated is the number of unrelated directors divided by the board size.

	Delta =0% None (1)			**Delta between 0-50% Moderate (2)**			**Delta > 50% Extensive (3)**			**p-values of differences**			
										Mean		**Median**	
	mean	**Std dev**	**med**	**mean**	**Std dev**	**med**	**mean**	**Std dev**	**med**	**(1) vs. (3)**	**(2) vs. (3)**	**(1) vs. (3)**	**(2) vs. (3)**
Delta %	0	0	0	0.167	0.126	0.138	0.757	0.190	0.703				
Tax save	0.171	0.229	0.070	0.114	0.163	0.059	0.148	0.392	0.017	0.633	0.424	**0.000**	**0.000**
Leverage	0.088	0.105	0.040	0.118	0.124	0.094	0.137	0.135	0.086	**0.007**	0.227	**0.001**	0.291
Cash cost ($US/ oz)	232	50	221	245	60	240	265	69	250	**0.000**	**0.017**	**0.001**	**0.028**
Sales ($US, millions)	41	57	15	67	83	35	92	122	17	**0.000**	0.067	0.117	0.313
VM ($US, millions)	790	1200	381	1337	1691	681	2601	3932	360	**0.000**	**0.003**	0.192	0.149
Acquisition	0.002	0.014	0	0.013	0.080	0	0.016	0.105	0	0.225	0.798	0.113	0.852
Exploration	0.003	0.003	0.002	0.004	0.004	0.003	0.005	0.019	0.001	0.404	0.510	0.123	**0.004**
Quick ratio	4.547	3.818	3.402	3.093	2.947	2.194	2.512	2.736	1.834	**0.000**	**0.080**	**0.000**	**0.030**
Institutional shareholding	0.284	0.298	0.199	0.169	0.261	0	0.091	0.134	0	**0.000**	**0.000**	**0.000**	0.090
D&O CS Value ($US, millions)	3.463	5.288	0.947	9.924	21.081	2.621	56.587	94.252	4.339	**0.000**	**0.000**	**0.000**	**0.053**
D&O nber of options (millions)	0.436	0.520	0.330	0.853	1.667	0.421	1.390	1.224	0.679	**0.000**	**0.001**	**0.000**	**0.000**
% of unrelated	0.670	0.157	0.667	0.722	0.154	0.742	0.652	0.157	0.667	0.424	**0.000**	0.128	**0.000**
Number of observations	88			314			92						

Table VI: RESULTS FOR THE SINGLE EQUATION MODEL

This table reports the results for a random firm effect Tobit model estimation of the whole sample. The dependent variable in the regression is the delta percentage defined as the fraction of the gold production that is hedged for the three future years. The delta% is measured at the quarter end. The independent variables are measured one quarter prior to the one in which the risk management data is available. In the Table, Tax save is the fiscal benefit from reducing the firm's earnings volatility by five percent, scaled by the firm's sales revenues; Leverage is the book value of the long term debt divided by the firm's market value; Cash cost is the operating cost of producing an ounce of gold, excluding all non cash items such as depreciation, amortisation and other financial costs; Exploration and Acquisition are respectively the exploration and acquisition expenditures during the quarter both scaled by the firm's market value at the quarter end; The quick ratio is the value of the cash on hand, short term investments and clients accounts divided by the short term liabilities; Institutional shareholding is the percentage of shares held by institutions; D&O CS Value is the number of the common shares owned by directors and officers multiplied by the share price at the quarter end; D&O nber of options is the number of options held by directors and officers at the quarter end; % of unrelated is the number of unrelated directors divided by the board size. Dummy COB is a dummy variable equal to one if the CEO is also the chief of the board and 0 otherwise; Dummy US is a dummy variable equal to one if the firm is US and 0 if it is Canadian. The significant values at the 95% level are in bold, those at the 90% marked with an asterisk

