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Exposure-based Cash-Flow-at-Risk under Macroeconomic Uncertainty

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Abstract

In this paper we derive an exposure-based measure of Cash-Flow-at-Risk (CFaR). Existing approaches to calculating CFaR either only focus on cash flow conditional on market changes or neglect market-risk exposures entirely. We argue here that an essential first step in a risk-management program is to quantify cash-flow exposure to macroeconomic and market risk. This is the information relevant for corporate hedging. However, it is the total level of cash flow in relation to the firm's capital needs that is the information relevant for decision-making. The firm's overall CFaR is then calculated based on an assessment of corporate risk exposure.

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Exposure-based Cash-Flow-at-Risk under Macroeconomic Uncertainty

It is increasingly recognized that measures of downside risk are likely to measure a risk that is more relevant to the stakeholders of a corporation, particularly its shareholders, than is the hitherto predominant standard deviation. In particular, it is the lower end tail of the cash flow distribution that can have costly consequences for the firm, such as not having enough funds to carry out the company's investment program, or even bankruptcy.[1] Downside risk measures are also more consistent with how risk is actually perceived by managers and investors.[2]

The Cash-Flow-at-Risk (CFaR) measure, which is the focus of this paper, belongs to the family of measures that targets downside risk. By stating the maximum shortfall of cash, relative to a target and associated with a certain level of statistical confidence, it explicitly addresses downside risk. It is the cash-flow equivalent of Value-at-Risk (VaR), another prominent member of the downside-risk family. VaR has gained significant attention in academia as well as widespread popularity in use among financial institutions. CFaR is gaining in popularity for much the same reasons as VaR has been recognized: it sums up all the company's risk exposures into a single, manageable number that comes attached with a probability. It is this number, the maximum shortfall given the probability level, and the fact that it can be directly compared to the firm's risk tolerance that is the unique feature of VaR and CFaR.

The calculation of a risk statistic such as CFaR requires an estimate of the probability distribution of cash flow at some future point in time. RiskMetrics, who originally developed CFaR, generally rely on a bottom-up approach, which identifies cash-flow components

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[1] See, for example, K A Froot, D S Scharfstein, and J C Stein, "Risk Management: Coordinating Corporate Investment and Financing Policies", *Journal of Finance* Vol. 48 (1993), pp. 1629-1658; K A Froot, D S Scharfstein, and J C Stein, "A Framework for Risk Management", *Harvard Business review* Vol. 72, No. 6 (1994), pp. 91-102; and R M Stulz, "Rethinking Risk Management", *Journal of Applied Corporate Finance* Vol. 9, No. 3 (1996), pp. 8-24.

[2] K D Miller and M J Leiblein "Corporate Risk-Return Relations: Returns Variability versus Downside Risk", *Academy of Management Journal* Vol. 39 (1996), pp. 91-122.

exposed to market risk.[3] Their definition of CFaR targets cash-flow volatility conditional on market risk. This approach is useful if the objective with the risk assessment is to estimate CFaR conditional on market risk and it is possible to identify all the causal linkages between market prices and corporate cash flows. We claim that if it is important to get an estimate of the firm's overall CFaR, then the bottom-up approach will not suffice. Moreover, if it is not possible to identify all sources of exposure to market risk, then exposure is more accurately measured as the firm's cash flow delta (the sensitivity of cash flow to a small change in the underlying market price), then the bottom-up approach is not the way to go.

Usher, LaGattuta, and Youngen (2001) instead apply a top-down approach, where the focus is on the overall cash-flow volatility.[4] They pool cash-flow data for a large number of comparable companies to estimate a pooled cash-flow distribution, as opposed to using only the company's own historical cash-flow data. This approach is advantageous, since it uses a large pool of cash-flow data to base the calculation of CFaR on, given that you believe that the criteria used to identify comparable companies are accurate. However, the top-down approach does not provide any estimation of CFaR conditional on market risk, nor can it be easily adapted to generate such a measure.

We instead suggest exposure-based CFaR as a method to calculating both the firm's overall CFaR and the CFaR conditional on macroeconomic and market risks. We argue that our approach is more informative than the top-down approach, since to manage risk, knowing variability is not enough; the *drivers* of that volatility must also be understood and their impact on cash flow quantified. Exposure-based CFaR is also more informative than the bottom-up approach, since it takes into consideration the total variability in cash flow. Exposure-based CFaR calls for a set of exposure coefficients (deltas) that provides information on how macroeconomic and market variables operate on the company's cash flow. We argue that these coefficients may be estimated using a multivariate regression

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[3] RiskMetrics, *CorporateMetrics*[TM] *Technical Document* (New York: RiskMetrics Group, 1999).

[4] J Stein, S Usher, D LaGatutta, and J Youngen, "A Comparables Approach to Measuring Cashflow-at-Risk for Non-Financial Firms", *Journal of Applied Corporate Finance* Vol. 13, No. 4 (2001), pp. 100-109.

framework like the MUST analysis, developed by Lars Oxelheim and Clas Wihlborg.[5] Simultaneously, our exposure-based CFaR provides an overall CFaR metric.

The MUST analysis is a comprehensive framework for estimating corporate exposure to macroeconomic and market risks. It recognizes the interdependency between the macroeconomic and market risks a company is exposed to and that they may influence corporate performance through a multitude of channels. Through a multiple regression analysis on cash flow, where the explanatory variables come from an analysis of the company's macroeconomic and competitive environment, the company obtains a model of its exposure to risk that can be used to calculate CFaR. In contrast to the top-down approach, management obtains a set of exposure coefficients that are capable of explaining variability in cash flow, as well as indicating how a hedge contract or change in financial structure influences the risk profile. Simultaneously, the analysis provides information on the cash-flow variability not caused by macroeconomic and market risks, allowing management to calculate the overall CFaR.

This article is outlined as follows. In the next section we review the origins of the at-Risk framework and evaluate the current approaches to measuring CFaR. Then follows a section that outlines the MUST analysis, followed by a presentation of exposure-based CFaR. In the section thereafter, we apply exposure-based CFaR to the Norwegian industrial conglomerate Norsk Hydro. Finally, we conclude the paper.

