Identifying and quantifying exposures

by

René M. Stulz and Rohan Williamson*

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* René M. Stulz is Reese Chair in Banking and Monetary Economics, Ohio State University Research Associate at the National Bureau of Economic Research, and Bower Fellow, Harvard Business School; Rohan Williamson is a Ph.D. student in the Finance Department at the Ohio State University.
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Abstract

The paper first examines the various concepts of exposure and relates them to existing theories of risk management. It then proceeds to investigate which methods are best suited to measure exposure under various circumstances. The paper provides a detailed comparison of the pro forma, regression and simulation methods of computing exposures.
**Section 1. Introduction.**

The current value of a firm is the present value of its future cash flows. The central proposition of risk management theory is that firm value can be increased by taking financial positions that pay off when the firm’s cash flow is lower than required for the firm to pursue its objectives.¹ To be able to implement a successful risk management policy, one must therefore know how the firm’s cash flow is affected by risks that can be hedged. In the language of risk management, one must know the firm’s exposures. A firm’s cash flow exposure to a specific risk is a quantitative measure of how the cash flow is related to that risk. If one knows the firm’s exposure to an interest rate, one can tell by how much the firm’s cash flow changes if that interest rate changes, for instance, by 10 basis points. This tells us how we can reduce the volatility of the firm’s cash flow by hedging it against unanticipated changes in that interest rate. In this chapter, we explain how exposures can be identified and quantified.

To understand the issues we address, let’s look at a simple example. Consider a firm, say XYZ, that has good investment opportunities. Its shareholders would lose if it cannot take advantage of these investment opportunities. Suppose then that the firm’s cash flow is random. If cash flow turns out to be low, XYZ cannot finance its investments out of internally generated funds. It must therefore go to the capital markets. Doing so may be expensive; in fact, it could in some cases be so expensive that the firm would choose to invest less rather than go to the capital markets. With this scenario, the firm’s shareholders would want the firm to find a way to have enough resources so that it can exhaust its valuable investment opportunities. In this example, we

¹ See Stulz (1998) for a complete analysis of how risk management can be used to increase firm value.
know the loss incurred if cash flow is too low, namely the firm cannot invest as much as would be profitable. If the firm has more cash flow than it can use profitably when cash flow is high, a risk management policy that reduces the variance of cash flow at low cost increases firm value.

Consider a simple risk management policy whereby XYZ enters a financial contract such that it receives cash when its cash flow is low and pays cash when its cash flow is high. As long as this financial contract is fairly priced, this risk management policy increases the value of firm XYZ because it insures that it does not miss out on profitable investment opportunities.

How can XYZ implement this risk management policy? To start with, it has to know the distribution of its cash flow. However, by itself, the distribution of cash flow is not very useful. Suppose that XYZ management finds out that there is one chance out of 20 that its cash flow will be low enough that its investment strategy cannot be implemented. This information tells XYZ management that there are benefits to risk management. However, to achieve these benefits, XYZ management must find out how the cash flow is affected by risks that XYZ’s management can hedge through financial transactions. In the language of risk management practice, the firm must find out its exposure to risks that can be hedged. Knowing these exposures allows XYZ to hedge. Any mistake in quantifying a firm’s exposures may lead the firm to adopt inappropriate hedges. With the wrong hedge, risk management can increase rather than decrease the volatility of cash.

In Section 2 of this paper, we use firm XYZ as an example and investigate the types of risks it might be exposed to. In Section 3, we look at cash flow projections and how they can be used to quantify the risks that XYZ is exposed to. Section 4 shows how information in past stock

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2 Smith and Stulz (1985) and Froot, Scharfstein and Stein (1993) provide theories of when and how risk management can increase value.
returns and cash flows can be used to quantify exposures. Section 5 investigates the use of simulation methods to measure exposures. Section 6 concludes.

**Section 2. The exposures of XYZ.**

Let’s suppose that XYZ is a car producer in the U.K. that exports parts of its production to the U.S. Table 1 shows an extremely simplified cash flow to equity statement for XYZ for 1996. To simplify the numbers, we assume that a pound is worth two dollars and that the tax rate is 25%. In 1996, the car producer exports half of its production to the U.S. and sells the remainder in the U.K. We would like to understand the distribution of future cash flows. This is a complicated undertaking because the cash flow for each year can be affected by a large number of variables. Some of these

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variables are directly under the control of management of XYZ. XYZ management has plans for the firm. For instance, it might have decided to expand production by building a new factory that comes on stream in three years. However, other variables are not under the control of management. Some of these variables are specific to XYZ. For instance, a factory could be destroyed by fire or a strike could take place that would immobilize a factory for a long period of time. Such risks are unique to XYZ. They can be quantified but there are no financial instruments that XYZ could use to hedge these risks. XYZ can reduce these risks in a variety of ways. For instance, it can install sprinklers and various fire alarms to minimize the danger of losing a plant to a fire. Once it has taken such protective measures, the only way that XYZ can protect itself further against such risks is through insurance contracts that are written specifically against contingencies faced by XYZ alone.

Another possible risk that could affect XYZ alone is if a creditor defaults. In this case, XYZ’s cash flow will be lower than expected. If XYZ has many different creditors and none is too important to its cash flow, it is most likely that credit risks will be diversifiable for XYZ. In other words, whereas there is some risk that a creditor will default, considering all creditors together the number and size of defaults will be highly predictable. In this case, it will make no sense for XYZ to try to protect itself against individual defaults because these defaults are not a source of risk when one looks at XYZ’s overall cash flow. If a firm has some large creditors, it becomes unlikely that credit risks will be diversifiable. These risks will not be market risks, however, in the sense that there will not be a broad-based market where they will be traded. The risk of default from a specific creditor depends on circumstances unique to that creditor. Hence,
to protect itself completely against the default of a specific creditor, the firm would have to enter a contract that is akin to an insurance contract. The probability that a specific creditor defaults will, most likely, be correlated with market-wide risks - a specific creditor is more likely to default when the economy is doing poorly than when it is doing well. This means that some protection against default risks can be obtained by trading in financial instruments whose value depends directly on market-wide price movements.

In addition to risks that affect it only, XYZ faces risks that affect other firms as well. For instance, a depreciation of the dollar means that for a constant dollar price of its cars in the U.S. XYZ will receive fewer pounds. An increase in the price of crude oil means that the demand for cars will fall and XYZ’s sales will drop. Broad-based risks corresponding to random changes in prices of macroeconomic variables such as exchange rate changes are called market risks. They are not under the control of individual firms and correspond to market prices that affect the economy as a whole. These risks can be managed with financial instruments that can be used for hedging purposes by a large number of firms. An example of such a financial instrument would be a forward contract on the dollar. The payoff of such a financial instrument does not depend at all on XYZ. However, XYZ can sell dollars forward to reduce the dependence of its pound income on the dollar exchange rate. To do that, XYZ has to figure out the size of the forward position that hedges its exchange rate risks. This position will depend on how changes in the exchange rate affect XYZ’s cash flows. The extent to which changes in the exchange rate affect XYZ’s cash flows is called XYZ’s exposure to the exchange rate.