	Tobit specification (A)		***Random effect Tobit specification(B)***	
	Slope	***p-value***	***Slope***	***p-value***
Constant	-0.1886*	0.051	**-0.1708**	**0.039**
Tax save	0.0973	0.101	0.0833*	0.086
Leverage	**0.4855**	**0.000**	**0.7443**	**0.000**
Cash cost	**0.0015**	**0.000**	**0.0006**	**0.002**
Ln (sales)	0.0102	0.379	**0.0666**	**0.000**
Acquisition	0.1262	0.374	0.0969	0.350
Exploration	1.6202	0.210	-0.8031	0.416
Quick ratio	**-0.0215**	**0.000**	**-0.0087**	**0.013**
Institutional shareholding	**-0.1257**	**0.016**	**-0.3683**	**0.000**
D&O CS Value	**0.0032**	**0.000**	**0.0006**	**0.046**
D&O number of options	-0.0175*	0.059	**-0.0213**	**0.004**
% of unrelated	0.0280	0.745	0.0615	0.376
Dummy COB	0.0237	0.369	-0.0068	0.776
Dummy US	**-0.1496**	**0.000**	0.0347	0.293
Sigma u, (random effect)			**0.2311**	**0.000**
Sigma e	**0.2448**	**0.009**	**0.1785**	**0.000**
Log likelihood	-71.4345		12.6552	
Number of observations	485		485	
Uncensored observations	404		404	
Censored observations	81		81	

Table VII: RESULTS FOR THE SIMULTANEOUS EQUATION SYSTEM

This table reports the results of the estimation with the minimum distance method of the simultaneous equations system. The first equation in the system models the risk management decision in the firm, and the second equation models the debt decision. In this case, debt and hedging decisions are supposed to be taken in the same time, at the quarter end. The dependent variables in the two equations are respectively the delta % and the firm's leverage. The independent variables are measured one quarter prior to the one in which the risk management and debt data is available. In this Table, delta % is the fraction of the gold production that is hedged for the three future years; Tax save is the fiscal benefit from reducing the firm earnings volatility by five percent, scaled by the firm sales revenues; Leverage is the book value of the long term debt divided by the firm's market value; Cash cost is the operating cost of producing an ounce of gold, excluding all non cash items such as depreciation, amortisation and other financial costs; Ln (sales) is the natural logarithm of the firm sales during the quarter; Exploration and Acquisition are respectively the exploration and acquisition expenditures during the quarter scaled by the firm's market value at the quarter end; The quick ratio is the value of the cash on hand, short term investments and clients accounts divided by the short term liabilities; Institutional shareholding is the percentage of shares held by institutions; D&O CS Value is the number of the common shares owned by directors and officers multiplied by the share price at the quarter end; D&O nber of options is the number of options held by directors and officers at the quarter end; Dummy US is a dummy variable equal to one if the firm is US and 0 otherwise; % of unrelated is the number of unrelated directors divided by the board size; Dummy COB is a dummy variable equal to one if the firm's CEO is also the chief of the board ; BV of pp&eq is the book value of property, plant and equipment scaled by the book value of total assets; Dep&Amt is depreciation and amortisation during the quarter scaled by the book value of total assets at the quarter end; MTR is the simulated marginal tax rate; Sgl&Adm is the Selling, general and administrative expenses during the quarter divided by the net sales of the firm during the same quarter; Operating income is the Operating income during the quarter scaled by the firm sales; Volatility of % change in OI is the volatility of the percentage change in the quarterly operating income. Exploration was multiplied by 1000 to fit in the software. The significant values at the 95% level are in bold.

	RM equation(A)		***Debt equation(B)***	
	Slope	***p-value***	***Slope***	***p-value***
Constant	-0.1250	0.335	**0.0629**	**0.004**
Tax save	-0.0469	0.791		
Leverage	**3.8125**	**0.023**		
Delta %			0.0464	0.355
Cash cost	**0.0003**	**0.030**		
Ln (sales)	0.0186	0.594	0.0127	0.117
Acquisition	-0.5469	0.097	0.1406	0.235
Exploration	-0.0011	0.647	**0.0030**	**0.008**
Quick ratio	**0.0132**	**0.002**		
Institutional shareholding	**-0.7461**	**0.000**		
D&O CS Value	**0.0022**	**0.005**		
D&O nber of options	**-0.0527**	**0.016**		
% of unrelated	0.0273	0.849		
Dummy COB	**0.0605**	**0.037**		
Operating income			**0.0112**	**0.043**
Sgl&Adm			**-0.1914**	**0.002**
Dep & Amt			0.3281	0.222
BV of pp&eq			0.0039	0.894
MTR			-0.0781	0.266
Volatility of % change in OI			**0.0001**	**0.038**
Dummy US	**0.1455**	**0.047**	**0.0820**	**0.001**
Number of observations	485		485	
Uncensored observations	405		401	
Censored observations	80		84	

