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How much do firms hedge with derivatives? ☆

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Abstract

For 234 large non-financial corporations using derivatives, we report the magnitude of their risk exposure hedged by financial derivatives. If interest rates, currency exchange rates, and commodity prices change simultaneously by three standard deviations, the median firm's derivatives portfolio, at most, generates \$15 million in cash and \$31 million in value. These amounts are modest relative to firm size, and operating and investing cash flows, and other benchmarks. Corporate derivatives use appears to be a small piece of non-financial firms' overall risk profile. This suggests a need to rethink past empirical research documenting the importance of firms' derivative use.

JEL classification: G1,G3,G32

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1. Introduction

Corporate risk management is an important element of a firm's overall business strategy. Stulz (1996, pp. 23–24) draws upon extant theories of corporate risk management to argue "the primary goal of risk management is to eliminate the

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probability of costly lower-tail outcomes—those that would cause financial distress or make a company unable to carry out its investment strategy".[1] Financial derivatives, including currency, interest rate, and commodity derivatives, are one means of managing risks facing corporations.

With the exception of industry studies such as Tufano (1996) or detailed case studies as in Brown (2001), previous research analyzes either categorical data indicating whether corporations use financial derivatives, or data on the notional principal of corporate derivative positions, to test whether corporate uses of derivatives accord with corporate risk-management theories.[2] To our knowledge, no study to date documents large-sample evidence on the *magnitude* of risk that firms hedge using financial derivatives. The primary objectives of our study are: (i) To provide evidence on the magnitude of risk inherent in corporations' financial derivatives portfolios; (ii) To empirically compare these magnitudes to the magnitudes of firm risks that hedging theory predicts are potentially costly; and, (iii) To explore whether the magnitude of risk inherent in firms' derivatives portfolios are likely to explain inferences drawn in the empirical literature on derivatives.

For a random sample of 234 large non-financial corporations, we present detailed evidence on the cash flow and market value sensitivities of financial derivatives portfolios to extreme changes in the underlying assets' prices. That is, for simultaneous extreme changes in interest rates, currency exchange rates, and commodity prices, we estimate both the dollar cash flow that a firm would derive from its derivatives portfolio, referred to as the cash flow sensitivity, and the change in the market value of the firm's derivatives portfolio, referred to as the market value sensitivity. For each sample firm, we estimate the derivatives portfolio's cash flow and market value sensitivities using corporate disclosures about the types, notional principals, and remaining times to maturities of interest rate, exchange rate, and commodity derivative securities held by the firm. We believe our method of estimating these sensitivities can facilitate future research by allowing the construction of richer tests of corporate derivatives use.

In estimating the magnitude of risk hedged by a firm's derivatives portfolio, we make three assumptions intended to ensure that we do not underestimate the importance of derivatives securities. First, we assume each firm's entire derivatives portfolio hedges its downside risk exposure (i.e., the cash flow generated by each derivative security is perfectly negatively correlated with the firm's unhedged cash flow). Second, we estimate the sensitivity of each firm's derivatives positions to extreme changes in the underlying asset prices (i.e., interest rates, exchange rates, and commodity prices), where we define an extreme change as three times the annual standard deviation of the historical time series (over the most recent ten years) of

[1] See also Ross (1977), Stulz (1984), Smith and Stulz (1985), DeMarzo and Duffie (1991), Froot et al. (1993), Smith (1995), and Leland (1998), among others.

[2] See Nance et al. (1993), Dolde (1995), Berkman and Bradbury (1996), Mian (1996), Tufano (1996), Geczy et al.(1997 and 2001), Allayannis and Ofek (1998), Haushalter (2000), Gay and Nam (1999), Guay (1999), Howton and Perfect (1999), Petersen and Thiagarajan (2000), Loderer and Pichler (2000), Hentschel and Kothari (2001), Graham and Rogers (2002), Knopf et al. (2002), and Rajgopal and Shevlin (2002).

asset price movements. Finally, we assume that the prices of all three underlying assets simultaneously experience a three standard deviation change, and that the effects of these price movements on both the cash flows and value of firms' derivatives positions are perfectly positively correlated.