Consider XYZ’s cash flow for 1998. Let’s consider a base case of constant exchange rates and no inflation. Let’s assume that XYZ will export 22,000 cars to the US in 1998 and sell each
car for $20,000. It will also sell 22,000 cars in the U.K. Suppose that there is no other source of uncertainty in XYZ’s cash flow. In this case, XYZ will receive $440m in 1998. The pound value of this amount will be $440m times the pound price of the dollar. If the only effect of a change in the exchange rate for XYZ is to change the pound value of the dollar sales, then $440m is the dollar exposure of the cash flow. Multiplying the exchange rate change by the exposure yields the cash flow impact of the change in the exchange rate.

Exposure measures are like dollar duration measures. Dollar duration provides an estimate of the dollar change in the value of a bond for a small yield change. It therefore measures the exposure of the bond to yield changes. Exposure to a specific market risk measures the dollar change in the value of a cash flow (\( \Delta \text{cash flow} \)) or a financial asset for a unit change in that market variable (\( \Delta M \)):

\[
\text{Exposure to } M = \frac{\Delta \text{Cash flow}}{\Delta M}
\]

With our example, exposure to the exchange rate is equal to $440m \times \frac{\Delta M}{\Delta M} = $440m, where \( \Delta M \) is the change in the exchange rate. Suppose that the dollar appreciates 10%, so that its price in pounds goes from 0.5 to 0.55. In this case, the cash flow impact of the appreciation is an increase in cash flow equal to 440m \times 0.05, which is £22m. This number is obtained by multiplying the exposure by the pound change in the price of the dollar.

2.1. Exposure Horizons

The nature of a firm’s exposures changes as the period for which one computes the
exposure is farther in the future. To see this, suppose first that we compute XYZ’s exposure to
the dollar exchange rate for its next quarterly cash flow. Most of that exposure is fixed. It depends
on transactions that have already been undertaken. For instance, the cars that will be sold in the
U.S. during this quarter are already there, the prices have already been agreed upon with the
dealers, and so on. In the short-run, most cash flow exposure is transaction exposure and
transaction exposure is measured quite precisely by the accounting system. Transaction exposure
is the extent to which the value of transactions already entered into is affected by market risks.

Next, suppose we consider the exposure of XYZ for the quarterly cash flow four quarters
from now. The firm’s exposure will consist of two components. One component will still be
transaction exposure resulting from booked transactions. For instance, XYZ might receive or
make payments in dollars that are already contracted for and booked today. It might have dollar
debt requiring coupon payments at that time. The other component will be contractual exposures
that are not associated with booked transactions. XYZ will have contractual agreements, implicit
or explicit, that affect its exposure at that horizon. For instance, it might have made commitments
to dealers about prices. Even though these commitments do not result in booked transactions,
they cannot be changed easily if at all. Such commitments create contractual exposures. These
exposures do not show up on the firm’s balance sheet, yet any change in the exchange rate affects
the value of the firm through its effect on the domestic currency value of these commitments.

With contractual exposures, the foreign currency amount of the exposure is generally fixed
and is not affected by exchange rate changes. For instance, if XYZ has promised to deliver a fixed
number of cars to dealers in the U.S. at a fixed dollar price, this creates a contractual exposure.

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3 See Lessard (1979), pp. 349-365, for an early treatment of this issue.
The pound value of the payments from the dealers is simply the dollar value of these payments translated at the exchange rate that prevails when the payments are made. For such an exposure, the relevant exchange rate is the nominal exchange rate at the time of these payments.

Let’s now look at the exposure of cash flows three years from now. Very little of that exposure is contractual exposure. In fact, as the exchange rate changes, XYZ can change its production, marketing, sourcing strategies. If the exchange rate changes so that keeping sales in the U.S. constant is not profitable, then XYZ can change its sales in the U.S. It can develop new markets or new products. The exposure at long horizons is a competitive exposure. Changes in market prices such as exchange rates affect the firm’s competitive position. The nature of the exposure therefore depends on the markets in which the firm does business. Others have called this exposure an operating exposure or an economic exposure. Contractual losses due to exchange rate changes are economic losses, which makes the concept of economic exposure not adequate to describe the exposure we have in mind. Operating exposure ignores the strategic implications of exchange rate changes - exchange rate changes do not affect only the profitability of current operations but what the firm does and where it does it. Although in our discussion of competitive exposures we focus mostly on exchange rate competitive exposures, the firm’s competitive position is generally affected by changes in other market prices.

2.1.1. Determining Exposure Horizons

Exposure depends on the period over which it is measured. For instance, in the short-run, a firm cannot change the location of its plants. In the long-run, it can do so. Consequently, there may be little exposure to the real exchange rate in the long run. This raises the question: Which
exposure should a firm focus on? Should it be short-run exposure or long-run exposure?

The answer depends on why the firm is estimating its exposure. Let’s consider various reasons for why a firm practices risk management and their implications for the choice of the horizon over which to compute exposures:

A. To avoid default and bankruptcy. In this case, the firm faces deadlines where it has to make specific payments and covenants that it has to meet. The firm will therefore have to make sure that it has enough resources at these specific times. These deadlines will define the periods over which it computes exposures.

B. To minimize the present value of tax payments. Typically, the firm will be concerned about risks taking place over the tax year.

C. To enable the implementation of a strategic plan. With a strategic plan that is implemented over several years, the firm wants to insure the availability of the resources necessary to implement the plan. The firm will therefore want to understand the risks that affect these resources over the planning period.

2.2 Competitive Exposure

What could XYZ’s competitive exposure to the dollar exchange rate depend on? There is a large literature that investigates competitive exposure. It generally emphasizes the importance of the type of competition the firm faces. To understand this, let’s consider two polar cases. At one

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4 See Flood and Lessard (1984), Levi (1994), and Marston (1996) for papers that deal with the issues we address here. +
extreme, XYZ could have no competitors. In this case, the key determinant of its exposure to the dollar would be the price-sensitivity of the demand for its cars (i.e., the percentage change in demand for a percent change in the price). Figure 1 presents the case where the demand is not very price-sensitive. Figure 1A shows the demand curve in pounds and figure 1B shows it in dollars. XYZ will sell cars up to the point where the marginal revenue equals the marginal cost. In other words, the impact on the total pound revenue of selling one more car has to be equal to the impact on the total cost of producing cars. As the dollar depreciates, there is no effect on the demand curve in dollars. However, for each quantity sold, the demand curve in pounds falls by the extent of the depreciation of the dollar. Hence, a depreciation of the dollar shifts the demand curve in pounds downwards in figure 1A but leaves the demand curve in dollars unchanged in figure 1B. If costs are exclusively denominated in pounds, the marginal cost curve in pounds is unaffected by the depreciation of the dollar. The net effect of the depreciation of the dollar is to reduce the quantity sold in the U.S. and increase the dollar price of the cars sold in the U.S. The dollar price of cars sold in the U.S. does not, however, increase by the full amount of the depreciation. In the case of the monopolist, the exchange rate exposure is roughly equal to the dollar revenue before the depreciation.