1. Cash Flow at Risk: existing approaches

Risk is not perceived as a symmetric phenomenon. This is a message that has been coming out of research in behavioral decision theory for the past three decades. Daniel Kahneman and Amos Tversky have shown that people react stronger to negative stimuli than positive and that reference levels are critical in people's assessment and perception of risk – risk is

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[5] See L Oxelheim and C Wihlborg, *Macroeconomic Uncertainty. International Risks and Opportunities for the Corporation* (Chichester, UK: Wiley, 1987); and L Oxelheim and C Wihlborg, *Managing in a Turbulent World Economy: Corporate Performance and Risk Exposure* (Chichester, UK: Wiley, 1997).

perceived of in terms of performing worse than some target level.[6] As Balzer puts it, "…it is clear that our intuition tells us that risk is an asymmetric phenomenon related to downside risk, and that an intuitive and realistic risk measure should also be asymmetric – it should treat upside and downside differently".[7] [8]

VaR, which was pioneered by JP Morgan in 1993, emerged to meet the demand for measurement of downside risk. It grew out of a desire to know the aggregated risk of all trading desks across a financial institution. It targets the total risk of any portfolio or financial institution, and makes the aggregated risk directly comparable between portfolios. This is a direct advantage over the sensitivity measures that traditionally have been used by traders. Although it has received a fair amount of criticism, VaR does appear to have considerable value added as a risk measure, at least judging from the way it has grown in popularity among practitioners as well as academics, and how it has been adopted under the Basel-II agreement by bank regulators to determine the amount of risk capital in banks.[9]

Even though VaR has met the demand for measures of downside risk in the context of portfolios of financial assets, it is inappropriate for the non-financial firm. If VaR is applied to a non-financial firm's portfolio of financial instruments (debt instruments, swaps, FX contracts, etc) it will capture only a small part of the company's exposure, since it ignores its underlying commercial cash flows. While VaR itself has limited applicability for a non-financial firm, the at-Risk framework is still relevant. What is called for is a transfer of the

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[6] D Kahneman and A Tversky, "Prospect Theory: An Analysis of Decisions under Risk", *Econometrica* Vol. 47 (1979), pp. 263-291.

[7] L A Balzer, "Investment Risk: a Unified Approach to Upside and Downside Returns", in F Sortino and S Satchell (eds), *Managing Downside Risk in Financial Markets* (Butterworth-Heinemann, 2001).

[8] From a statistical point of view, risk could very well be a symmetric phenomenon. This depends on the statistical properties of the risky variable. If corporate cash flows are normally distributed, then cash-flow risk will per definition be symmetric. The standard deviation will then be a theoretically correct measure of risk. It might not be a perceptually correct measure, however. If people's perception of risk is asymmetric, the standard deviation will provide the incorrect information.

[9] For a critique of VaR, see C L Culp, M Merton, and A Neves, "Value at Risk: Uses and Abuses", *Journal of Applied Corporate Finance* Vol. 10, No. 4 (1998), pp. 26-38.

ideas behind VaR to a setting in which cash flow is the target variable. CFaR is such an effort: a transfer of the VaR concept to encompass corporate cash flows.

CFaR was developed in response to increased interest from the business community in the methodology behind VaR. The derivation of CFaR requires a forecasted probability distribution of cash flow at some future point in time. The question is how to best generate such a distribution. RiskMetrics does not take a firm stand on this, on the basis that the choice depends on the context of each individual firm, but the dominant methodology in their documentation is the bottom-up approach. Under this approach, a pro-forma cash-flow statement is created in which production volumes and/or volumes of local currency are the basic building blocks. Then random values are drawn for production prices and/or exchange rates based on their variance-covariance matrix and inserted into the pro-forma statement to calculate conditional values of cash flow in domestic currency. From the resulting cash-flow distribution, CFaR is derived.

The bottom-up approach assumes a direct link between production volumes and volumes of local currency on the one hand and cash flow on the other. However, the main conclusion coming out of 20-plus years of research into how and why firms are exposed to macroeconomic and market risks is that risk exposure is so complex and multifaceted a phenomenon that any exercise at modeling it analytically in a pro-forma statement is fruitless.[10] For example, how to model the impact of an exchange-rate change that simultaneously influences the firm's and competitors' input and output prices and future sales volumes due to consumers' responses to price changes, at the same time as it affects interest rates, which in turn affect the firm's interest expenses and consumers' willingness to spend money on consumption? The exposures that can be meaningfully captured in a pro-forma statement are generally only a small part of a firm's total exposure.

Stein's et al top-down approach is founded on the assumption that total variability in cash flow is the ultimate variable of interest.[11] This is in contrast with RiskMetrics' definition of

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[10] For a summary of the research on measurement of corporate risk exposure, see N Andrén, *Essays on Corporate Exposure to Macroeconomic Risk* (Lund Studies in Economics and Management 62, Lund, Sweden: Lund Business Press, 2001); or L Oxelheim and C Wihlborg (1997), cited earlier.

[11] J Stein et al (2001), cited earlier.

CFaR, which talks of the maximum shortfall due to the impact of market risk. That is, the RiskMetrics definition of CFaR isolates the variability that is conditional on market risks, whereas in Stein's et al framework total cash flow is the target variable.

Variability in total cash flow can be estimated from a company's historical cash flow, provided such data exists. Stein et al suggest that data on any given company's own cash flow is insufficient to get a statistically significant estimate of volatility. They therefore call for the pooling of cash-flow data for a large number of firms in order to get a volatility estimate that is statistically acceptable. Using the Compustat database they obtain no less than 85,000 observations on EBITDA (Earnings Before Interest, Taxes, Depreciation, and Amortization) using just 6 years of company data. The authors identify four characteristics that have good explanatory power for patterns in unexpected changes in EBITDA in their sample: size, profitability, riskiness of industry cash flow, and stock-price volatility. Using these key characteristics, they sort firms into pools of comparable companies. The pooled cash flows for comparable companies are then used to calculate each firm's cash-flow distribution. Thus, while this approach aggregates a large number of companies, the results are applied on the firm level for each individual firm based on these key characteristics.