1.1. Summary of results

We find that, under the above assumptions, the median (75th percentile) firm's derivative cash flow sensitivity is \$15 (\$81) million, and the market value sensitivity is \$30 (\$126) million. That is, when the median derivatives-user firm simultaneously experiences a three standard deviation change in interest rates, exchange rates, and commodity prices, the entire derivatives portfolio rises in value by at most \$30 million, with \$15 million of this amount being realized as cash flow in the current period. For most of the sample firms, the cash flow and market value sensitivities are small relative to the magnitudes of operating and investing cash flows, the absolute values of the changes in operating cash flows and accounting income, cash holdings, and firm size. For example, the median derivatives-user's annual operating cash flow and investing cash outflow are \$178 million and \$178 million, respectively. As another example, we estimate that the sensitivity of the median firm's equity value to a three standard deviation change in interest rates and exchange rates is \$825 million and \$458 million, respectively.

We also examine whether the firms that theory predicts benefit most from hedging hold derivatives positions with relatively larger cash flow and market value sensitivities. We find some evidence of increased use of derivatives for larger firms and for firms with greater investment opportunities. We also observe increased derivatives use among more geographically diverse firms and among firms for which the CEO's sensitivity of wealth to stock price is relatively large. However, the magnitudes of the derivatives positions are quite small for all partitions of the data. Multivariate tests indicate that geographic diversification and investment opportunities have the greatest power to explain firms' hedging intensities. The results also suggest that inferences about the determinants of derivatives use are different when we use cash flow and market value sensitivities as proxies for the magnitude of derivatives use instead of the more commonly used proxy—notional principal.

Although our results suggest most firms hold derivatives positions that are small in magnitude relative to entity-level risks, optimizing firms will use derivatives only if the benefits of their programs exceed the costs. As we note in our conclusions, Brown's (2001) case study suggests that the cost of initiating and maintaining a derivatives program is not trivial. Therefore, an economically small derivatives program is potentially consistent with:

(i) Firms using derivatives to fine-tune an overall risk-management program that likely includes other means of hedging (e.g., operational hedges). This may be due to the fact that much of the overall risk facing non-financial firms (e.g., operating risks) cannot be managed through the use of standard derivatives contracts written over asset prices such as interest rates, exchange rates, and commodity prices. Further, to qualify for favorable accounting treatment, some firms may restrict their use of derivatives to transaction-based hedging, to manage, for instance, the risk inherent in foreign sales/purchases or specific interest-bearing debt securities.

(ii) Firms making decentralized decisions on derivatives use for internal budgeting, contracting, or performance evaluation purposes. For example, decisions by some division-level managers to use derivatives to hedge specific transactions may be economically important for the performance of those divisions, yet the positions in aggregate are not necessarily large relative to the overall entity-level exposure.

(iii) Firms using derivatives for purposes other than those predicted by traditional risk-management theory. For example, firms may use derivatives to speculate on asset prices or to mitigate the likelihood that changes in asset prices increase analyst forecast errors.

Brown (2001) reaches some similar conclusions in a case study that examines extensive transaction-level derivatives data for a large multinational corporation. Specifically, he finds that the impact of derivatives instruments has a limited effect on the firm's cash flows, that traditional theoretical risk-management motivations are unlikely to explain derivatives use, and that internal budgeting, performance evaluation, and analyst forecast error concerns significantly influence the objectives of the derivatives program.