The other polar case is the one where XYZ sells cars in a highly competitive market. Suppose first that the competitors of XYZ are American firms with dollar costs. In this case, as the dollar depreciates, nothing changes for XYZ’s competition. Figure 2 shows this case where the demand for XYZ’s cars is highly price-sensitive. If XYZ offers cars at a slightly higher price than its competitors, its demand vanishes. XYZ sells cars up to the point where the marginal cost of producing cars equals the marginal revenue from selling them. In this case, however, the
marginal revenue curve is equal to the demand curve. Looking at figure 2A, where the demand curve is in pounds, we see that a depreciation of the dollar moves the demand curve downwards by the extent of the depreciation. In the example shown in figure 2A, the depreciation has the effect of pushing the demand curve completely below the marginal cost curve, so that it is no longer profitable for the firm to sell in the U.S. In this case, the exposure of the firm depends on its ability to shift sales away from the U.S. If the firm can shift sales rapidly and at low cost, it may have very little exposure to the exchange rate.

It is important to note that in both figures we assume that the demand curve in dollars is unchanged as the exchange rate changes. This means that the price levels in the U.S. and the U.K. do not change with the change in the exchange rate. If the price level in the U.S. changed exactly to offset the change in the nominal exchange rate, the change in the nominal exchange rate would have no impact on the pound revenue of XYZ. Suppose that the price level in the U.S. increases by 10% and the dollar depreciates by 10%. Since all prices in the U.S. increase, XYZ can increase the price of its cars in the U.S. by 10%. At that higher price, the price of XYZ cars relative to U.S. goods will be unchanged and, consequently, demand will be unchanged. This means that the exchange rate changes that are relevant from the perspective of a firm’s competitive exposure are real exchange rate changes - exchange rate changes net of price level changes. Empirical evidence shows that in the short and medium term nominal exchange rate changes are also real exchange rate changes.

What if XYZ is a small player in a highly competitive U.S. market dominated by German car makers? Suppose that the demand for the market as a whole is not very price-sensitive, but the demand for XYZ cars is extremely price-sensitive. In other words, XYZ has very little ability
to set its prices. In this case, the key question in understanding the exposure of XYZ to the dollar exchange rate has to do with how the DM and the pound prices of the dollar move together. Suppose that XYZ expects the two exchange rates to move closely together. In this case, a depreciation of the dollar with respect to the pound also means a depreciation of the dollar with respect to the DM. Consequently, the German producers will increase their dollar prices and XYZ can do the same. This means that the impact of the depreciation on cash flow will be fairly small. Alternatively, suppose that the pound price of the dollar and the DM price of the dollar move independently. In this case, an appreciation of the pound with respect to the dollar that is not accompanied by an appreciation of the DM with respect to the dollar has an extremely adverse effect on XYZ’s income from dollar sales and may force it to exit the U.S. market. An appreciation of the DM against the dollar that is not accompanied by an appreciation of the pound with respect to the dollar is good news for XYZ because its competitors in the U.S. increase their dollar price. In this case, XYZ has an exposure to the DM even though it does not export to Germany. The reason for this is that its competitors are German.

2.3. Components of Cash Flow Exposure

In our discussion, we have assumed that everything else is maintained constant. In other words, the only source of exchange rate exposure for XYZ is its revenue from the U.S. In general, however, some of the costs of XYZ will also depend on the exchange rate, which complicates the analysis. For instance, it could be that XYZ incurs some costs in the U.S. to sell cars in the U.S. In this case, the pound costs of XYZ will fall since the dollar costs are now less in pounds. This will shift downwards the pound marginal cost curve in our examples and hence
reduce the loss to XYZ from a depreciation of the pound. In the extreme case where XYZ has only dollar costs for its sales in the U.S., the exposure would be limited to the repatriated profits. Hence, instead of having all the dollar revenue exposed to changes in the exchange rate, XYZ would only have its dollar profits exposed to the exchange rate.

So far, we have focused on the exposure of a single year’s cash flow. This exposure is important because if a single year’s cash flow is low, the firm might not be able to invest as much as it should or might be in default. However, a low cash flow one year is not a problem if the value of a firm’s equity is high enough. A firm whose equity is high enough can raise riskless debt. If firm value falls significantly, the firm might be in trouble even if that year’s cash flow is not particularly low. Therefore, a firm’s equity exposure is important also. Since a firm’s equity is the present value of the cash flows accruing to equity, the firm’s equity exposure is closely related to the exposure of its cash flows. If a firm hedges the exposure of all its cash flows, it also hedges the exposure of its equity. If a firm hedges only the coming year’s cash flow through transaction hedging, it hedges equity only partially, however. It could then face a situation where the coming year’s cash flow is hedged but equity falls because of adverse shocks to future cash flows. In this case, it would be able to invest in the short run but not in the long run.

Shocks to exchange rates affect the firm’s balance sheet through translation exposure. A firm’s assets and liabilities in foreign currencies have to be translated into the domestic currency at the end of the firm’s fiscal year. As exchange rates change unexpectedly, the value of the firm’s assets and liabilities can change dramatically. The exposure of a firm’s balance sheet is easy to figure out since every foreign currency asset and liability needs to be translated at the end of the fiscal year and accounting conventions prescribe for each asset and liability whether this
translation takes place at the current exchange rate or at some historical exchange rate. These assets and liabilities are known in the foreign currency so that the exposure itself is known. Sometimes, translation exposure can be quite important. This will be the case when the firm has to maintain some accounting ratios to avoid default and these accounting ratios involve translated accounts. In general, however, translation exposure is not particularly important for firms because they are not close to technical default based on accounting covenants.

2.3.1. What if the firm focuses on the wrong exposure?

An oft-cited example is the case of a European airline concerned about the volatility of its cash flow. It therefore decides to hedge transactions exposure. Its most important transaction is an order of planes from Boeing. The payment will have to be made in dollars. The company interprets this to mean that the firm is short dollars and hedges by buying dollars forward. During the period of time that the hedge is maintained, the dollar depreciates and the airline loses money on the forward contract that it makes up in its cash position. Yet, the firm’s cash flow is low enough to create concern despite the transaction hedging.

What went wrong? The prices that the airline charges are fixed in dollars because of the structure of the airline market. Hence, if the dollar falls, the airline loses income in its home currency. This does not correspond to booked transactions when the firm decides on its risk management policy, so that focusing on transaction exposure, the airline forgot about the exposure inherent in its operations. Because of the airline’s blindness to its competitive exposure,

5 This example is cited in a recent controversial article on foreign exchange risk management, Copeland and Joshi (1996).
its risk management policy was inadequate. Had the firm taken into account its competitive exposure, it could have hedged its cash flow effectively.\textsuperscript{6}

**Section 3. Using the pro forma statement to evaluate exposures.**

Using a firm’s income statement, one can obtain a cash flow statement. Each item in that cash flow statement is risky and its exposure to a risk factor can be evaluated by estimating by how much that item would change if that risk factor changed unexpectedly. Adding up the impact of a change in the risk factor across all items of the cash flow statement, one can compute the exposure of cash flow with respect to that risk factor for a given change in the risk factor. We call this the pro forma approach to evaluating exposures.