We agree that total variability in cash flow is the relevant aspect of a CFaR analysis. From a managerial perspective a distribution that is entirely conditional on market variables is less useful than one that captures the whole variability in cash flow, regardless of the source. For example, Froot and co-authors argue that shortfalls of internally generated cash, *irrespective of the reason for the shortfall*, keep firms from undertaking profitable investments.[12] They suggest that the main objective for a risk-management program should be to ensure that enough internally generated cash is available to fund the firm's investment program. Rene Stulz instead proposes as goal for risk management "…the elimination of costly lower-tail outcomes – that is designed to reduced the expected costs of financial distress, while preserving a company's ability to exploit any comparative advantage it may have".[13] Once again, the source of costly lower-tail outcomes is irrelevant.

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[12] K A Froot et al (1993 and 1994), cited earlier.

[13] R M Stulz (1996), cited earlier.

However, even though variability in total cash flow is important, it is still important to know through what channels the cash-flow volatility is generated. As Christopher Culp suggests, market risks will normally be the first risks to hedge or control, as few firms have the informational advantage required to exploit these risks profitably.[14] This requires a measure of CFaR conditional on market risk. Conditional CFaR tells how much cash flow is at risk, given the specified probability, due to fluctuations in macroeconomic and market factors. CFaR can be used to evaluate how the future distribution of cash flow is affected if, for example, an option contract is entered to reduce a specific exposure. It could also provide information about the relative contribution of macroeconomic and market risks to volatility versus that of other sources of cash-flow volatility. Stein et al point to targeting the ultimate variable of interest (total cash flow) directly as one of the virtues of their approach. We are of a different opinion: the very process of mapping out the firm's exposure and of asking difficult questions about how and through what channels the firm's cash flow is exposed to risk is one of the key benefits of having a risk-management program.

2. Measuring commercial exposure to macroeconomic and market risk

We have argued that quantification of exposure to risk should be an essential first step in a CFaR analysis, but it is important to perform this exercise correctly. We are of the opinion that using pro-forma cash-flow statements to model risk exposure will yield biased results since a) more subtle ways in which a risk factor operates on cash flow will not be included and b) it is very difficult, to say the least, to deal with more than one exposure at a time. However, we know that a) risk does operate on cash flow in multitude of ways, many of which do not lend themselves to mathematical specification, and b) different risks are interrelated, so that when one risk materializes, it could be either offset or strengthened by other risks.

To take the example of exchange-rate risk, pro-forma based exposure measures are usually derived from looking at outstanding contractual obligations, i.e. accounts payables and receivables. The level of cash flow in domestic currency (DC) is here exposed to exchange rate risk only when converting account payables and receivables in foreign currency (FC) to

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[14] C L Culp, *The Risk Management Process. Business Strategy and Tactics* (New York: Wiley, 2001).

DC. This way of measuring exposure ignores possible shifts in competitiveness as a result of shifts in exchange rates. But the exchange rate could have an effect on the firm's ability to compete on the world markets. The general idea is that if a company's product is priced in a currency that appreciates, the product will become more expensive on world markets. In line with the law of supply and demand, this tends to lead to a decrease in the demand for the company's products. As Rawls and Smithson point out, there exist a large number of cases where misunderstanding of competitive exposure has imposed large losses on a company and even jeopardized its operations.[15]

Even when bottom-up modeling takes aim at this sort of competitive exposures by introducing more complex relationships between the exchange rate and cash flow, problems remain. Such modeling has a tendency to ignore the simultaneous impact of exchange rates and other macroeconomic and market variables, such as interest rates, inflation, and commodity prices. What is more, since macroeconomic price variables are determined in a general-equilibrium system that simultaneously adjusts to shocks in the economy, there is a tendency for macroeconomic variables to co-vary that will influence the degree to which a firm is exposed to macroeconomic risks. That is, from a firm's point of view, inflation, interest, and exchange rates can be partly or wholly offsetting in their adjustment to external shocks.

We argue that the CFaR has to be improved by the recognition of the drivers of corporate macroeconomic exposure. We suggest that the CFaR should be improved by the incorporation of the MUST analysis, which provides an adequate framework for measuring corporate exposure to interdependent macroeconomic and market variables.[16] This approach begins with a fundamental analysis of the company's exposure to changes in the macro economy. The merits of the MUST analysis in the CFaR context are that it provides a series of answers to important questions like, for example, the company's currency compositions of its sales, production costs, and input purchases, its positions in the factor and output markets and the bargaining power relative to suppliers and customers, the sensitivities of its customers to

[15] S W Rawls and C W Smithson, "Strategic Risk Management", *Journal of Applied Corporate Finance Vol.* 2, No. 4 (1990), pp. 6-18.

[16] See L Oxelheim and C Wihlborg (1987 and 1997), cited earlier.

price, cross-price, interest-rate, and real-income changes, and the structure of its financial positions. More answers are generated by a similar analysis of the firm's competitors so that the likely impact of changes in macroeconomic variables on competitiveness can be estimated. This fundamental analysis of the company's exposures, and of relative exposures in the industry, will indicate a set of macroeconomic and market risks that are potentially important drivers of the company's performance. A multivariate regression analysis on cash flow can then be performed using random changes in these factors as explanatory variables:

$$\begin{aligned} X_t^{DC} - E_{t-1}\left[X_t^{DC}\right] = \beta_0 &+ \beta_1\left(\pi_t^{DC} - E_{t-1}\left[\pi_t^{DC}\right]\right) \\ &+ \beta_2\left(\pi_t^{FC} - E_{t-1}\left[\pi_t^{FC}\right]\right) \\ &+ \beta_3\left(S_t^{DC/FC} - E_{t-1}\left[S_t^{DC/FC}\right]\right) \\ &+ \beta_4\left(i_t^{DC} - E_{t-1}\left[i_t^{DC}\right]\right) \\ &+ \beta_5\left(i_t^{FC} - E_{t-1}\left[i_t^{FC}\right]\right) \\ &+ \beta_6\left(P_t^{DC} - E_{t-1}\left[P_t^{DC}\right]\right) \\ &+ \varepsilon_t \end{aligned} \qquad (1)$$

where X_t^{DC} is the cash flow in DC in period t, π is inflation, $S^{DC/FC}$ is the spot exchange rate in DC/FC, i is an interest rate, and P is a market price of relevance to corporate profitability. E_{t-1} is the expectations operator in period t-1, while ε_t measures cash-flow changes in period t independent of macroeconomic and market variables.