APPENDIX I

The problem for the firm is to choose simultaneously the level of hedging h and the face value of its debt F in order to maximise the following program:

$$L = \int_{x_f}^{+\infty} \left[w_0 \left[h + (1-h)x \right] + \alpha x w_0 - F \right] g(x) dx$$
$$+ \lambda \left[\int_{-\infty}^{x_f} \left[w_0 \left[h + (1-h)x \right] + \alpha x w_0 - c \right] g(x) dx + F \left[1 - G(x_F) \right] - D(1+r) \right]$$

From (3) we have $x_F = \dfrac{F - w_0 h}{w_0 (1 - h + \alpha)}$ and corresponds to the minimal value of x that allows firms to avoid bankruptcy. Since x_F is a function of both F and h, we need to compute its derivative w.r.t. these two variables. We can easily show that:

$$\frac{dx_F}{dF} = \frac{1}{w_0 (1-h+\alpha)}$$

$$\frac{dx_F}{dh} = \frac{F - w_0 (1+\alpha)}{w_0 (1-h+\alpha)^2}$$

The first order conditions w.r.t. F and h are respectively:

$$\begin{cases} \left[G(x_F) - 1 \right] + \lambda \left[- c g(x_F) \dfrac{dx_F}{dF} + \left[1 - G(x_F) \right] \right] = 0 \\ - w_0 \sigma^2 g(x_F) + \lambda \left[- c g(x_F) \dfrac{dx_F}{dh} + w_0 \sigma^2 g(x_F) \right] = 0 \end{cases} \tag{A1}$$

$$\begin{cases} \lambda = \dfrac{1 - G(x_F)}{1 - G(x_F) - c g(x_F) \dfrac{1}{w_0 (1-h+\alpha)}} \\ \lambda = \dfrac{w_0 \sigma^2}{w_0 \sigma^2 - c \dfrac{F - w_0 (1+\alpha)}{w_0 (1-h+\alpha)^2}} \end{cases}$$

λ will be grater than 1 as long as 1-h+$\alpha > 0$ and $F - w_0 (1+\alpha) > 0$. Equating both equations to solve for F^* and h^* give us:

$$\frac{1-G(x_F)}{1-G(x_F)-cg(x_F)\dfrac{1}{w_0(1-h^*+\alpha)}}=\frac{w_0\sigma^2}{w_0\sigma^2-c\dfrac{F^*-w_0(1+\alpha)}{w_0(1-h^*+\alpha)^2}}$$

$$\Leftrightarrow [1-G(x_F)]\left[\frac{F^*-w_0(1+\alpha)}{w_0\sigma^2 g(x_F)}\right]=(1-h^*+\alpha)$$

$$\Leftrightarrow h^*=\underbrace{1-\frac{1}{\sigma^2}\left[\frac{1-G(x_f)}{g(x_f)}\right]\left[\frac{F^*-w_0}{w_0}\right]}_{h^*\ for\ \alpha=0}+\alpha\left[1+\underbrace{\frac{1}{\sigma^2}\left[\frac{1-G(x_f)}{g(x_f)}\right]}_{>0}\right] \qquad \text{(A2)}$$

$$\Leftrightarrow F^*=w_0\left[1+\alpha+\sigma^2\frac{g(x_f)}{1-G(x_f)}(1-h^*+\alpha)\right]$$