In the analysis in the text, we will focus on XYZ and its exchange rate exposure throughout the chapter. Boxes show how the concepts we develop in this and the next section can be applied to the case of firm ABC which has a commodity exposure. Let’s go back to the cash flow statement of XYZ. We can forecast the cash flow statement for a particular year based on assumptions about the variables that affect cash flow. Let’s say that the only random variable that affects XYZ’s cash flow is the dollar/pound exchange rate. The cash flow exposure of XYZ to the exchange rate is the sum of the exposures of the components of the cash flow statement. To see this, consider our simple cash flow statement for XYZ:

\[
\text{Cash flow} = \text{Sales} - \text{Costs of goods sold} - \text{Taxes} - \text{Investment}
\]

\textsuperscript{6} Copeland and Joshi (1996) use the example to argue against risk management.
The exposure of cash flow to the exchange rate is the impact of a unit change in the exchange rate. Consequently, the impact on cash flow of a £0.01 change in the pound price of the dollar is:

\[
\text{Cash flow exposure} \times 0.01
\]

However, using the right-hand side of the cash flow equation, it follows that the impact of a £0.01 change in the exchange rate on cash flow must be equal to its impact on sales minus its impact on costs of goods sold, minus its impact on taxes, and minus its impact on investment.

We can look at the cash flow of XYZ for 1998 keeping the assumptions of the previous section and assuming 10% growth in sales, costs and investment:

\[
\text{Cash flow} = \text{Sales} - \text{Costs of goods sold} - \text{Taxes} - \text{Investment}
\]

\[
27.5m = 440m - 330m - 0.25 \times 110m - 55m
\]

A change in the exchange rate can affect each component of cash flow. Suppose first that it changes only the pound value of U.S. sales. In this case, the exposure of cash flow is simply the amount of sales in the U.S. times 1 minus the tax rate. The tax rate is generally ignored in discussions of exposure, but it is important. If the dollar depreciates, this reduces the firm’s cash flow, but it also reduces its taxable income. Each pound lost because of the decrease in the pound value of dollar sales means that taxes paid are reduced by a quarter of a pound. We can obtain this exposure by noticing that the pound value of U.S. sales is:
Dollar price per car x Number of cars sold x Pound price of the dollar

If the dollar price per car and the number of cars sold are constant, the dollar revenue is constant. The dollar exposure of XYZ is then simply that dollar amount times one minus the tax rate. In this case:

Cash flow exposure of XYZ to the dollar = Dollar revenue of XYZ x (1 - 0.25)

Using the pro forma cash flow statement, this corresponds to $440m x (1 - 0.25) = $330m. The cash flow exposure can then be used to compute cash flow under different assumptions about exchange rate changes. First, suppose that one believes that the worst possible exchange rate move is a ten percent depreciation. In this case, one can use the exposure measure to compute the cash flow shortfall if that ten percent depreciation takes place. Note that a ten percent depreciation means that cash flow has a shortfall relative to no depreciation of:

Cash flow exposure of XYZ to the dollar x Pound value of 10% depreciation of the dollar

Remember that we assume the pound to be worth two dollars in the base case. Hence, this means that a 10% depreciation of the dollar brings the dollar from £0.50 to £0.45. Consequently, with our assumptions, this shortfall is worth £16.5m, namely 330m x 0.05.

Alternatively, one can use the exposure to compute the volatility of cash flow. Remember that with our assumptions, the dollar exchange rate is the only risk affecting cash flow. Consequently:
Volatility of cash flow = Exposure x Volatility of exchange rate

Suppose that the volatility of the exchange rate is 10% p.a. In this case, the pound volatility of 1998 cash flow viewed from the beginning of 1997 depends on the volatility of the exchange rate over a two-year period. This volatility is the square root of two times 10%, or 14.14%. This gives us a cash flow volatility of 14.14% of 330, or £46.66m. Using the volatility of cash flow, we can compute a Value at Risk measure. For instance, there is a one chance in twenty that cash flow will be at least £76.99m below projections assuming no change in the exchange rate. Remember that if the cash flow is distributed normally, the fifth percentile of the distribution of cash flow is 1.65 times the volatility of cash flow. Consequently, £46.66 x 1.65 gives us £76.99m.

The analysis becomes more complicated if the dollar price of cars and/or the quantity of cars sold in the U.S. also change with the dollar exchange rate. It is still possible to compute the worst outcome if one believes that the dollar will at most depreciate by 10%. In this case, however, one has to make assumptions about the demand curve and the marginal cost curve. We consider the case corresponding to figure 2, but for simplicity we assume that XYZ only sells in the U.S. and does not sell in the U.K. Let’s further assume that the marginal revenue of selling in the U.S. for XYZ is fixed and does not depend on the actions of XYZ because XYZ sells in a highly competitive market. This dollar marginal revenue is equal to the price of a car, that is $20,000. The marginal cost in pounds for XYZ depends on the cost function of XYZ. We assume that the total cost for XYZ is given by the following function:

\[ \text{Cost} = 10m + 0.25 \times (\text{Quantity produced}^2) \]
Consider the numbers from Table 1 but ignore taxes for simplicity. We assumed that XYZ sold cars in the U.S. at $20,000 a piece and sold 20,000 cars there. Using our cost function, the marginal cost of a car produced is:

\[
\text{Marginal cost of a car produced} = 0.5 \times (\text{Quantity produced})
\]

If XYZ produces 20,000 cars the marginal cost of a car is 0.5 x 20,000, which amounts to £10,000 or, when the dollar costs £0.5, $20,000. Consequently, when XYZ sells 20,000 cars in the U.S. marginal cost equals marginal revenue. In this case, XYZ’s profit is £100m.

Suppose now that the dollar depreciates by 10%. In this case, the quantity sold in the U.S. becomes 18,000. The profit falls to £81m. Figure 3 shows the pound profit as a function of the exchange rate. This is a nonlinear function. This means that to compute the loss resulting from depreciation of the dollar we have to compute the profits for the exchange rate after the depreciation and compare them to the profits before the depreciation. Instead of having one exposure measure that applies irrespective of the magnitude of the exchange rate change, we now have an exposure measure for each exchange rate change! This suggests that the only way we can figure out the exposure of XYZ in this case is by computing profits for various scenarios. There is an alternative, however, which is to use an approximation for the exposure similar to duration. Remember that duration measures the sensitivity of a bond price to a small change in the yield. Using a similar measure here, we can compute the sensitivity of profits to a small change in the exchange rate evaluated at the current exchange rate. This sensitivity is given by the slope of the profit function when the exchange rate is 0.5:
Exposure = Change in profits for a small change in the exchange rate from its current value

Expressed in terms of a unit change in the exchange rate, the exposure approximated this way is equal to $400m, which correspond to the dollar sales at that exchange rate. Using this approximation, we find that a £0.05 decrease in the value of the dollar decreases pound profits by £20m. Computing the loss by comparing profits when the exchange rate is £0.45 to profits when the exchange rate is £0.50, we get instead that the depreciation reduces profits by £19m. The two numbers are sufficiently close that measuring the exposure using a duration-like approximation works well. This obviously need not always be the case.