1.2. Implications for empirical research on derivatives

Our findings have implications for the large body of empirical derivatives research that assumes corporate derivatives are an important component of firms' risk-management activities and/or that the magnitude of derivatives use is sufficiently large to have an economically significant effect on firm value and volatility. For example, Allayannis and Weston (2001) conclude that in a broad sample of firms, the use of foreign currency derivatives increases total firm value by as much as 4.87%, on average. Graham and Rogers (2002) document a positive relation between derivatives use and debt capacity in a broad sample of firms and argue that derivatives-induced debt capacity increases firm value by 1.1%, on average. Yet, neither study explores whether the sample firms' derivatives positions are sufficiently large to produce benefits of this magnitude (both studies use regression coefficients on derivatives use to infer the magnitude of the effect on firm value). The evidence in our broad-sample study raises doubts about these conclusions. Indeed, our findings suggest that the substantial increases in firm value documented in the previous studies are either driven by other risk-management activities (e.g., operational hedges) that are correlated with derivatives use, or that the results are spurious.

Our results also potentially explain the mixed findings of some studies that test whether economic theories of optimal hedging predict derivatives use by firms (e.g., Nance et al., 1993; Mian, 1996; Geczy et al., 1997; Allayannis and Ofek, 1998; Guay, 1999; Knopf et al., 2002). As Smithson (1996) and Graham and Rogers (1999) note, these studies find conflicting evidence about the extent to which hedging theories explain corporate uses of derivatives. For example, all of the studies listed above examine the relation between firm leverage and derivatives use. Three studies find support for a positive relation between hedging and leverage while three fail to find evidence of such a relation. Results are similarly mixed regarding the frequently tested risk-management hypothesis that agency costs of underinvestment drive derivatives use; some studies find the hypothesized positive relation between derivatives use and both the market-to-book ratio and R&D expenditures, while other studies find no such relation. Each study listed above assumes that the use of derivatives is a good proxy for risk-management activities. However, recent research (e.g., Geczy et al., 2001; Pantzalis et al., 2001) questions this assumption and concludes that operational hedging techniques are an important component of firms' overall risk-management activities. If hedging with derivatives is, in fact, only a small component of firms' overall risk-management activities, then derivatives use will be a noisy proxy for risk-management activities and the mixed results documented in the literature are understandable. Our evidence is consistent with this interpretation.

Finally, our findings question the assumptions underlying studies that examine the relation between executive risk aversion and derivatives use in broad samples of firms (e.g., Geczy et al., 1997; Knopf et al., 2002; Graham and Rogers, 2002). These studies use proxies for the sensitivities of executives' stock and option holdings to both stock price and volatility to estimate executives' tolerance toward risk and thus their incentives to modify stock price risk through the use of derivatives. If executives have rational expectations about the potential magnitude of the influence of derivatives on stock price volatility, an important assumption underlying the tests in these papers is that firms' derivatives use materially affects stock price volatility. Our evidence that most non-financial firms' derivatives portfolios are not large enough to have a noticeable effect on stock return volatility suggests that the validity of this assumption deserves further attention (also see Hentschel and Kothari, 2001).

1.3. Outline of the paper

Section 2 reviews the theories of corporate risk management. Section 3 describes sample selection and presents descriptive statistics on the economic characteristics of sample firms and their derivative positions. The main results of the paper appear in Section 4 where we report the sample firms' cash flow and market value sensitivities in the event of extreme changes in the underlying assets' prices. Section 4 also reports descriptive statistics that compare the sensitivities to proxies for the sample firms' economic risk exposures and examines cross-sectional variation in the sensitivities. We summarize the paper and offer conclusions in Section 5.

2. Hypothesis development and risk-management theory

In the absence of market imperfections, hedging does not affect firm value (Modigliani and Miller, 1958). Corporate risk-management theory, however, identifies several market imperfections that can make volatility costly. These imperfections can be broadly summarized as: (i) Costly external financing (Froot et al., 1993); (ii) Taxes (Smith and Stulz, 1985; Stulz, 1996; Leland, 1998); (iii) Costs of managerial risk aversion (Stulz, 1984; Smith and Stulz, 1985); and, (iv) Financial distress costs (Myers, 1977; Smith and Stulz, 1985).

