Exposure-Based Cash-Flow-at-Risk: An Alternative to VaR for Industrial Companies

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When confronted with the task of valuing companies or projects, corporate finance theorists tend to use two-sided measures of risk such as beta and the standard deviation of returns. But as financial institutions have long recognized, measures of “downside” risk are likely to be more useful for purposes of managing their own risk. It is the “lower tail” of the cash flow distribution that can have costly consequences, such as insufficient 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 corporate managers and many investors, especially creditors.2

The focus of this paper is a measure of downside risk known as Cash-Flow-at-Risk, or CFaR. It is the cash flow equivalent of Value-at-Risk, or VaR, which is widely used as the basis for risk management systems within financial institutions. Whereas VaR-based systems specify the maximum amount of total value a firm is expected to lose under most foreseeable conditions (for example, with a 95% confidence level), CFaR-based systems determine the maximum shortfall of cash the firm is willing to tolerate (again, with a specified level of statistical confidence). CFaR is gaining in popularity among industrial companies for much the same reasons VaR has succeeded with financial firms: it sums up all the company’s risk exposures in a single number that can be used to guide corporate risk management decisions. It is this number—the maximum shortfall given the targeted probability level—and the fact that it can be directly compared to the firm’s risk tolerance that are the uniquely attractive features of both 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, the firm that originally developed CFaR, generally relies on a “bottom-up” approach that attempts to identify cash flow components that are exposed to market risk.3 Their definition of CFaR thus targets cash flow volatility conditional on specified levels of market risk. This approach is useful when management has confidence in its estimates of risk and in its understanding of how changes in market prices affect corporate cash flows. But when there is considerable uncertainty about both the risks and their expected effects on cash flows, management will want to calculate the firm’s overall (as opposed to its “conditional”) CFaR—and for this purpose the bottom-up approach will not work. Moreover, in cases where it is impossible to identify all sources of exposure to market risk, a firm’s total exposure is more accurately measured by its cash flow “delta” (the sensitivity of its cash flow to a small change in the underlying market price). And here again the bottom-up approach cannot provide such a measure.

The authors of a recent article in this journal (hereafter referred to as “Stein et al.”) instead apply a “top-down” approach in which the focus is on overall cash flow volatility.4 In place of bottom-up estimates based on a company’s historical data and line managers’ projections, the top-down method pools cash flow data for a large number of comparable companies to estimate a pooled cash flow distribution. The advantage of such an approach is its ability to provide a historical average exposure estimate that reflects the collective experience of many firms under a variety of market conditions. But this approach also has an obvious limitation in that the firm in question could be very different from the “average” company in the sample. Moreover, the top-down approach does not provide an estimate of CFaR conditional on market risk, nor can it be easily adapted to do so.

Given the limitations of both the top-down and bottom-up methods, our recommendation is to use a third approach—one that we call “Exposure-Based CFaR”—which can be used to calculate both the firm’s overall CFaR and its CFaR conditional on macroeconomic and market

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risks. We argue that our approach is more informative than the top-down approach because knowledge about variability alone is not sufficient for managing risk; the drivers of that volatility must also be understood and their impact on cash flow quantified. At the same time, Exposure-Based CFaR’s ability to take into consideration the total variability of cash flow makes it potentially more informative and useful for risk management purposes than the bottom-up approach.

How does it work? Exposure-Based CFaR involves the estimation of a set of exposure coefficients (deltas) that provide information about how various macroeconomic and market variables are expected to affect the company’s cash flow. We argue that these coefficients can be estimated using a multivariate regression framework for analyzing corporate exposures to macroeconomic and market risks that recognizes the interdependence of such exposures. Hence, we advocate implementing a framework like the MUST analysis. The resulting model of the company’s risk exposures can then be used to calculate its CFaR. Unlike the top-down approach to calculating CFaR, our approach gives management a set of exposure coefficients that can explain the variability in cash flow as a function of various risks; and for this reason, it can also be used to predict how a hedging contract or change in financial structure will affect the company’s risk profile. At the same time, our method also provides information about that part of the firm’s cash flow variability that is not attributable to macroeconomic and market risks, but is necessary to calculate the firm’s overall variability and CFaR.