One issue that arises from investigating the approximation we used is whether the result that the exposure to a small change in the exchange rate is equal to sales in that currency at the current exchange rate is a general result. In a recent working paper, Marston (1996) argues that this result holds in a large number of cases. For instance, it holds both in the monopolistic case and the duopoly case where the firms take into account the impact of their actions on their competitor. Note however that we ignored taxes. Had we taken into account taxes, we would have needed to use dollar sales times one minus the tax rate.

In the example we just discussed, XYZ had to have a fair amount of information to compute its exposure to a large exchange rate change and ended up with an exposure that itself depended on the level of the exchange rate. Despite being complicated, the example we looked at was heavily simplified. For instance, there was only a single source of risk. This raises the question of whether there are alternative approaches that can be used when the analytical approach we described cannot be used in practical situations or can be used to complement this analytical approach. We discuss such
alternative approaches in the next two sections. First, in section 4, we show how to use a firm’s past history to get a measure of exposure. Then, in section 5, we discuss simulation approaches.

3.1. Example: Pro Forma Exposure Measurement - ABC Manufacturing

ABC Manufacturing produces small household appliances and kitchen utensils. The firm's small appliances division uses small electric motors that require copper wiring to produce. Additionally, the kitchen utensils division makes pots, pans and other small kitchen utensils from aluminum. The firm uses a just-in-time production process and thus purchases its copper and aluminum on the open market at regular intervals. The new treasurer feels that she will need to hedge the price of copper and aluminum but is unsure about the exposure of cash flow to commodity prices.

She decides to conduct a pro-forma analysis to evaluate the exposure of cash flow to the prices of both aluminum and copper. She knows that these prices will affect the overall cash flow but since the uses of the products vary between the subsidiaries, she wants to know the components of the cash flow statement that are affected.

After careful analysis, she concludes that in the small appliance subsidiary, copper and aluminum each accounts for about 10% of the total cost of sales. Conversely, in the kitchen utensils division, the cost of aluminum accounts for 60% of the cost of sales while copper is an insignificant component of the cost of sales. Each subsidiary accounts for half of the total sales of the firm.

From a simple pro forma analysis, the treasurer concludes that a 10% increase in the price of aluminum and copper, assuming no hedging by the firm, will increase the cost of sales in the small appliances division by 2% (1% each for copper and aluminum) and in the kitchen utensils division by 6% due to the aluminum price increase.
The treasurer is not sure how much of the increase in cost can be passed on to the customer. The marketing manager informs her that the sales in both subsidiaries are very price sensitive due to the competitiveness of the industry. Therefore, past increases in the price of copper and aluminum were not fully passed on to the customer. In fact, the marketing manager informs the treasurer that as a first estimate, she can assume that none of the cost will be passed on to the customer.

<table>
<thead>
<tr>
<th>ABC Manufacturing Corporation</th>
<th>1996 Pro Forma Cash Flow Statement ($Millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Small Appliances</td>
</tr>
<tr>
<td>Revenue</td>
<td>150</td>
</tr>
<tr>
<td>Cost of Sales</td>
<td>(120)</td>
</tr>
<tr>
<td>Taxes (34%)</td>
<td>(10.2)</td>
</tr>
<tr>
<td>Net Cash Flow</td>
<td>19.8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ABC Manufacturing Corporation</th>
<th>Pro Forma Cash Flow After a 10% increase in the cost of Copper and Aluminum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Small Appliances</td>
</tr>
<tr>
<td>Revenue</td>
<td>150</td>
</tr>
<tr>
<td>Cost Of Sales</td>
<td>(122.4)</td>
</tr>
<tr>
<td>Taxes (34%)</td>
<td>(9.4)</td>
</tr>
<tr>
<td>Net Cash Flow</td>
<td>18.2</td>
</tr>
</tbody>
</table>

From the pro forma analysis it can be seen that the 10% increase in the costs of aluminum and copper results in a 3.82% increase in the cost of sales for the firm while the resultant effect on the firm’s cash
flow is a decrease of 10.6%. The $8.4 million dollar increase in the firm’s costs will result in a $5.6 million decrease in cash flow. The difference in the dollar change between cost of sales and cash flow is due to the tax rate.

Section 4. Using past history to measure exposure.

We saw in section 3 that measuring a firm’s exposure can be quite complicated even in extremely simplified examples. If we are concerned about how exchange rate changes affect the value of a large firm with lots of different activities, an analytic approach similar to the one described earlier would seem rather difficult to implement. Even if one were able to implement such an approach, one would want to have some way to check whether its results are sensible. An important tool to evaluate a firm’s exposure is simply to look at the past history of that firm. Such an approach is quite valuable when one believes that the future will not be too different from the past. In other words, such an approach works well when one believes that past exposures are similar to future exposures. In this section, we illustrate this approach focusing on the exposure of a firm’s equity, but the same historical approach can be used for the exposure of cash flow or components of cash flow.

Consider a firm’s stock returns. If we wanted to have an estimate of a firm’s exposure to the stock market, we would use the firm’s stock beta. Remember that the firm’s stock beta is the covariance of the firm’s stock return and the market’s return divided by the variance of the market return. Typically, the firm’s stock beta is estimated using a regression. We can proceed exactly in the same way to estimate a stock’s exposure to other market risks.7

7 Adler and Dumas (1984) define exposure this way.
Using regression analysis to measure the exposure of a firm’s cash flow to changes in financial prices is similar to the market model approach used by financial analysts to measure a firm’s beta risk. Remember the market model is simply obtained by a regression of the rate of return of a security ($R_i$), on the rate of return on the market ($R_m$)

$$R_{it} = \alpha + \beta_i R_{mt} + \epsilon_i$$  \hspace{1cm} (1)

where, beta ($\beta$) is the estimate of the firm’s stock market risk.

A firm’s exposure to a market risk makes it’s value sensitive to this risk. Consequently, we can evaluate this sensitivity using regression analysis. This approach decomposes the random return of the firm into one part that depends on the market risk and one part that does not. Consider the situation where one would like to estimate the sensitivity of the firm’s equity to some risk factor $x$. We can obtain this sensitivity by regressing the return of the firm’s equity to changes in that factor:

$$R_{it} = \alpha + \beta_i x_{it} + \epsilon_i$$ \hspace{1cm} (2)

In this regression, $R_{it}$ is the firms cash flow or return on its securities, $\alpha$ is the constant, $x_{it}$ is the change in the financial risk factor, and $\beta_i$ (beta) measures the exposure of the firm to the particular financial risk and $\epsilon_i$ is the error term. The beta measure of the sensitivity of the value of the firm to the financial risk factor of interest. This measure is equally valid if this factor is the interest rate foreign exchange rate and/or commodity prices.

There is, however, an important difference between the analytical approach used in the previous section and the approach estimating a firm’s sensitivity to a market risk with regression
analysis. In the previous section, we obtained the sensitivity of XYZ to the dollar/pound exchange rate. If the cash flow of XYZ is sensitive to other exchange rates because XYZ also exports to these countries, this would not affect the measure of exposure derived in the previous section. However, with the statistical approach used here, all sources of correlation of firm value with the dollar/pound exchange rate will affect the beta coefficient. For instance, if XYZ also sold to Canada and if we estimated a regression of XYZ’s equity return on the change in the U.S. dollar/pound exchange rate, XYZ’s sales to Canada would affect the regression beta of XYZ on the U.S. dollar/pound exchange rate because the Canadian dollar/pound exchange rate is correlated with the U.S. dollar/pound exchange rate.