To isolate the relation between F^* and h^* we derive this last expression w.r.t. h^*

$$\frac{\partial F^*}{\partial h^*}=\underbrace{-\sigma^2\frac{g(x_F)}{1-G(x_F)}}_{<0}+\underbrace{(1-h^*+\alpha)\frac{d\left(\dfrac{g(x_F)}{1-G(x_F)}\right)}{dx_F}\frac{dx_F}{dh^*}}_{>0} \qquad \text{(A3)}$$

The first term in equation (A3) indicates that an increase in h reduces the firm's risk and gives her access to a higher debt capacity by reducing the face value of debt. The second term describes an indirect effect via the hazard rate. Under the normal assumption for *x*, the default intensity is an increasing function of x_F which is also an increasing function of h under the standard debt contract assumption. Therefore, increasing the hedging activities will increase both $\frac{dx_F}{dh^*}$ and the default intensity. This will lead to a second positive effect between the firm's face value and its hedging activities.

APPENDIX II

The system structural form (SF) can be written as:

$$\begin{cases} y^*_{1it} = \alpha_{12} y^*_{2it} + X'_{1it}\beta_1 + u_{1i} + e_{1it} \\ y^*_{2it} = \alpha_{21} y^*_{1it} + X'_{2it}\beta_2 + u_{2i} + e_{2it} \end{cases}$$

where y^*_{1it} and y^*_{2it} are respectively the risk management level and the long-term debt level targeted by the firm, X_{1it} and X_{2it} are $(k_1 \times 1)$ and $(k_2 \times 1)$ vectors of exogenous variables (including a constant term) supposed to affect respectively the risk management and the debt decisions. The terms u and e correspond respectively to the random firm effect and error components. α's and β's are parameters to be estimated. In this case, only maximum (y^*_{1it},0), maximum (y^*_{2it},0), X_{1it} and X_{2it} are observed. We assume that (u_{1i}, u_{2i}) and (e_{1it}, e_{2it}) are jointly normally distributed with a zero mean.

$$\begin{cases} y^*_{1it} - \alpha_{12} y^*_{2it} - X'_{1it}\beta_1 = u_{1i} + e_{1it} \\ y^*_{2it} - \alpha_{21} y^*_{1it} - X'_{2it}\beta_2 = u_{2i} + e_{2it} \end{cases}$$

Let's call $\varepsilon_{1it} = u_{1i} + e_{1it}$ and $\varepsilon_{2it} = u_{2i} + e_{2it}$. We can rewrite this system using matrices:

$$\begin{bmatrix} 1 & -\alpha_{12} \\ -\alpha_{21} & 1 \end{bmatrix} \begin{bmatrix} y^*_{1it} \\ y^*_{2it} \end{bmatrix} + \begin{bmatrix} X'_{1it} & X'_{2it} \end{bmatrix} \begin{bmatrix} -\beta_1 & 0 \\ 0 & -\beta_2 \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} \varepsilon_{1it} \\ \varepsilon_{2it} \end{bmatrix}$$

which give us the following equation:

$$Y_{it} = B^{-1}\left[\Sigma_{it} - X'_{it}C\right]$$

where:

$$Y_{it} = \begin{bmatrix} y^*_{1it} \\ y^*_{2it} \end{bmatrix};\ X'_{it} = \begin{bmatrix} X'_{1it} & X'_{2it} \end{bmatrix};\ \Sigma_{it} = \begin{bmatrix} \varepsilon_{1it} \\ \varepsilon_{2it} \end{bmatrix};\ B = \begin{bmatrix} 1 & -\alpha_{12} \\ -\alpha_{21} & 1 \end{bmatrix};\ C = \begin{bmatrix} -\beta_1 & 0 \\ 0 & -\beta_2 \end{bmatrix}$$

Let's call $\Delta = 1 - \alpha_{12}\alpha_{21}$, we assume that $\Delta \neq 0$. Since $B^{-1} = \begin{bmatrix} \frac{1}{\Delta} & \frac{\alpha_{12}}{\Delta} \\ \frac{\alpha_{21}}{\Delta} & \frac{1}{\Delta} \end{bmatrix}$ we can rewrite the system as:

$$\begin{bmatrix} y^*_{1it} \\ y^*_{2it} \end{bmatrix} = \begin{bmatrix} \frac{1}{\Delta} & \frac{\alpha_{12}}{\Delta} \\ \frac{\alpha_{21}}{\Delta} & \frac{1}{\Delta} \end{bmatrix} \begin{bmatrix} \varepsilon_{1it} + X'_{1it}\beta_1 \\ \varepsilon_{2it} + X'_{2it}\beta_2 \end{bmatrix}$$