In the next section of the paper, we review the origins of the at-Risk framework and evaluate the current approaches to measuring CFaR. Then, following a section outlining how we favor measuring corporate risk exposure, we present the Exposure-Based CFaR. Finally, we demonstrate the application of this approach to the case of Norsk Hydro, a Norwegian industrial conglomerate.

Cash-Flow-at-Risk: Existing Approaches

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 aggregate risk of all trading desks across a financial institution. It targets the total risk of any portfolio or financial institution, and makes the aggregate risk of portfolios or companies directly comparable. And although it has received a fair amount of criticism, VaR continues to have considerable popularity with practitioners as well as academics. Moreover, it has been adopted under the Basel II agreement as the method used by bank regulators in determining the amount of risk capital in banks.

But while VaR has met the demand for measures of downside risk in the context of portfolios of financial assets, it is clearly inappropriate for most non-financial firms. If applied to a non-financial firm’s portfolio of financial instruments (debt instruments, swaps, FX contracts, and so on), VaR will capture only a small part of the company’s overall exposure since it ignores the risk of its underlying commercial cash flows. But if VaR itself has only limited applicability for non-financial firms, the “at-Risk” framework is still relevant. And that brings us to CFaR, which represents a transfer of the concept underlying VaR to a setting in which cash flows are the targeted variable.

The derivation of CFaR requires a forecast of the probability distribution of cash flow at some future point in time. The question is how best to generate such a distribution. RiskMetrics does not take a clear stand on this, arguing that the choice depends on the context of each individual firm. But, as mentioned earlier, the dominant method in their literature is the bottom-up approach. Using this approach, one begins with a pro forma cash flow statement in which production volumes, revenues, and costs (typically denominated in the local currency) are the basic building blocks. Random values are then generated for production prices and exchange rates using a variance-covariance matrix, and the resulting prices and rates are inserted into the pro forma statement to calculate conditional values of cash flow in the domestic currency. CFaR is derived from the resulting cash flow distribution.

The bottom-up approach, then, assumes a direct link between production volumes and exchange rates on the one hand and cash flow on the other. But this assumption appears to be contradicted by one of the main conclusions coming out of more than 20 years of research into how and why firms are exposed to macroeconomic and market risks; namely, that total corporate risk exposures are so complex and multifaceted as to defy any attempt at analytical modeling in a pro forma statement. How, for example, would one think about modeling the effect on corporate cash flow of an exchange rate change that influences both the firm’s and its competitors’ input and output prices...and their future sales volumes due to consumers’ responses to price changes,


while at the same time affecting interest rates, which in turn affect the firm’s interest expense and consumers’ willingness to spend money on consumption? Because of these complex linkages and interactions, the exposures that can be meaningfully captured in a pro forma statement are generally only a small part of a firm’s total exposure.

As noted earlier, RiskMetrics’ definition of CFaR focuses on the maximum shortfall attributable to the impact of market risks. By contrast, Stein et al.’s top-down approach is based on the assumption that total cash flow volatility is the ultimate variable of interest. Such volatility can be estimated from a company’s historical cash flows when such data exist. But because the data on any given company’s cash flow might be insufficient to provide a statistically significant estimate of volatility, Stein et al. call for the pooling of cash flow data for a large number of firms in order to arrive at a volatility estimate that is statistically reliable.

Using the Compustat database, they obtain some 85,000 observations of EBITDA (earnings before interest, taxes, depreciation, and amortization) using just six years of company data. The authors then identify four characteristics with significant explanatory power for predicting patterns in unexpected changes in EBITDA in their sample: size, profitability, riskiness of industry cash flow, and stock price volatility. On the basis of these key characteristics, they sort all the firms into pools of comparable companies. The pooled cash flows for the comparable companies are then used to calculate each firm’s cash flow distribution. Thus, while this approach aggregates data for a large number of companies, the results are applied to individual firms in a way that reflects these four key characteristics.