While all of the risk-management theories posit that hedging can increase firm value, the type of firm risk targeted by the theories varies. The hedging theories that emphasize costly external financing focus on the volatility of cash flows as the risk measure to be hedged. For example, Froot et al. (1993) hypothesize that if external financing is more costly than internal financing, hedging can be a value-increasing activity if it more closely matches fund inflows with outflows, thereby lowering the probability that a firm needs to access the capital markets. There also exist potential tax motivations for hedging the volatility of cash flows and income. Smith and Stulz (1985) demonstrate that a reduction in the volatility of taxable income can lower expected taxes for firms with convex effective tax functions.[3] Stulz (1996) and Leland (1998) argue further that a reduction in cash-flow volatility through hedging can increase debt capacity and generate greater tax benefits, and Graham and Rogers (2002) provide empirical support for this hypothesis.

When managers are risk averse and under-diversified with respect to their compensation and firm-specific wealth, they are likely to require extra compensation to bear this risk. Thus, managers have an incentive to reduce firm risk and hedging can potentially reduce the required risk premium (Stulz, 1984; Smith and Stulz, 1985). The type of risk targeted for hedging, be it cash flows, earnings, or stock price volatility, depends on the nature of a manager's compensation contract and firm-specific wealth. Given that stock and option holdings account for the majority of firm-specific risk for top executives (e.g., Hall and Liebman, 1998), we expect that stock price volatility is the primary risk measure of concern to risk-averse executives. However, we also consider the possibility that executives use derivatives to smooth earnings performance due to accounting-based bonus compensation. Agency and contracting cost considerations can also motivate divisional managers of large firms with diversified business segment operations and/or geographically diverse operations to engage in hedging to smooth out or remove noise from their divisional performance (e.g., Brown, 2001).

Finally, Smith and Stulz (1985) argue that hedging can increase the value of a levered firm when the expected costs of financial distress are decreasing in firm value. By narrowing the distribution of firm-value outcomes, hedging reduces the expected costs of financial distress. Furthermore, Myers (1977) demonstrates that financial distress can provide equityholders with incentives to forgo positive net present value projects if the gains accrue primarily to fixed claimholders. Thus, hedging firm value

[3] Although we do examine income volatility as a potential determinant of derivatives use, we do not conduct a detailed analysis of tax convexity as a determinant of derivatives use. Graham and Smith (1999) find that tax convexity is not large for most firms and Graham and Rogers (2002) find that tax convexity is not an important determinant of derivatives use.

reduces the probability of distress and the likelihood that equityholders will find it beneficial to pass up valuable projects.

These risk-management theories are relevant to this study because our goal is to examine the extent to which firms hedge their risk exposures with derivative securities. The risk-management theories described above point to at least three risk exposures of interest: (i) Volatility of cash flows; (ii) Volatility of income; and, (iii) Volatility of firm value. Because it is not possible to identify a single risk measure that fully captures a firm's motivation for using derivatives, we examine the magnitude of firms' derivatives positions relative to each of these risk measures for all sample firms.

To gain additional perspective on firms' risk-management practices, we also examine the magnitude of risk hedged by the derivatives positions relative to other firm characteristics:

(i) Cash flows from investing activities;
(ii) Liquidity, measured as cash plus marketable securities;
(iii) Interest expense for firms that use interest rate derivatives;
(iv) Firm size, measured alternatively as cash flows from operations, absolute values of the changes in operating cash flows and net income, market value of equity, and book value of assets; and
(v) Exposures of market values of equity to financial prices—interest rate exposures for firms that use interest rate derivatives and exchange rate exposures for firms that use exchange rate derivatives.

3. Sample selection and descriptive statistics

We describe our sample selection procedure and the derivatives variables for which we gather information from firms' financial filings in Section 3.1. In Section 3.2, we present descriptive statistics on economic characteristics of the sample firms, which are useful in assessing the degree to which firms' derivatives positions might hedge potential risks. Section 3.3 explains our procedure for calculating cash flow and market value sensitivities using information about firms' derivatives positions and extreme movements in the underlying asset prices.