To estimate the sensitivity of the equity of XYZ to the U.S. dollar/pound exchange rate only, one would therefore have to estimate the regression controlling for other sources of risk that affect the equity of XYZ and are correlated with the U.S. dollar/pound exchange rate. This means that if there are two sources of risk for the equity of XYZ, namely the U.S. dollar/pound exchange rate and the Canadian dollar/pound exchange rate, one would have to regress the return on the equity of XYZ on the two sources of risk. However, if one is interested in XYZ’s sensitivity with respect to exchange rates for the purpose of risk management, one would have to regress XYZ only on the sources of risk for which hedging instruments are available and will be used. If the only hedging instrument one intends to use is a forward contract on the U.S. dollar, one can use this contract to partly hedge the firm’s exposure to the Canadian dollar since that currency’s changes are positively correlated with those of the U.S. dollar.

If one wants to estimate the exposure of the firm to several risk factors, one has to use a multivariate regression. With such a regression, one regresses the return on the firm’s equity on all
the sources of risk one is interested in. For instance, if one is concerned about the firm’s exposure to the stock market as well as to one financial risk factor, one estimates the following regression:

\[ R_{it} = \alpha + \beta_i R_{mt} + \gamma_i R_{xt} + \epsilon_i \]  (3)

where, \( R_{mt} \) is the return on the market portfolio and \( \beta_i \) is the market exposure of the firm, \( \gamma_i \) is the exposure of the financial risk factor. In the case of exchange rates, Jorion (1990) uses the regression in equation (3) to evaluate the exposure of U.S. multinational firms to the dollar price of a tradeweighted basket of foreign currencies. He shows that the exposure to the price of a basket of foreign currencies systematically increases as a firm has more foreign operations.

The multivariate regression analysis could be used to evaluate all of the exposures to financial risks to which a firm may be subjected. The analysis will then include the financial prices and sensitivity factors of these financial risks. A firm may be exposed to exchange rates from more than one country as well as to interest rates and to commodity prices it uses as inputs to production. The implementation of the multivariate approach will then use many different financial prices as independent variables. The problem that arises with this approach, though, is that market risks are correlated. This makes it hard to estimate the exposure of a firm to many market risks precisely using the regression approach.

Let’s now look at an example. General Motors is a large auto manufacturer with global sales and competition. The Opel subsidiary of the firm is located in Europe and accounts for a large portion of the firm’s international vehicle sales. A very high percentage of these sales are done in the German market. Also, it faces major competition from Japanese firms in both the North American
and European market. Finally, a high percentage of the firm’s vehicle sales are financed, so the vehicle sales should be exposed to the level of interest rates. With these factors in mind, one would expect that the firm will have exposure to the value of the yen and German mark against the dollar and to the level of U.S. interest rates.

We want to understand the firm’s equity exposures. To do so, we use the monthly change in returns on the firm’s stock including dividends. To proxy for permanent shocks to the mark/dollar and yen/dollar exchange rates, we use the real exchange rate. The real rate is the nominal exchange rate adjusted for the wholesale price index. Since vehicles are usually financed for 3-6 years we will use for the interest rate an index of corporate bonds with maturities from 3-10 years.

If we first wanted to know the exposure of GM to the value of the German mark, while controlling for the general market factors, we would consider the following regression:

$$ R_{GM,t} = \alpha + \beta R_{mt} + \gamma S_{DM}. $$

(4)

where, \( \beta \) and \( \gamma \) represent the exposure of GM for the general market and the mark/dollar exchange rate, respectively. The resulting regression for monthly exchange rate and returns data from 1973 - 1995 is the following:

$$ R_{GM,t} = 0.001 + 0.924 R_{mt} + 0.335 S_{DM} $$

(0.368) (11.157) (2.642)

(5)

where the number in parentheses represent the t-statistic of the regression coefficient. The interpretation of the above regression results of the exposure of the cash flow of GM to a change in the value of the German mark is that a 10% depreciation in the value of the dollar relative to the mark
will lead to a 3.35% increase in the value of the firm’s equity. This coefficient is obtained after controlling for the sensitivity of the cash flow to general market factors which is 0.924 for the firm’s return relative to that of the general market.

Next, as stated above, the firm is also exposed to the value of the yen because of the competition from the Japanese firms in the North American market. Thus, an increase in sales of the Japanese firms should result in a decrease in sales for GM. Also, because the method in which the firm sells its product, we would expect that the firm would be exposed to the level of interest rates.

To test the firm’s exposure to these factors, we would run the following regression:

\[ R_{GM,t} = \alpha + \beta R_{mt} + \gamma S_{DM} + \delta S_{¥} + \lambda R_{B} \]. \hspace{1cm} (6)

Where, \( \alpha \) is a constant, \( \beta \) is the firm systematic risk, \( \gamma, \delta \) and \( \lambda \) is the sensitivity to the German mark, Japanese yen and U.S. interest rates, respectively. The result of this regression is:

\[ R_{GM,t} = 0.0007 + 0.965 R_{mt} + 0.472 S_{DM} - 0.353 S_{¥} - 0.198 R_{B} \]. \hspace{1cm} (7)

So, GM has significant exposure to the mark, to the yen, and to the level of U.S. interest rates. A depreciation of the yen relative to the U.S. dollar will decrease firm value. Also, an increase in the U.S. interest rate will decrease the cash flow of the firm. Numerically, a 10% appreciation in the dollar relative to the yen and the German mark along with a 10% increase in interest rates will lead to a decrease of 3.53% and 1.98% from the yen and the interest rate, respectively and an increase of 4.72% as a result of the German mark increase. This results in a 0.61% decrease in the value of the firm’s equity.
The example of General Motors shows how we can analyze the exposure of a firm to various financial prices by including these prices in a simple linear regression equation. A similar analysis could be done with the inclusion of commodity prices of the firm’s inputs or any other factor that the analyst feels may be important after evaluation of the firm and industry characteristics along with a pro forma analysis. Careful examination of the results of the regression can assist the financial manager in determining the proper risk management strategy for the firm.

There are a few caveats about the use of the regression approach that must be kept in mind before its implementation. First, the regression coefficients are based on past information and may not hold for the firm in the future. For example, the world automotive industry went from a period of relatively benign competition in the 1970’s to a period of more intense competition beginning in the early 1980’s. This competitive change probably had some effect on the exposure of cash flows of GM to the changes in the yen. Also, the sales in Europe became more significant over this period. This means that this approach might have done a poor job of estimating exposures for the 1980’s using data from the 1970’s.

Secondly, the firm may be exposed to more market risks than those used in the regressions. To understand how much of the volatility in equity is explained by the market risks used in the regression, one can evaluate the coefficient of determination ($R^2$) of the regression. The $R^2$ represents the amount of the change in equity value that is explained by the regression. In the case of the second regression, the $R^2$ is 35%. This shows that our risk factors explain slightly more than 1/3 of the volatility of General Motors’ stock. Further examination of the characteristics of the firm, including its financial position, commodity and source of inputs and the competitive nature of the industry would be helpful in identifying additional risk factors.
Finally, the above regressions assume a simple linear relationship between the cash flows of the firm and the financial risk factors. This may not necessarily be the case. The relationship can also be nonlinear. For instance, the interaction between two market risks can matter for firm value. Such a nonlinear structure can be incorporated in the regression, but to know that it exists, one has to already have a good understanding of the firm’s exposures.