We agree that total variability in cash flow is the most important aspect of a CFaR analysis for risk management purposes. From a managerial perspective, a distribution that is entirely conditional on market variables is less useful than one that captures all sources of variability in cash flow.9 As Ken Froot and David Scharfstein have argued, the main objective of a risk management program should be to ensure that enough internally generated cash is available to fund the firm’s investment program.9 Here again, it is total variability—and not some conditional version of it—that matters in ensuring such an outcome.

But even if variability in total cash flow is of greatest importance, it is also important to understand the sources of such volatility. And this requires a measure of CFaR that is conditional on the firm’s major market risks. Conditional CFaR tells managers how much cash flow is at risk, given the specified probabilities associated with fluctuations in macroeconomic and market factors such as interest rates, exchange rates, and key commodity prices. And for this reason, CFaR can also be used to evaluate how the expected future distribution of cash flow would be affected if, for example, an option contract were used to reduce a specific exposure. It can 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. cite the simplicity of targeting total cash flow volatility as one of the virtues of their approach. But we would qualify their argument as follows: 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.

**Measuring Commercial Exposures to Macroeconomic and Market Risk**

The quantification of exposure to risk is the essential first step in a CFaR analysis, and it is important to perform this exercise correctly. We believe that the use of pro forma cash flow statements to model risk exposures tends to yield biased results because (1) it ignores more subtle ways in which different risk factors affect cash flows and (2) it is very difficult to deal with more than one exposure at a time. In reality, risks operate on cash flow in many ways, few of which lend themselves to mathematical specification, and such risks often have interdependent effects that can either accentuate or offset each other.

Take the case of exchange rate risk. In this case, pro forma-based exposure measures are usually derived by looking at outstanding contractual obligations such as accounts payable and receivables. The level of cash flow in domestic currency is exposed here to exchange rate risk only when converting foreign currency payables and receivables. The problem, however, is that this way of measuring exposure ignores possible shifts in competitiveness that can result from shifts in exchange rates. For example, if a company’s product is priced in a currency that appreciates, the product will become more expensive on world markets, possibly leading to a drop in demand.

Even when bottom-up modeling attempts to reflect such competitive exposures by introducing more complex relationships between exchange rates and cash flow, such modeling has a tendency to ignore the simultaneous impact of exchange rates and the effects of other macroeconomic and market variables such as interest rates, inflation, and commodity prices. What’s more, since macroeconomic price variables are determined in a general equilibrium system that simultaneously adjusts to shocks in the economy, there is a

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9. Consistent with this objective, R. Stulz has proposed that the proper goal of corporate risk management is “the elimination of costly lower-tail outcomes, which is designed to reduce the expected costs of financial distress while preserving a company’s ability to exploit any comparative advantage it may have”; R. Stulz (1996), cited earlier.
tendency for macroeconomic variables to covary that will influence the degree to which a firm is exposed to macroeconomic risks. And this means that, from the firm’s point of view, the effects of inflation, interest rates, and exchange rates on cash flows can be partly or wholly offsetting.

We argue that CFaR can be improved by undertaking a more careful analysis of the drivers of corporate macroeconomic exposure, one that takes account of interdependencies among different macroeconomic and market variables and the various channels through which such variables affect corporate cash flows. Our approach begins with a fundamental analysis of the company’s exposure to changes in the macro economy. Such analysis attempts to provide answers to important questions about the currency composition of the company’s sales, production costs, and input purchases, its positions in the factor and output markets and bargaining power relative to suppliers and customers, the sensitivities of its customers to 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. As stated, such a fundamental analysis of the company’s exposures, and of relative exposures in the industry, can provide valuable information about potentially important drivers of the company’s performance.