This gives a neutral, statistical estimate of the firm's sensitivity to price changes in the macroeconomic and financial environment. The coefficients in this regression model can then be put to three uses. Firstly, they can be used to determine the size of hedge contracts that will reduce or eliminate the company's exposure. The regression coefficients can easily be translated into hedge positions. Secondly, They can be used to adjust historical cash flow to filter out the impact of macroeconomic and market risks. The regression analysis decomposes cash flow into two components: cash-flow changes caused by macroeconomic and market changes and cash-flow changes independent of such changes. Thirdly, they can form the basis for a CFaR calculation.

4. Exposure-based CFaR

As discussed earlier, the total variability of cash flow is, from a managerial perspective, the relevant target variable. This total variability can be attributed to a multitude of different factors. We focus on random events occurring in the real and financial markets as they materialize in the form of fluctuations in macroeconomic and market prices – exchange rates, interest rates, inflation rates, and commodity prices. In the exposure assessment the total cash-flow variability is decomposed into fluctuations due to such changes and fluctuations independent of such changes. The relative importance of the macroeconomic exposure will be indicated by the coefficient of determination (R^2) of the exposure model, while the relative importance of non-macroeconomic and market risk is given by $1 – R^2$.[17]

To derive a conditional distribution of cash flow, Equation (1) must be complemented with the variance/covariance matrix of the macroeconomic and market variables identified in the exposure model. We apply simulations, where values are picked randomly from the variance/covariance matrix of the explanatory variables. In each of these iterations the randomly picked values are inserted into Equation (1), rendering a simulated value of cash flow conditional on macroeconomic and market variables. If 10,000 scenarios are simulated, we get 10,000 simulated values of cash flow.

To get an estimate of total cash flow we must complement the conditional cash-flow distribution with a distribution of the error term. If the error term is well behaved, it has by definition no correlation with any of the explanatory variables or its own past values, and we can simply draw a value from a normal distribution ($N \sim [0,\sigma^2]$) and add that value to the conditional distribution.

To summarize, calculating exposure-based CFAR is a six-step process:

[17] Actually, there is one additional source of variability, which we do not take into consideration. The coefficients in Equation (1) are estimates that are normally distributed; the estimated exposure is the mean of the distribution of possible coefficients. This source of variability could be added by entering the exposure coefficients as random variables in the coming simulations.

Estimation of corporate risk exposure

1. Identify macroeconomic and market variables expected to be significant to corporate performance by investigating the firm's macroeconomic and competitive environment, the firm's and its major competitors' cost and revenue structures, and price and wealth sensitivities of its customers.

2. Acquire or calculate forecasts of the identified macroeconomic and market variables. Risk derives from random, unexpected deviations from the forecasts.

3. Estimate the exposure model. This is a process where knowledge of corporate fundamentals and statistics interact to derive a model with economic logic (results that can be motivated) and good statistical properties (high explanatory value, statistical significance, and well-behaved error terms).

Estimation of exposure-based CFaR

4. Simulate values of the macroeconomic and market variables by randomly picking observations from their variance/covariance matrix (for example, 10,000 Monte Carlo simulations). In each simulation run, draw a random value for ε.

5. Insert the simulated values in the exposure model to derive a distribution of cash flow conditional on macroeconomic and market volatility and a distribution of cash flow independent of macroeconomic and market volatility.

6. Aggregate the two cash-flow distributions into one, select confidence level, and calculate CFaR.

5. The case of Norsk Hydro

In this section we use Norsk Hydro, a Norwegian industrial conglomerate headquartered in Oslo, to demonstrate the merits of exposure–based CFaR. Our time-period is the first quarter 1996 to the last quarter 2003 and we use EBITDA as our target variable. EBITDA captures commercial cash flows, but excludes all financial cash flows. This essentially means that we exclude all balance-sheet items from our investigation. In particular, since we exclude all financial cash flows our analysis is largely pre-hedging.[18] We follow the six-step process outline above, beginning with investigating the potential sources of commercial exposure to macroeconomic and market risks of each of Hydro's three main business areas. First, though, a brief presentation of Hydro.

From having been a widely diversified conglomerate, Hydro in the 1990s initiated a strategy of focusing on three main business areas: Oil, Aluminum, and Fertilizers (Agri). By acquiring the German aluminum maker VAW in 2002, Hydro established itself as one of the world's three largest integrated players in the aluminum market. In 2003, the board decided to divest the fertilizer division. The divestment took place in early 2004.[19] Of operating revenues of NOK 172 bn in 2003, the Oil & Gas division accounted for 35%, Aluminum 40%, and Agri 22%, with Other Activities making up the remaining 3%. HOE stands for Hydro Oil & Energy, HAL for Hydro Aluminium, HA for Hydro Agri, and HG for Hydro Group. We have not performed a review of exposures in HOA as this group of businesses is too dispersed and opaque.

Step 1: Analyzing sources of commercial exposure

We cover four groups of macroeconomic and market prices of relevance to Hydro, namely commodity prices, exchange rates, inflation rates, and interest rates.

<u>Channels of commercial exposures to commodity-price risk</u>

For HOE, a large chunk of its commercial exposure is made up of exposure to the price of oil. Hydro's production of oil and oil equivalents in 2003 amounted to 530,000 barrels of oil per day. The downstream portion of HOE's oil activities is small relative to many of its competitors and Hydro's oil division has remained essentially an exploration and production company. Gas production is also growing in importance, but as of early 2004 there is only a minor exposure to the spot price of gas as HOE's portfolio of gas contracts consists mainly of long-term contracts written with reference to the oil price.