4.1. Example: Regression Analysis Exposure Measurement - ABC Manufacturing

From the box in section 3, the treasurer of ABC used a pro-forma analysis to evaluate the exposure of the firm to aluminum and copper prices. The analysis was based on the information from the marketing manager that cost increases will not be passed on to the customer. Considering the impact on the firm’s cash flow the treasurer feels that in order to get a better picture of the impact of the commodity price changes on the cash flow of the firm she would need to incorporate past information on the firm’s cash flow sensitivity to commodity prices. Therefore, she collects the firm’s monthly cash flow level over the past ten years. She also realizes that the firm has gone through some structural changes over this period and these may have an impact on the exposure of the firm. Additionally, the industry has become much more competitive over the last five years with the strong growth of kitchen redecorating. Consequently, these occurrences should have a more significant affect on the sensitivity of the firm to the price of its inputs to production.

To implement the regression analysis, the treasurer also collects monthly commodity prices over the same ten year period. She then evaluates the following regression:

\[ CF_t = \alpha + \beta A_t + \gamma C_t. \]
Where, $CF_t$ is the percent change in the firm’s cash flow, $A_t$ is the percent change in aluminum prices and $C_t$ is the percent change in copper prices. The results of the regression yield the following relationship:

$$CF_t = 0.857 - 0.823A_t - 0.076C_t.$$  
(3.24)  (2.36)  (1.15)

The regression equation shows that a 10% increase in the price of aluminum will result in an 8.23% decrease in cash flow, which is significant at the 5% percent level. Surprisingly, the cash flow of the firm is significantly not affected by the change in the price of copper. After investigating this peculiar result, the treasurer then discovers that ABC acquired the small appliances subsidiary five years ago which also coincided with an increase in the competitive level of the industry. She then evaluates the regression over the last 5-years resulting in the following relationship:

$$CF_t = 0.857 - 0.723A_t - 0.266C_t.$$  
(2.74)  (2.06)  (1.76)

This results in a cash flow exposure to copper of 2.66% for a 10% change in copper prices. These results should enhance those found using just a pro forma analysis. Therefore the exposure to the cash flow of the firm based on past information will assist the treasurer in developing the appropriate risk management program for the firm’s commodity exposure.

**Section 5. Simulation approaches.**

Consider a firm whose current situation is quite different from the situation it faced in its recent history. Consequently, historical exposures estimated through a multiple regression do not
correctly describe the exposures that will apply in the future. If future cash flows can be modeled in
the way that we modeled the cash flow of XYZ, the cash flow exposures at each point in time are
easily obtained analytically. However, there are many situations where such an approach is not going
to work because exposures cannot be obtained analytically. Let’s examine such a situation and discuss
how it could be handled.

Exposures are often path-dependent. This means that the exposure of cash flow two years
hence depends on what happens to the exchange rate next year. Consider the simplest example of a
path-dependent exposure. Suppose that we change slightly the XYZ example, so that now XYZ
exports to the U.S. 1,667 cars every month in 1998. Each car is sold for $20,000 and the pound value
of the car depends on the exchange rate at the end of the month in which it is sold. In this case, the
yearly cash flow of XYZ does not depend on a single exchange rate, but rather on the exchange rate
at the end of each month. There is no number we can compute that gives us exactly the exposure of
XYZ’s 1998 cash flow to the dollar/pound exchange rate.

Suppose that we still would like to have an estimate of how the 1998 cash flow of XYZ is
related to the dollar/pound exchange rate at the end of the year. How could we get such a number?
The end-of-year exchange rate could be £0.40 for instance. However, there are lots of possible ways
that the exchange rate could end up at £0.40. It could increase throughout the year, so that £0.40 is
its highest value. It could go up and down throughout the year, so that £0.40 would be close to the
average exchange rate. Finally, it could fall throughout the year. This means that for a given end-of-
year exchange rate, multiple average exchange rates are possible and hence multiple cash flow values.
This does not prevent us from obtaining a statistical measure of the dependence of the cash flow on
the end of period exchange rate. However, there is no longer a one-to-one relation between a
exchange rate and cash flow.

If we know the exchange rate today and the monthly distribution of its changes, we can use this knowledge to simulate possible paths of the exchange rate from now to the end of 1998. This is called conducting a Monte Carlo analysis. For such an analysis to be reasonable, one would have to simulate hundreds of possible paths of the exchange rate. A possible exchange rate path will give us a value for the exchange rate for each month in 1998. For that path, we can compute the cash flow for each month and therefore the cash flow for 1998. Having obtained the cash flow for each simulated exchange rate path, we can compute the beta coefficient of cash flow with respect to the end-of-period exchange rate. This tells us statistically how cash flow is expected to vary with the exchange rate at the end of 1998.

This approach works provided that we have a good understanding of the distribution of exchange rate changes. It has the advantage that it is completely forward looking. It does not assume that the future for XYZ is similar to the past. In the context of our example, there is no other sensible way to obtain a measure of XYZ’s cash flow exposure for 1998.

The example we focused on in this section to illustrate the simulation method was a simple example. It shows the benefit of the approach when analytical solutions are not practical. This method can be applied when there are multiple sources of risk as well. The box describes a Monte Carlo analysis in detail for a variant of XYZ, XYZ’. To implement such an analysis, the first step is to understand the distribution of risk factors. In the case of XYZ’, we have focused on the exchange as the risk factor we are concerned about. This means that we have to understand the distribution of exchange rate changes. Historically, the normal distribution provides a good approximation of the distribution of the percentage change in the exchange rate. We can then use a spreadsheet program
to generate exchange rate changes assuming that the percentage change in the exchange rate is normally distributed. In our application, we are concerned about the exchange rate each year from 1997 to 2005. We can generate the exchange rates over that period by applying randomly generated percentage changes to successive exchange rates. If we have several risk factors, we need to obtain the joint distribution of these risk factors. This means that we have to understand how they covary. In the case of XYZ, the other risk factor is the arrival of a competitor. This competitor is more likely to enter the market if the dollar price of the pound exceeds $1.95. This means that this risk covaries positively with the dollar price of the pound.

Suppose that we have generated exchange rates for the period from 1997 to 2005. This constitutes a simulation trial. For this trial, we can compute the firm’s cash flows for each year. This requires us to have a model of how the cash flow is related to the risk factor. With this approach, we can allow the cash flow in one year to depend on the exchange rate of that year as well as on exchange rates in the previous years. This feature of the Monte Carlo analysis is what makes it possible to use that approach to take into account path dependencies that cannot be handled in other ways. For instance, in the example in the box, there is some chance that a competitor will enter the market and the probability that the competitor will enter the market depends on the exchange rate in 1997. Hence, once the competitor has entered the market, all future cash flows are affected. We also assume in the example that the firm sets prices at the end of a calendar year based on the exchange rate in effect then for the next calendar year. With the Monte Carlo approach, one can take into account when computing the cash flows in some year whether the competitor entered the market earlier or not as well as the dependence of prices on earlier exchange rates.