The output of such analysis takes the form of a multivariate regression of relevant macro and market variables on corporate cash flow that looks as follows:

$$X_{t}^{DC} - E_{t-1}[X_{t}^{DC}] = \beta_0 + \beta_1 \left( \pi_t^{DC} - E_{t-1}[\pi_t^{DC}] \right) + \beta_2 \left( r_t^{FC} - E_{t-1}[r_t^{FC}] \right) + \beta_3 \left( S_t^{DC/FC} - E_{t-1}[S_t^{DC/FC}] \right) + \beta_4 \left( i_t^{DC} - E_{t-1}[i_t^{DC}] \right) + \beta_5 \left( i_t^{FC} - E_{t-1}[i_t^{FC}] \right) + \beta_6 \left( P_t^{DC} - E_{t-1}[P_t^{DC}] \right) + \epsilon_t$$

where $X_t^{DC}$ is the cash flow in domestic currency (DC) in period $t$, and the market variables might include a measure of inflation ($\pi$), the spot exchange rate ($S^{DC/FC}$), interest rates ($i$), and, where relevant, a key commodity price ($P$). Because risk derives from random, unexpected deviations from forecasts, expected or forecasted values ($E_t[.]$) are included to capture forecasted or expected developments of the market variables in each period. The coefficients produced by such a regression provide measures of exposure that can then be put to three uses: (1) determining the size of hedge contracts that will reduce or eliminate the company’s exposure; (2) adjusting historical cash flows to filter out the impact of macroeconomic and market risks; and (3) providing the basis for a CFaR calculation.

**Exposure-Based CFaR**

As stated earlier, the total variability of cash flow is, from a managerial perspective, the relevant target variable. This total variability can be attributed to a number of different factors, including fluctuations in exchange rates, interest rates, inflation rates, and commodity prices. In assessing exposures, 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 is 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 $1 - R^2$.

To derive a conditional distribution of cash flow, the regression model must be used together with the variance/covariance matrix of the macroeconomic and market variables identified in the exposure model. We apply simulations in which the values for the various explanatory variables are picked randomly from the variance/covariance matrix. In each of these iterations, the randomly picked values are inserted into the regression model to generate 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 estimate 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 ($N[-0, \sigma^2]$) and add that value to the conditional distribution.

To summarize, then, the calculation of Exposure-Based CFaR is a six-step process:

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 the price and wealth sensitivities of its customers.

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11. Actually, there is one additional source of variability that we do not take into consideration. The coefficients in the regression model 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.
2) Acquire or generate forecasts of the identified macroeconomic and market variables.

3) Estimate the exposure model. This is a process where knowledge of corporate fundamentals and statistics interact to derive a model that has both a plausible economic theory behind it and good statistical properties (high explanatory value, statistical significance, and well-behaved error terms).

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

5) Insert the simulated values in the exposure model to derive both a conditional distribution of cash flow—one that reflects the effects of just macroeconomic and market volatility—and a distribution of cash flow that reflects all other non-macroeconomic sources of volatility (the error term).

6) Combine the two cash flow distributions into a single distribution, determine the targeted confidence level, and then calculate CFaR.

The Case of Norsk Hydro

We now demonstrate the application of Exposure-Based CFaR to an actual company, Norsk Hydro, a Norwegian industrial conglomerate headquartered in Oslo, during the period 1996 to 2003. Our analysis uses as the target cash flow variable EBITDA, which effectively excludes the effect of financing and hedging decisions. We follow the six-step process just described, starting with an investigation of the potential exposure to macroeconomic and market risks of each of Hydro’s main businesses.

Hydro’s strategy throughout the 1990s was to focus on three main business areas: oil and gas, aluminum, and fertilizers. In 2002, it acquired the German aluminum maker VAW, establishing itself as one of the world’s three largest integrated players in the aluminum market. In 2003, the company’s total operating revenues were NOK (Norwegian krone) 172 billion (or roughly US$25 billion). Of that total, the oil and gas division (Hydro Oil & Energy, or HOE) accounted for 35%, Hydro Aluminum (HAL) for 30%, the fertilizer business Hydro Agri (HA) for 13%, and other activities made up the remaining 3%. We now turn to the application of the six-step CFaR exposure analysis to Hydro’s three main businesses.