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[18] Unfortunately, the cash-flow numbers available to us are not pre-all-hedging activities. For example, Hydro reports contracts locking in commodity prices as part of operating income.

[19] We focus on the period prior to the divestment of the fertilizer division and thus include it in our case study.

In 2003, HAL produced a total of 3.3 million tons of aluminum. The exposure to the aluminum price is somewhat mitigated by having some of the costs of inputs linked to it. Aluminum is a standardized product, where the global nature of the market makes each player basically a price taker. HAL also has a large downstream sector where aluminum is refined and sold at a premium over the aluminum price to, for instance, the car and aviation industries. HAL competes mainly with two other integrated aluminum producers, Alcoa in the US and Alcan in Canada. There is also a large exposure to energy prices on the cost side, as aluminum production is a very energy-intense process, but the commercial exposure to the spot price of electricity has been locked in by long-term purchase contracts.

The market for fertilizers consists of a huge number of players, each having only a small slice of total market share. HA, despite being world leader, has a global market share of no more than 6%. In Western Europe, HA has a market share of 30% in nitrate fertilizers, for which Urea and Can serve as reference prices. The total number of fertilizers and related products in HA's product portfolio is large and HA operates in over 100 countries worldwide, implying a very complex market setting. Ultimately, though, these products are expected to respond to the same factors: the overall development in the demand for grain and the expected profitability of the farming industry. On the cost side, manufacturing Urea and Can requires Ammonia (NH_3) as input. NH_3 production, in turn, requires significant amounts of natural gas. An increase in the price of gas (which is highly correlated with the oil price) tends to be passed through to NH_3, which in turn is passed through to Urea and Can. The degrees of pass-through, which depend on a lot of factors and varies over time, will determine the correlation between these variables, and therefore also HA's overall exposure to fertilizers and oil.

To summarize, we identify five main sources of commodity-price exposure: the prices of oil, aluminum, Urea, Can, and NH_3.

<u>Channels of commercial exposures to exchange-rate risk</u>

The oil price is a world commodity with the reference price set in USD. HOE's cost base is highly concentrated to Norway. The non-Norwegian share of oil production is on the rise, but only accounts for 4% of total production. The strength of the NOK to the USD should be a determinant of Hydro's performance relative to the industry.

The world aluminum price is also set in USD, but due to price arbitrage across the Atlantic being very expensive, the EUR is the functional currency of aluminum trading on the

European market. HAL's aluminum production is sold mainly in Europe and invoiced in EUR. HAL has a large portion of its cost base in Norway, making the NOK/EUR rate important. It also has many production sites in the EMU, HAL and its main competitors compete in the same product markets, but have their main cost bases in different currencies. Thus, to the extent the NOK weakens against USD and CAD, this would tend to benefit HAL relative to its competitors.

Roughly, the reference price for Urea is set in USD, whereas Can has its reference price in EUR. HA's sales are mainly invoiced in USD and EUR, but parts are invoiced in local currencies. This creates a situation in which there is a short-term transaction exposure to a multitude of local currencies, but where the underlying exposure should be to the USD and the EUR. Competitive effects of exchange rates are known to exist. For example, changes in the USD/EUR rate alters the relative attractiveness of Urea and Can, two fertilizer products that are of differing quality but essentially substitutes. As for currency exposures on the cost side, HA is highly geographically diversified, but have major production centers in Norway (NOK) and Belgium (EUR), making NOK/EUR and NOK/USD potentially important currencies.

To summarize, we identify three sources of exchange-risk exposure: NOK/USD, NOK/EUR, and NOK/CAD.

Channels of commercial exposure to inflation risk

The importance of exchange-rate risk to competitiveness is also determined by inflation differentials; if exchange-rate changes are completely offset by inflation differentials, exchange rates will not influence competitiveness. A company with exposure to relatively higher inflation rates in its cost base may find it harder to compete on price and loose market share, or alternatively suffer decreased margins. In particular HAL has the pre-conditions for this type of exposure since the three major players have the main part of their cost bases in different currencies. HOE could also be exposed to relative inflation rates, given its unique cost base and its standardized output negating any cost pass-through. HA is more diversified and, so, presumably less sensitive to inflation-induced competitive exposures.

More generally, inflation can affect performance negatively if costs tend to rise faster with inflation than revenues. HG's product prices are pro-cyclical and hence could be assumed to reflect inflation rates in the economy. Whether HG’s cost bases generally have higher inflation rates is hard to determine a priori and is largely an empirical matter.

To summarize, we identify four sources of inflation-risk exposure: inflation in Norway, the EMU, the US, and Canada.

Channels of commercial exposures to interest-rate risk

Interest rates may have an effect on operating cash flow to the extent demand in an industry is sensitive to the cost of capital. This goes for the aluminum industry, where buyers of refined aluminum products are often in very capital-intense industries. The profitability for farmers using Agri’s fertilizers, and therefore their willingness to invest, is also influenced by interest rates given long lead times between crop and harvesting. Accordingly, long-term European and US interest rates could be expected to be important determinants of HAL’s and HA’s commercial interest-risk exposures.

One might also empirically observe a cash-flow sensitivity to the interest rate to the extent that it proxies for the business cycle and the development in aggregate demand. HAL, in particular, is known to be cyclical. However, aluminum prices are pro-cyclical (aluminum betas tend to be around 1.1-1.3), making it an empirical issue whether interest rates or aluminum prices capture this cyclicality. HOE is also partly cyclical but, again, it is uncertain whether interest rates or oil prices best proxy for this.

A third effect on commercial cash flow could arise if the definition of EBITDA includes interest income/expenses from current assets. Hydro does have an item called “Financial expense on operating capital”, which includes factoring costs, so the short-term reference interest rate could have a negative effect on EBITDA. However, the size of this item in 2003, NOK 35Mn, indicates that the size of this exposure is negligible.

To summarize, we identify three sources of interest-risk exposure: the long-term Norwegian, European, and US interest rates.