We develop this matricial equation and get the following system:

$$\begin{cases} y_{1it}^{*} = \dfrac{1}{\Delta}\varepsilon_{1it} + \dfrac{\beta_1}{\Delta}X'_{1it} + \dfrac{\alpha_{12}}{\Delta}\varepsilon_{2it} + \dfrac{\beta_2\alpha_{12}}{\Delta}X'_{2it} \\ y_{2it}^{*} = \dfrac{\alpha_{21}}{\Delta}\varepsilon_{1it} + \dfrac{\beta_1\alpha_{21}}{\Delta}X'_{1it} + \dfrac{1}{\Delta}\varepsilon_{2it} + \dfrac{\beta_2}{\Delta}X'_{2it} \end{cases}$$

Let's call $\eta_1 = \begin{bmatrix} \dfrac{\beta_1}{\Delta} \\ \dfrac{\beta_2\alpha_{12}}{\Delta} \end{bmatrix}$ and $\eta_2 = \begin{bmatrix} \dfrac{\beta_2\alpha_{21}}{\Delta} \\ \dfrac{\beta_2}{\Delta} \end{bmatrix}$. We replace ε_{1it} and ε_{2it} by their respective expressions. This will give us:

$$\begin{cases} y_{1it}^{*} = X'_{it}\eta_1 + \dfrac{1}{\Delta}(u_{1i} + e_{1it}) + \dfrac{\alpha_{12}}{\Delta}(u_{2i} + e_{2it}) \\ y_{2it}^{*} = X'_{it}\eta_2 + \dfrac{\alpha_{21}}{\Delta}(u_{1i} + e_{1it}) + \dfrac{1}{\Delta}(u_{2i} + e_{2it}) \end{cases}$$

The system reduced form (RF) can be derived as:

$$\begin{cases} y_{1it}^{*} = X'_{it}\eta_1 + l_{1i} + \gamma_{1it} \\ y_{2it}^{*} = X'_{it}\eta_2 + l_{2i} + \gamma_{2it} \end{cases}$$

where

$$\begin{cases} l_{1i} = \dfrac{1}{\Delta}u_{1i} + \dfrac{\alpha_{12}}{\Delta}u_{2i} \quad ; \quad l_{1i} \sim N(0,\theta_1^2) \\ l_{2i} = \dfrac{\alpha_{21}}{\Delta}u_{1i} + \dfrac{1}{\Delta}u_{2i} \quad ; \quad l_{2i} \sim N(0,\theta_2^2) \\ \gamma_{1it} = \dfrac{1}{\Delta}e_{1it} + \dfrac{\alpha_{12}}{\Delta}e_{2it} \quad ; \quad \lambda_{1it} \sim N(0,\sigma_1^2) \\ \gamma_{2it} = \dfrac{\alpha_{21}}{\Delta}e_{1it} + \dfrac{1}{\Delta}e_{2it} \quad ; \quad \lambda_{2it} \sim N(0,\sigma_2^2) \end{cases}$$

Comparing the system SF and RF, we have:

$$\begin{cases} \eta_1 = \alpha_{11}\eta_2 + J_1\beta_1 \\ \eta_2 = \alpha_{21}\eta_1 + J_2\beta_3 \end{cases}$$

where J_1 and J_2 are the exclusion matrices constructed such as: $X'_{it}J_1 = X'_{1it}$ and $X'_{it}J_2 = X'_{2it}$.