Step 1: Analyzing Sources of Commercial Exposure

In the analysis that follows, we consider four major sources of macroeconomic and market risk faced by Hydro in 2003: commodity prices, exchange rates, inflation rates, and interest rates.

Channels of commercial exposures to commodity-price risk. A large part of HOE’s commercial output is exposed to changes in 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 that of 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 was only a minor exposure to the spot price of gas since HOE’s portfolio of gas contracts consists mainly of long-term contracts written with reference to the oil price.

In 2003, HAL produced a total of 1.5 million tons of aluminum. The company’s exposure to aluminum prices 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 buyer basically a price taker. HAL also has a large downstream sector that refines and then sells aluminum to the car and aviation industries, among others. HAL competes mainly with two other integrated aluminum producers, Alcoa in the U.S. and Alcan in Canada. Because aluminum production is an energy-intensive process, HAL has a large exposure to energy prices on the cost side, but its exposure to the spot price of electricity is managed through the use of long-term purchase contracts.

The market for fertilizers has a huge number of players, each with only a small slice of total market share. HA, although the world leader, has a global share of no more than 6%. In Western Europe, HA has a market share of 25% in nitrate fertilizers, for which urea and CAN (calcium ammonium nitrate) serve as reference prices. There are numerous fertilizers and related products in HA’s product portfolio and the business operates in about 50 countries, and sells to over 100 countries worldwide, implying a very complex market setting. Ultimately, though, all 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 as a primary input, and ammonia production in turn requires significant amounts of natural gas. An increase in the price of gas (which is highly correlated with light sulphate fuel oil, an oil derivative) tends to be passed through to ammonia, which in turn is passed through to urea and CAN. The degrees of pass-through, which depend on a lot of factors and vary over time, determine the extent
of 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 facing Hydro in 2003: the prices of oil, aluminum, urea, CAN, and ammonia.

Channels of commercial exposures to exchange rate risk. The oil price is a world commodity with the reference price set in U.S. dollars, while HOE’s cost base is heavily concentrated in Norway. The non-Norwegian share of Hydro’s oil production is on the rise, but accounts for only 11% of total production. The strength of the Norwegian kroner (NOK) to the U.S. dollar should thus be a positive determinant of Hydro’s performance relative to the industry.

The world aluminum price is also set in U.S. dollars. HAL’s aluminum production is sold mainly in Europe and invoiced in euros. HAL’s upstream production has a large portion of its cost base in Norway, making the NOK/euro rate important. Downstream production and sales are largely located in the European market, but with some production in Norway; and while HAL and its main competitors compete in the same product markets, they have their main cost bases in different currencies. Thus, to the extent the NOK weakens against the U.S. and Canadian dollars, this would tend to benefit HAL relative to its competitors, particularly in downstream operations.

Roughly speaking, the reference price for urea is set in U.S. dollars, whereas CAN has its reference price in euros, but the U.S. dollar is considered to be the functional currency for both commodities. HA’s sales are mainly invoiced in U.S. dollars and euros, but parts are invoiced in local currencies. This creates a situation in which there is a short-term transaction exposure to a number of local currencies, but where the underlying exposure should be to the U.S. dollar. Competitive effects of exchange rates are known to exist. For example, changes in the USD/euro rate alter the relative attractiveness of urea and CAN, two fertilizer products that are of differing quality but essentially substitutes. As for currency exposures include the interest income and 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 of its local cost base and standardized output in negating any cost pass-through. By contrast, HA is more diversified and thus 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. All of Hydro’s product prices are pro-cyclical and hence could be assumed to reflect inflation rates in the economy. But whether the company’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 exposure to inflation risk: inflation in Norway, the European Union, the U.S., and Canada.