Step 2: Forecasting macroeconomic and market prices

Risk derives from unexpected changes and estimating exposures to risk thus requires forecasts to base risk on. Considering our frequency of observations, quarterly data, we assume that all variables included follow random walks, which would make all changes unexpected.

Alternatively, since we primarily are working with market risks, forward rates could have been used as market forecasts.

Step 3: Estimating exposures

<u>Data</u>

The MUST analysis is a tool for assessing the exposure of a predefined target variable. This target variable should be selected so as to be consistent with the objective of the firm and its evaluation system. We follow Stein et al in emphasizing EBITDA.[20] The cash-flow data we use are quarterly EBITDA in NOK covering the period 1996:I to 2003:IV, for HOE, HAL, HA, and HG. Data on commodity prices, exchange, interest, and inflation rates are quarterly averages between 1996:I and 2003:IV collected from the EcoWin database.

It is important that the analysis is performed on structurally stable data. If the company or its environment has experienced too many or large fundamental changes, it will be more difficult to extract the information we are looking for from the data set. Although some significant restructurings have been carried out in this period, HG's overall business model have been fairly stable.

Exposure can be estimated using data in levels, first differences, or percentage changes. From an informational point of view it should be noted that information in one dimension easily could be expressed in terms of another, so in that sense the choice is irrelevant. Instead the statistical properties of the time series should guide the decision. As a general principle, time series should be stationary. Further guidance should come from an analysis of the model's error terms. To induce stationarity, regressions were run using data in first differences. Error terms have been subjected to the Breusch-Godfrey test for serial correlation and the Jarque-Bera test for normality.

<u>Results</u>

The results of the exposure assessments are presented in Table 1 (*p*-values in parenthesis). Specifying an acceptable exposure model is a combination of art and science. In our preferred

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[20] See J Stein et al (2001), cited earlier.

exposure models, we have included variables based on their statistical significances and their economic logic relative to HG's operations. Models with higher explanatory value may exist, but then they have weaker economic logic. Brent Crude is the USD reference price for oil produced in the North Sea. The Aluminum price is the USD spot price as quoted on the London Metal Exchange converted to EUR. Urea and Can are fertilizer prices in USD and EUR and NH_3 (in USD) is the price of ammonia. The long-term interest rates are the yields to maturity on 10-year German, Norwegian, and US government bonds. Inflation rates are based on CPI All Items in the US, the EMU, Norway (NO), and Canada (CA) (we do not take first differences on inflation rates as they are already expressed as relative changes). Quarterly dummies are included to control for seasonal cash-flow patterns.

Table 1 Estimated exposure models for Norsk Hydro and its three divisions (1996:I to 2003:IV). Coefficients show average cash flow changes in Mn NOK from one-unit increases (one-percent increases in the case of inflation) in the independent variables.

	HOE	*HAL*	*HA*	*HG*
Intercept	516 (0.05)	-130 (0.30)	3 (0.97)	488 (0.17)
Brent Crude	219 (0.00)		-26 (0.10)	161 (0.03)
Aluminum		3 (0.00)		4 (0.07)
NH_3			3 (0.08)	
Urea			10 (0.01)	22 (0.10)
Can				
NOK/USD	676 (0.13)	-925 (0.00)	240 (0.11)	
NOK/EUR		387 (0.01)		
NOK/CAD				
Gvt 10y US				
Gvt 10y Norway				
Gvt 10 Germany				
Inflation US				
Inflation NO				
Inflation EMU				
Inflation CA				
Q1	51 (0.89)	488 (0.02)	574 (0.00)	788 (0.15)
Q2	-1,006 (0.01)	300 (0.11)	-87 (0.47)	-784 (0.12)
Q3	483 (0.19)	-43 (0.81)	-367 (0.01)	-938 (0.07)
R^2	0.56	0.55	0.82	0.62
SE of regression	700	346	225	967
BG statistic	1.14	0.70	2.95	1.49
JB statistic	9.88	0.18	1.97	0.64

The HOE exposure model indicates a Brent exposure of NOK 219Mn. Hence, on average over the study period, a one-unit increase in the oil price caused HOE's cash flow to increase by NOK 219Mn. This is also our forecast of the relationship between future oil-price changes and cash flow. It is important to note that the coefficients show the marginal exposures to the risk factors, assuming that all other variables in the model are held constant. That is, the 219Mn oil-price exposure is estimated on the assumption that the NOK/USD remains constant. As expected, cash flow increases when the oil price increases and when NOK depreciates against the USD.

HAL's cash flow increases with the EUR price of aluminum and depreciations of the NOK against the EUR, whereas it decreases from depreciations of the NOK/USD. It appears that HAL, contrary to both our and the company's own assumptions, is not long in USD.[21] Our result, a short position in USD, is stable across model specifications and independent of the sample period used. The fact that aluminum is traded in USD motivates Hydro in believing in a long position in USD. However, we believe that transportation costs segment the US and European aluminum markets, making EUR the functional currency of aluminum trading in Europe. If the better part of HAL's revenues are invoiced in EUR, HAL's business would tend to be EUR driven and the fact that the price is nominally set in USD is not relevant in terms of actual exposure. HAL instead has a short position in USD, which could result from HAL believing, and acting accordingly, that it is long in USD.

HA's cash flow is affected negatively by oil-price increases, but positively by increases in the prices of NH_3 and Urea and depreciations of the NOK/USD. HG, finally, gains from increases in the prices of oil, aluminum, and NH_3.

A notable result is the fact that the coefficient on the aluminum price is larger – though not significantly larger – in the HG model (NOK 4Mn) than in the HAL model (NOK 3Mn). This could be a result of the price of aluminum being a proxy for the business cycle and that it captures cyclical effects on other cash flows. Another eye-catcher is the coefficient on Urea in the HG model, which is larger – though once gain not significantly larger – than in the HA model. In the HG model, where NH_3 is excluded, Urea captures the exposure of this variable and the other fertilizer products. Including all three would in this case be superfluous as they compete in expressing the same information.