After having computed cash flows for each year in each simulation trial, we have the
distribution of the cash flows that obtains given the distribution of the exchange rate. We can then relate cash flows to exchange rates. In particular, we can measure the covariance between a given year’s cash flows and the exchange rate in that year. This allows us to obtain a hedge coefficient for that year’s cash flow like we did when we used the regression approach. The difference between the regression approach and the approach discussed here is that the regression approach assumes that the future is like the past. The Monte Carlo approach assumes that the distribution of the risk factors in the future is the same as in the past. It does not assume that the distribution of cash flows is the same as in the past. Consequently, the Monte Carlo approach could be used for a firm that has no history. This would not be possible with the regression approach.

In the example Monte Carlo analysis discussed earlier in this section as well as the one in the box, we took operating policies as given. It is important to stress that the Monte Carlo approach is generally the best method to deal with situations where the firm’s activities depend on the risk factors. For instance, it could be that a firm produces in one country if the exchange rate has some value and in another country if it has a different value. Such a situation can be modeled as a situation where the firm has an option to switch production and can be analyzed using contingent claims pricing techniques. Typically, though, such situations are best handled with the Monte Carlo approach.

5.1. Example: Simulation: A variant of XYZ Corporation

XYZ Corporation is a car producer in the U.K. XYZ has a vehicle in a market segment that it now dominates in the U.K. and wants to expand its success to the U.S. market. The firm is presently contemplating the sales and wants to forecast the future success of the project taking into

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8 See Mello, Parsons and Triantis (1995) for an example.
consideration a number of possible scenarios. The company is worried about the impact of changes in the exchange rate on the net present value of the project. An analyst is therefore asked to evaluate the exposure of the net present value of the project as well as the exposure of each annual cash flows to the dollar/pound exchange rate. To evaluate the exposures the analyst uses her knowledge of XYZ’s costs and of its competitive position in the U.S. market.

The demand function for the cars in the U.S. is assumed to be:

Number of cars customers are willing to buy = 40,000 - Dollar price of a car

The marginal cost of a car is £5,000 per unit and it is assumed to be constant over time. At an exchange rate of $2 per pound, it is optimal for the firm to sell 25,000 cars at $15,000. The analyst realizes that there is a strong possibility that a U.S. producer will enter the market segment with a comparable vehicle. This will have an effect on the pricing and thus the sales volume of XYZ’ cars. The demand function with an entrant becomes:

\[ \text{Demand} = 40,000 - 1.25 \times \text{Dollar price of a car} \]

Consequently, the entrant makes the demand for XYZ’ cars more sensitive to price. The analyst believes that the probability XYZ’ will face a competitor is 75% if the exchange rate exceeds $1.95 per pound and 50% otherwise. To sell in the U.S., XYZ’ has to spend £100,000,000 in 1997. It can then sell in the U.S. starting in 1998. Depreciation is straightline starting in 1997 over five years. The tax rate on profits is 45% if profits are positive and zero otherwise. XYZ’ fixes the dollar price of its
cars at the end of a calendar year for all of the following calendar year. The sales proceeds in dollars are brought back to the U.K. at the end of each calendar year at the prevailing exchange rate.

This example includes nine random variables: whether an entrant comes in or not, and the exchange rate for each calendar year from 1997 to 2005. Whether an entrant comes in or not is distributed binomially with a probability of 0.75 if the exchange rate in 1997 exceeds 1.95. The percentage change of the exchange rate from one year to the next is distributed normally with mean of 2.2% and standard deviation of 14.35%. These random variables do not influence the present value in a straightforward way. We argue in the text that the Monte Carlo analysis is particularly useful in the presence of path-dependencies. In this case, there are two important path dependencies: first, the cash flows depend on whether there is an entrant in 1997 which itself depends on the exchange rate; second, the cash flow for one year depends on that year’s exchange rate as well as on the exchange rate the year before.

We performed a Monte Carlo analysis using 400 trials. The output of the Monte Carlo analysis can be used to understand the exposure of XYZ to the dollar/pound exchange rate in many different ways. Here, we show two of these ways. First, the figure shows the relation between the 1999 cash flow and the exchange rate in that year. At high exchange rates, it becomes likely that the cash flow will be negative and there is a decreasing nonlinear relation between pound cash flow and the dollar/pound exchange rate. Because of the path dependencies we emphasized, the 1999 cash flow will depend on the exchange rate in earlier years also. An alternative way to use the output of the Monte Carlo analysis is to regress the pound net present value of the project (NPV) of selling in the
This figure shows the relation between the pound cash flow in 1999 and the dollar price of the pound in 1999 for the XYZ’ simulation. We draw four hundred different exchange rate series from 1997 to 2005. For each of these exchange rate series, we use the binomial distribution to obtain the decision of whether a competitor enters the market or not. Based on the realization of the random variables, we compute the cash flows from 1997 to 2005. The 1999 cash flows and their associated 1999 exchange rates are then plotted on the figure.
U.S. on the future exchange rates. This shows the sensitivity of the net present value to future exchange rates. The NPV is measured in million pounds. We get:

\[
\]

where X(j) is the exchange rate in year j and t-statistics are in parentheses below the regression coefficients. The R-squared of this regression is 78%. Whereas the NPV is negatively related to all exchange rates, not all future exchange rates are equally important determinants of the net present value. This is not surprising. First, the net present value calculation puts less weight on the cash flows that are received farther in the future. Second, our example has complicated path dependencies. Note, however, that some exchange rates have an extremely large effect on the NPV. For instance, if the 1998 dollar price of the pound is unexpectedly higher by 10 cents, the NPV is lower by 14.5 million pounds. The NPV obtained by averaging across 400 trials is £345 million. A 10 cents deviation in the 1998 exchange rate (about 4%) correspond to a change in the NPV of slightly more than 4%.

Section 6. The bottom line.

We have shown that there are three important ways of computing a firm’s exposure to a risk factor:

1. The pro forma approach takes a firm’s cash flow statement and evaluates how it would change if some risk factor changed. This approach works well when there is only one source of
risk and there are no path dependencies. For the exchange rate case, this means that each year’s cash flow depends on that year’s exchange rate but not on the exchange rate in previous years. The approach can accommodate multiple sources of risk, but it becomes difficult to deal with when the cash flow components depend on the interaction among risk factors. In this case, it no longer yields a single exposure measure with respect to a risk factor, but multiple exposure measures which depend on the level of the other risk factors.

2. When the pro forma approach does not work because the relationship between cash flow and risk factors is hard to discern, it is possible to compute a historical exposure measure using regression analysis. This historical exposure measure is useful whenever one expects the future to be similar to the past. This measure can be used to measure the exposure of cash flows as well as the exposure of equity. It’s usefulness is limited when the exposure depends on the levels of the risk factors, however.

3. If one knows how the cash flow components relate to the risk factors, one can use this knowledge to implement a Monte Carlo analysis. The advantage of this analysis is that it does not assume that the future will be similar to the past and can deal with any kind of nonlinearity or path-dependency.
References


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