APPENDIX III

Each equation of the reduced form corresponds to a random effect Tobit model. The general form of a random firm effect Tobit model can be written as:

$$
\begin{aligned}
y_{it} &= y_{it}^{*} \quad \text{if } y_{it}^{*} > 0 \text{ where } y_{it}^{*} = X'_{it}\eta + l_i + \gamma_{it} \\
y_{it} &= 0 \quad \text{otherwise}
\end{aligned}
$$

where y_{it} is the dependent variable censored at zero, X_{it} is a $(k \times 1)$ matrix of exogenous variables (including a constant term). The terms l and γ correspond respectively to the random firm effect and error terms. η's are parameters to be estimated. We assume that $\gamma_{it} \sim N(0,\sigma^2)$ and $l_i \sim N(0,\theta^2)$.

$$P[y_{it} = 0] = P[y_{it}^{*} \le 0] = P[X'_{it}\eta + l_i + \gamma_{it} \le 0]$$

$$= P\left[\frac{\gamma_{it}}{\sigma} \le \frac{-X'_{it}\eta - l_i}{\sigma}\right] = \Phi\left[\frac{-X'_{it}\eta - l_i}{\sigma}\right]$$

where Φ is the normal cdf.

$$P[y_{it} = y_{it}^{*}] = P[y_{it} = X'_{it}\eta + l_i + \gamma_{it}] = P[\gamma_{it} = y_{it} - X'_{it}\eta - l_i]$$

$$= P\left[\frac{\gamma_{it}}{\sigma} = \frac{y_{it} - X'_{it}\eta - l_i}{\sigma}\right] = \varphi\left[\frac{y_{it} - X'_{it}\eta - l_i}{\sigma}\right] \times \frac{1}{\sigma}$$

where φ is the normal pdf.

Let's define $d_{it} = 1$ if $y_{it} = y_{it}^{*}$ and $d_{it} = 0$ if $y_{it} = 0$. For a given l_i, we have:

$$P(y_{it}/l_i) = \Phi\left[\frac{-X'_{it}\eta - l_i}{\sigma}\right]^{1-d_{it}} \times \left[\varphi\left[\frac{y_{it} - X'_{it}\eta - l_i}{\sigma}\right] \times \frac{1}{\sigma}\right]^{d_{it}}$$

$$P(y_i/l_i) = \prod_{t=1}^{T_i} \left[\Phi\left[\frac{-X'_{it}\eta - l_i}{\sigma}\right]^{1-d_{it}} \times \left[\varphi\left[\frac{y_{it} - X'_{it}\eta - l_i}{\sigma}\right] \times \frac{1}{\sigma}\right]^{d_{it}}\right].$$

Using Bayes theorem, we can write:

$$P(y_i) = \int_{-\infty}^{+\infty} \left\{\prod_{t=1}^{T_i} \left[\Phi\left[\frac{-X'_{it}\eta - l_i}{\sigma}\right]^{1-d_{it}} \times \left[\varphi\left[\frac{y_{it} - X'_{it}\eta - l_i}{\sigma}\right] \times \frac{1}{\sigma}\right]^{d_{it}}\right]\right\}\left[\frac{1}{\theta} \times \varphi\left(\frac{l_i}{\theta}\right)\right] dl_i,$$

$$P(y)=\prod_{i=1}^{N}\left\{\int_{-\infty}^{+\infty}\left\{\prod_{t=1}^{T_i}\left[\Phi\left[\frac{-X'_{it}\eta-l_i}{\sigma}\right]^{1-d_{it}}\times\left[\varphi\left[\frac{y_{it}-X'_{it}\eta-l_i}{\sigma}\right]\times\frac{1}{\sigma}\right]^{d_{it}}\right]\right\}\left[\frac{1}{\theta}\times\varphi\left(\frac{l_i}{\theta}\right)\right]dl_i\right\},$$

$$\text{Log-L}=\sum_{i=1}^{N}\log\left\{\int_{-\infty}^{+\infty}\left\{\prod_{t=1}^{T_i}\left[\Phi\left[\frac{-X'_{it}\eta-l_i}{\sigma}\right]^{1-d_{it}}\times\left[\varphi\left[\frac{y_{it}-X'_{it}\eta-l_i}{\sigma}\right]\times\frac{1}{\sigma}\right]^{d_{it}}\right]\right\}\left[\frac{1}{\theta}\times\varphi\left(\frac{l_i}{\theta}\right)\right]dl_i\right\}.$$

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