Steps 4-6: Estimating exposure-based CFaR

To calculate exposure-based CFaR, we need an estimate of the variance/covariance matrix for the risk factors. We use the same dataset as for estimating the exposure models, that is,

[21] In the annual report 2003 (page 85) Hydro writes "[n]ormally, Hydro's operating income will increase when the US dollar appreciates against European currencies and decline when the value of the US dollar falls. To reduce the long-term effects of fluctuations in the US dollar exchange rates, Hydro has issued most of its debt in US dollars". Hydro also estimates the impact of a 1 NOK/USD increase on pre-tax income to be NOK 875Mn.

quarterly averages between 1996:I and 2003:IV collected from the EcoWin database, still assuming that the risk factors follow random walks without trend. Standard deviations and correlations of quarterly first differences are shown in Table 2.

Table 2 Standard deviations and correlations of the independent variables (quarterly changes 1996:I-2003:IV)

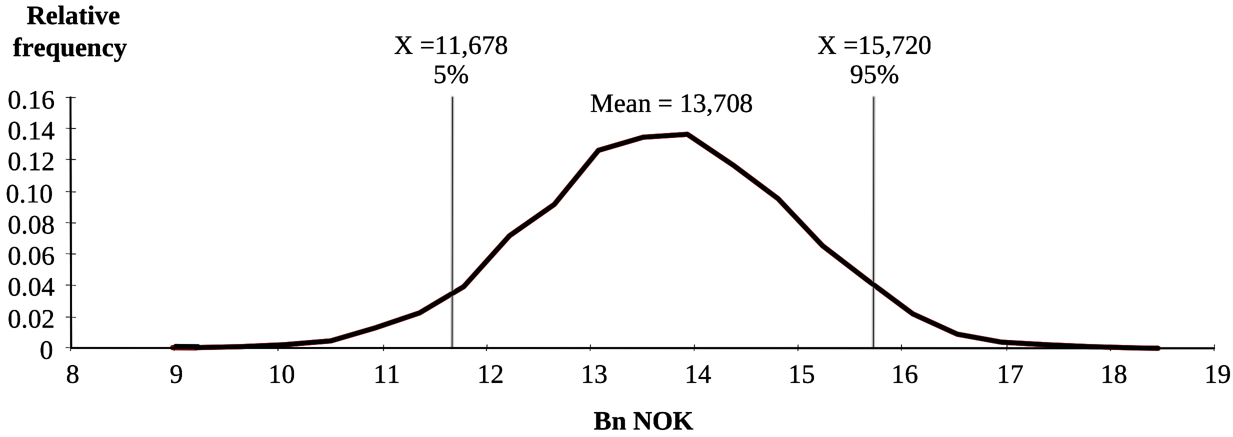
		Correlations				
	Standard deviation	*Aluminum*	*NH_3*	*Urea*	*NOK/ USD*	*NOK/ EUR*
Brent crude	2.9	0.37	0.23	0.21	-0.13	-0.39
Aluminum	86		-0.08	0.01	0.47	-0.35
NH_3	29.6			0.48	-0.30	0.11
Urea	14.6				-0.31	0.06
NOK/USD	0.31					0.17
NOK/EUR	0.19					

Using the variance/covariance matrix, @Risk (a simulation software) is programmed to run 10,000 scenarios of the variables in the forecasting system. Following the methodology outlined in Section IV, Hydro's cash flow is the sum of each of the simulated macroeconomic and market variables multiplied by the relevant exposure coefficient, plus a constant and a simulated value of ε (the standard deviation is given by the standard error of regression from the exposure models). For each of the 10,000 simulations, @Risk recalculates the value of Hydro's cash flow. Doing this, we end up with a distribution for cash flow that is built up from not just the cash-flow sensitivities, but also the expected variances and covariances of the risk factors. In Table 3, we report estimated CFaR's for each of the business areas and Hydro Group. In Figure 1, we show the resulting distribution for Hydro Group's cash flow one quarter hence as estimated in 2003:IV.

Table 3 Exposure-based CFaR estimates for 2004:I (Mn NOK)

	Expected Cash Flow	*95% percentile Cash Flow*	*CFaR*	*CFaR in percent*
	(A)	*(B)*	*(C = A – B)*	*(D = C / A)*
HOE	9,706	8,105	1,601	16.5%
HAL	2,167	1,451	716	33.0%
HA	2,061	1,572	489	23.7%
HG	13,708	11,678	2,030	14.8%

Figure 1 Simulated Distribution for HG's cash flow, 2004:1



How do we interpret the information in Table 3? For example, given the selected confidence level we interpret the CFaR estimate for HG as follows: we are 95% sure that cash flow will not fall short of expected by an amount larger than NOK 2,030Mn. Put differently, in one scenario out of twenty do we expect cash flow to fall below (13,708 – 2,030) = NOK 11,678Mn. We note that in relative terms, HAL's cash flow is associated with the largest risk (33%).

Analyzing exposure-based CFaR

One of the benefits of implementing the exposure-based CFaR is that it opens up rich possibilities for decomposing the CFaR estimate and gaining insights into the cash-flow dynamics of the company and the key drivers of cash-flow risk. One important benefit is the possibilities for understanding the portfolio aspects of corporate risk.

Portfolio aspects appear on three levels. Firstly, we may observe offsetting exposures, so that quantitative information is obtained on natural hedges in Hydro's portfolio of exposures. We have seen that HOE is long in Brent as indicated by the 219Mn exposure coefficient (see exposure models in Table 1), whereas HA has a short position amounting to NOK -26Mn. In a similar manner, the NOK/USD exchange rate, while significant for all business areas separately, doesn't appear to be so in the Group model (*p*-value = 0.25 and excluded due to the diversification). The long positions in HOE and HA appear to be canceled out by HAL's short position in the same exchange rate.

Secondly, the error term (cash flow changes independent of the risk factors) could be correlated across business areas. A correlation between the error terms would indicate that there is a tendency for macro-independent changes to be systematic across business areas. An analysis of the error terms from the models in Table 1 indicates that correlations are generally insignificant, which would mean that macro-independent changes are diversified in the HG portfolio. Notably, the error terms in the HAL and HOE models seem somewhat correlated, which reduces the diversification effect to some extent.