Channels of commercial exposures to interest rate risk. Interest rates can have an effect on operating cash flow to the extent demand in an industry is sensitive to the cost of capital. This clearly applies to the aluminum industry, where buyers of refined aluminum products are often in very capital-intense industries, and for farmers using Agri’s fertilizers, as agriculture is also capital intensive. Accordingly, long-term European and U.S. interest rates could be expected to be important determinants of HAL’s and HA’s commercial interest rate 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. Aluminum prices are pro-cyclical (the aluminum price is highly correlated with industrial production), 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 provide the best proxy for this cyclicality and risk.

A third effect of interest rates on commercial cash flow could arise if our definition of EBITDA were changed to include the interest income and 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 35 million, indicates that the size of this exposure is negligible.

To summarize, we identify three sources of interest rate exposure: Norwegian, European, and U.S. long-term interest rates.

Step 2: Forecasting Macroeconomic and Market Prices Risk derives from unexpected changes in macro and market variables, and the estimation of exposures to risk
thus requires forecasts of such variables. Given our use of quarterly data, we assume that all variables included follow random walks, which means that all changes are unexpected. But since we are working primarily with market risks, the use of forward rates as market forecasts is also a reasonable alternative.

Step 3: Estimating Exposures

Data. As discussed earlier, the target variable used when assessing exposures should be consistent with the objective of the firm and its evaluation system. We follow Stein et al. in emphasizing EBITDA. The cash flow data we use are quarterly EBITDA in NOK for each of the three main businesses (HOE, HAL, and HA) as well as the entire company (HG) starting with the first quarter of 1996 and running through the end of 2003. Our data on commodity prices, exchange, interest, and inflation rates are quarterly averages over the same period collected from the EcoWin Economic and Financial database.

It is important that the analysis be 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 has been fairly stable.

Results. The results of the exposure assessments are presented in Table 1. Specifying an acceptable exposure model is a combination of art and science. Our preferred exposure models include variables with a strong basis in economic theory that are supported by empirical evidence. In other words, to gain acceptance from top management, a risk management model must have not only statistical backing, but a clear and compelling logic as to how we would expect the main variables to affect the company’s cash flow.

In defining the key relationships in our model, we chose Brent Crude as the U.S. dollar reference price for oil produced in the North Sea. The aluminum price is the U.S. dollar spot price as quoted on the London Metal Exchange. Urea and CAN fertilizer prices are in U.S. dollars and euros, and the price of ammonia is in U.S. dollars. The long-term interest rates are the yields to maturity on ten-year German, Norwegian, and U.S. government bonds. Inflation rates are based on CPI All Items in the U.S., the European Union (EMU), Norway (NO), and Canada (CA). Quarterly dummies are included to control for seasonal cash flow patterns.

Our HOE exposure model indicates a Brent exposure of NOK 219 million. This means that, over the eight-year period we examined, a one dollar increase in the oil price was accompanied, on average, by an increase in HOE’s cash flow of NOK 219 million. 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 NOK 219 million oil price exposure is estimated on the assumption that the NOK/USD exchange rate remains constant. As expected, cash flow increases both when the oil price increases and when the Norwegian krone depreciates against the U.S. dollar.

The results in Table 1 also confirm our expectation that HAL's cash flow will increase with increases in the euro price of aluminum and with depreciations of the NOK against the euro. Somewhat surprisingly, however, our results suggest that the aluminum division's cash flows decline in response to depreciations of the NOK/USD. Thus, it appears that HAL, contrary to both our and the company's own assumptions, does not have an effective long position in U.S. dollars. Moreover, our finding of a short position in U.S. dollars may actually result at least in part from management's belief—and the actions based on that belief—that the division is long U.S. dollars.

As we expected, HA's cash flow is affected negatively by oil price increases, but positively by increases in the prices of ammonia and urea and depreciations of the NOK/USD. Finally, the entire company appears to have long positions in oil, aluminum, and ammonia.