Thirdly, there could be a portfolio effect from being exposed to correlated risk factors. A high correlation between two risk factors will have an impact on estimated CFaR, and the sign of the exposure coefficients determines which way this impact hits. If two risk factors are positively correlated, but the firm is negatively exposed to one and positively to the other, there is a dampening effect on cash-flow risk. Looking at Table 2, we see that correlations are generally low, implying that there is a clear diversification effect. Some of Hydro's product prices do appear somewhat correlated. The correlation coefficient between the two most important ones, oil and aluminum prices, is 0.37. Of all correlations, this one is likely to have the largest bearing on overall risk. Furthermore, Urea and NH_3 have a correlation of 0.48. Another portfolio effect is the fact that not all product prices need be included in the HA and HG exposure models. In the HG model, including Urea seems sufficient to capture exposure to the fertilizer business. Given that these prices are correlated it is, from a perspective of a portfolio of risks, sufficient to measure exposure to one or two fertilizer prices. Managing exposure to a single price that, due to correlations, represents exposure to a whole category of risks, could entail savings in terms of transaction costs.

All in all, the effects of less-than-perfect correlations and natural hedges add up to a risk reduction on the Hydro group level as compared to the risk in the three main business areas. As a measure of this diversification we can compare the CFaR of Hydro Group (NOK 2,030Mn) to the sum of the CFaR's for the three business areas (NOK 2,806Mn) (see Table 3). The difference, NOK 776Mn, can be attributed to the existence of natural hedges and less-than-perfect correlation between residuals and exogenous risk factors.

Hedging CFaR

Another clear benefit of exposure-based CFaR is that evaluation of hedging decisions is greatly facilitated. Management can swiftly evaluate the impact on CFaR from different hedging strategies. The information for deciding the size of the hedge position is contained in the coefficients in the exposure model. For example, in the HA model the indicated exposure to NOK/USD is 240Mn for each unit increase in the exchange rate (see Table 1). If management wishes to neutralize its exposure to this exchange rate for the next quarter it would sell forward exactly this number of dollars. The forward position would then have the same delta as HA's cash flow and they would cancel out, leaving HA's cash flow unexposed.[22]

The effectiveness of these partial hedges in terms of reducing cash-flow risk depends on three things: 1) the size of the exposure, 2) the volatility of the risk factor being hedged, and 3) the correlation between the risk factor being hedged and other risk factors in the model. The effects of 1 and 2 are likely to be the most important ones. Generally speaking, the combined effect of exposure and volatility will determine a risk factor's contribution to cash-flow volatility. We have compared the effects of hedging 100% of the exposure for all variables in the Hydro Group model (in actuality, no forward market exist for Urea, but here we assume it is a hedgeable risk). The base case CFaR is that of HG as reported in Table 3. As indicated by

[22] Again, here we ignore that the coefficients are themselves statistical estimates and thus are associated with uncertainty.

Table 4, hedging the exposure to Brent is the most effective course of action in terms of risk reduction. While Urea has a higher volatility than Brent, Hydro has a much larger exposure to Brent, which is the dominating effect in this case. Exposure to the aluminum price is also relatively large, but the effectiveness of an aluminum hedge is brought down by the relative stability of the aluminum price.

Table 4 Hydro Group's CFaR estimates under different hedging strategies

	Base case CFaR (no hedge)	*Hedged CFaR (100% hedge of each risk factor)*	*Risk reduction in %*
Brent crude	2,030	1,762	13.2%
Aluminum	2,030	1,886	7.1%
Urea	2,030	1,881	7.3%

Filtering out the impact of macroeconomic and market risk

A further decomposition is obtained from distinguishing between macroeconomic risk and macro-independent changes. For Hydro Group, macroeconomic and market risk explains about 62% of the volatility in cash flow (given by R^2). The CFaR conditional on these macroeconomic and market risk factors is estimated to be NOK 1,290Mn, whereas the CFaR estimated from macro-independent changes is NOK 1,591Mn (to see how these respective numbers are estimated, see steps 4 and 5 in the six-step process described in Section 4). The two risk components are not additive, since the error term is defined to be the cash-flow volatility independent of macroeconomic and market risk. Additivity would only come about in the case of perfect correlation. We also observe that while over 50% of cash-flow volatility is explained by the exposure model, this doesn't necessarily mean that the conditional CFaR is higher than the CFaR due to macro-independent changes. This will depend on the degree of volatility and correlation among the explanatory variables in the model relative to the volatility of macro-independent changes.

Estimating the CFaR due to macro-independent changes is the very opposite of what we criticized the RiskMetrics’ definition of CFaR for, namely focusing solely on the conditional distribution. Only by investigating the two distributions jointly do we get an indicator of future uncertainty in cash flow that is meaningful for a corporate manager. The distribution for macro-independent changes represents a sort of maximum-risk-reduction strategy, a distribution where all hedgeable exposures to macroeconomic and market risk have been reduced to zero. That is, by hedging away all its macroeconomic and market risk, the minimum achievable CFaR for Hydro management is NOK 1,591Mn.

6. Conclusions

Existing approaches to calculating CFaR either only focus on cash flow conditional on market changes or neglect market-risk exposures entirely. We argue that an essential initial step in a risk-management program is to quantify cash-flow exposures to macroeconomic and market risk. A fundamental analysis of the channels of corporate exposure is instrumental to this process. The output then forms the input to the estimation of relevant sensitivity coefficients within a multivariate regression framework as suggested by the MUST analysis. This first step should be seen as providing the threshold information for adequate corporate hedging.

However, it is the total level of cash flow in relation to what is needed for investments, meeting interest payments and amortizations, etc that is the information relevant for corporate decision-making. Here we have suggested that the traditional measure of a firm’s overall CFaR should be improved by being based on the sensitivity coefficients generated by the MUST analysis. The merits of such an improvement are illustrated by the case of Norsk Hydro.