One notable finding is that the coefficient on the aluminum price is slightly larger for the entire company (HG = NOK 4MM) than for the aluminum business (HAL = NOK 3MM). This result suggests that the price of aluminum functions partly as a proxy for the business cycle and captures cyclical effects on other cash flows. The same is true of the coefficient on ammonia in the HG model relative to its coefficient in the HA model. In the HG model, which excludes urea, ammonia captures the exposure of this variable and that of the other fertilizer products.

### 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 data set used for estimating the exposure models—that is, quarterly averages from 1996-2003 collected from the EcoWin database—while continuing to assume that the risk factors follow random walks without trend. Standard deviations and correlations of quarterly first differences are shown in Table 2.

Using the variance/covariance matrix summarized in Table 2, we programmed a simulation software called @Risk to run 10,000 scenarios of the variables in the forecasting system. Following the methodology outlined in the previous section, we used the software to estimate Hydro's cash flow for each of the 10,000 simulations as a function of the simulated macroeconomic and market variables multiplied by the relevant exposure coefficients. By so doing, we ended up with a distribution of expected cash flow that reflects not just the cash flow sensitivities to each of the individual

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16. Hydro's 2003 annual report (p. 85) states, "Normally, Hydro's operating income will increase when the U.S. dollar appreciates against European currencies and decline when the value of the U.S. dollar falls. To reduce the long-term effects of fluctuations in the US dollar exchange rates, Hydro has issued most of its debt in U.S. dollars." Hydro also estimates the impact on pre-tax income of a one-unit NOK/USD increase to be NOK 875MM.
risk factors, but also the expected variances and covariances of those risks. And the resulting distribution of cash flow in turn enabled us to estimate the CFaRs for the next quarter (Q1 2004) for each of the three business areas that are summarized in Table 3 and depicted graphically for the company as a whole in Figure 1.

How do we interpret the information in Table 3? As an example, given our selected confidence level of 95%, we interpret the CFaR estimate for HG as follows: we are 95% certain that the company’s cash flow will not fall short of the expected amount of NOK 13,814 million by more than NOK 2,002 million. In other words, we expect cash flow to fall below NOK 11,812 million (13,814 – 2,002) in only one scenario out of 20. Also clear from Table 3 is that, of the three main businesses, HAL’s cash flow is associated with the largest risk (31%).

Analyzing Exposure-Based CFaR
Exposure-based CFaR opens up rich possibilities for decomposing the CFaR estimate into individual risk exposures, thereby providing insights into the cash flow dynamics of the company and the key drivers of risk. In particular, the method allows for a clearer view of the portfolio aspects of corporate risk.

Portfolio considerations exist on three levels. First, there may be offsetting exposures, or what amount to natural hedges, in Hydro’s portfolio of exposures. For example, HOE has a long position in Brent crude, as indicated by the 219 million exposure coefficient (see exposure models in Table 1), whereas HA has an offsetting short position amounting to NOK -26 million. And while the NOK/USD exchange rate is significant for each of the three business areas when viewed separately, there is no significant exposure for the company as a whole (HG) (p-value = 0.25). Thus, the long positions of HOE and HA in U.S. dollars appear to be canceled out by HAL’s short position.

Second, the error terms in the regressions—which reflect 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 the correlations are generally insignificant, which suggests that the macro-independent changes in cash flows are diversified in the HG portfolio.

Third, there could be a portfolio effect from exposures 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 whether the overall net impact is positive or negative. 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 the correlations among risk factors are generally low, implying that there is a clear diversification effect. But some of Hydro’s product prices do appear somewhat correlated. For example, the correlation coefficient between the prices of the company’s two main commodities—oil and aluminum—is 0.39. Of all the correlations, this one is likely to have the largest bearing on
overall risk. Furthermore, urea and ammonia have a correlation of 0.48.

Another insight that comes from taking a portfolio view of risk is that, in some cases, not all product prices need be included in the exposure models. In the HG model, for example, the inclusion of ammonia alone seems sufficient to capture the entire commodity price exposure of the fertilizer business. In such a case, managing exposure to a single price that, because of high correlations, represents exposures to a whole category of risks could mean major savings in terms of transaction costs.

All in all, then, the effects of less-than-perfect correlations and natural hedges add up to lower risk at the Hydro Group level than the sum of the risks in the three main business areas. As a measure of this diversification benefit, the CFaR for Hydro Group reported in Table 3 is NOK 2,002 million, considerably lower than the sum of the CFaRs for the three business areas (NOK 2,759MM). The difference of NOK 757 million can be attributed to the natural hedges provided by the less-than-perfect correlations between the risk factors and their residuals.

Hedging CFaR
Another benefit of Exposure-Based CFaR is its ability to inform hedging decisions. Using the CFaR methodology, management can readily assess the impact on cash flow variability of different hedging strategies. Indeed, much if not all of the information necessary 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 240 million for each krone depreciation to the dollar (as shown in Table 1). This means that 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.\(^{17}\)

For example, if the krone were to depreciate by 0.10 krone to the dollar, cash flow would increase by 24 million. But the forward position would fall equally in value, neutralizing the effect on Hydro’s cash flow.

The effectiveness of such partial hedges in terms of reducing cash flow risk depends on three factors: (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 first two effects 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 reality, there is no forward market for ammonia, but we assume the risk is hedgeable). The base case CFaR is the number reported for HG in Table 3. As indicated by Table 4, hedging the exposure to Brent is the most effective way of reducing risk (provided that is management’s goal). While ammonia 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 effect of an aluminum hedge on risk is limited by the relative stability of the aluminum price.

Filtering Out the Impact of Macroeconomic and Market Risks
A further decomposition of exposures can be made by distinguishing between the effects of macroeconomic risk and “macro-independent” changes. For Hydro Group, macroeconomic and market risks account for about 69% of the variability in cash flow (as measured by R\(^2\)). The CFaR conditional on these macroeconomic and market risk factors is estimated to be NOK 1,385 million, as compared to the CFaR estimated from macro-independent changes of NOK 1,444 million (to see how these respective numbers are estimated, see steps 4 and 5 in the six-step process described earlier). The two risk components should not be viewed as additive, or summing to a whole, 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 two-thirds 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.

But as stated earlier, we feel that an exclusive focus on either conditional CFaR or total (“macro-independent”) CFaR is likely to be a mistake. Only by examining both of these distributions can corporate managers get a meaning-

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17. Again, we ignore the fact that the coefficients are themselves statistical estimates and thus associated with uncertainty.
ful indicator of uncertainty about future cash flow. An exclusive focus on the distribution of macro-independent changes could lead to a maximum risk-reduction strategy, one in which all hedgeable exposures are reduced to zero. By hedging all its macroeconomic and market risk, the company could reduce the CFaR for Hydro to NOK 1,444 million (the CFaR from macro-independent changes alone).

Conclusion
Cash-Flow-at-Risk, or CFaR, is the cash flow equivalent of Value-at-Risk, or VaR, which is widely used as the basis for risk management systems within financial institutions. CFaR is gaining in popularity among industrial companies for much the same reasons that VaR has succeeded with financial firms: it sums up all the company’s risk exposures into a single number that can be used to guide corporate hedging decisions.

The two most popular approaches to calculating CFaR—one “bottom up” and the other “top down”—tend to focus either on cash flow conditional on market changes or on total variability, with little attempt to isolate specific exposures. Our approach, which we call Exposure-Based CFaR, involves the estimation of a set of exposure coefficients that provide information about how various macroeconomic and market variables are expected to affect the company’s cash flow, and that also attempt to take account of inter-dependencies and correlations among such effects. Unlike the top-down approach to calculating CFaR, the resulting model of the company’s risk exposures gives management a set of exposure coefficients that are capable of explaining the variability in cash flow as a function of various risks; and for this reason, it can also be used to predict how a hedging contract or change in financial structure will affect the company’s risk profile. At the same time, our method also provides information about that part of the firm’s cash flow variability that is not attributable to macroeconomic and market risks, but is necessary to calculate the firm’s overall variability and CFaR.

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