3.1. Sample selection

We use the Compustat annual database to identify an initial sample of the 1,000 largest market-valued, non-financial firms as of the end of 1995. We require that sample firms have return data on the Center for Research in Security Prices (CRSP) tapes and that they have a December fiscal year-end for financial reporting purposes. We focus on large stocks because previous evidence shows that large firms are more likely to be derivatives users (see, e.g., Nance et al., 1993; Hentschel and Kothari, 2001; Graham and Rogers, 2002), and because the largest 1,000 firms represent an economically important fraction of the value-weighted portfolio of US stocks.

Availability of return data on CRSP enables us to estimate firms' economic exposures and market value sensitivities. Finally, restricting the sample to December year-end firms facilitates data analysis by allowing consistent assumptions about prevailing interest rates, exchange rates, and commodity prices when we estimate cash flow and market value sensitivities.

From the initial sample of the 1,000 largest firms, we select every other firm and thereby reduce the sample to 500 firms. This reduction facilitates our hand collection of a significant quantity of information about each firm's derivatives positions as of December 1997 from Form 10-K filings with the SEC. Note, even though we gather derivatives data for 1997, we select the sample from the 1,000 largest firms as of 1995, not 1997. The reason is that market value is positively correlated with immediate past performance (i.e., largest firms are likely to have experienced good past performance and smallest firms poor performance). By selecting our sample in 1995, we increase the likelihood that our sample firms vary cross-sectionally in terms of financial health and other characteristics as of 1997. Of the 500 sample firms, 72 firms are dropped from the study because they merged or went out of business between the sample selection year, 1995, and the year we collect derivatives data, 1997. This attrition is more common among the smaller sample firms. We also exclude 15 firms because the Form 10-K filings indicate these firms use some or all of their derivatives for trading purposes as opposed to hedging purposes. The final sample contains 413 non-financial firms.

For each firm, we collect fiscal year-end 1997 information on the types of derivative securities held, the notional principal of each derivative instrument held, the remaining time-to-maturity of each instrument held, and whether the firm uses derivatives for trading purposes. Fiscal year 1997 is the latest year for which data were available at the time we began gathering data for this study. For 1997, GAAP pertaining to disclosure about financial derivatives is contained in the Statement of Financial Accounting Standards No. 119 (SFAS 119), "Disclosure about derivative financial instruments and fair value of financial instruments", which was released in 1994. Appendix A contains Intel Corporation's 1997 Form 10-K derivatives disclosure, as an example of a derivatives disclosure prepared in accordance with SFAS 119.

3.2. Descriptive characteristics

In Table 1, we present means and medians of firm size variables and a number of operating and investing flow variables, including three-year averages for cash flows from operations, absolute change in cash flows from operations, absolute change in net income, and investing cash flows. Columns 1 and 2 of Table 1 report mean and median values for the aggregate sample of 413 firms; the next two columns provide descriptive statistics separately for the 234 (56.7%) derivative users reporting derivatives positions at fiscal year-end 1997, and the last two columns contain data for the 179 (43.3%) derivatives non-users reporting no derivatives positions at fiscal year-end 1997. We mainly discuss the descriptive statistics for the derivatives users because the analysis examining the extent to which derivatives are used for risk

Table 1
Sample characteristics

Descriptive statistics ($ millions)	All firms		Derivatives users		Derivatives non-users	
	Mean	Median	Mean	Median	Mean	Median
MV equity	5,877	1,673	8,571	2,376	2,384	1,145
Assets	5,224	1,496	7,226	2,050	2,632	1,118
3-yr avg. CFO	502	127	735	178	201	86
3-yr avg. NI	219	59	318	74	91	52
3-yr avg. cash + mkt. securities	253	55	374	71	93	41
3-yr avg. investing CF	455	135	637	178	221	106
3-yr avg. interest expense	123	33	169	50	61	23
3-yr avg. absolute change in CFO	125	40	194	62	57	30
3-yr max. absolute change in CFO	241	67	349	104	101	48
3-yr avg. absolute change in NI	93	30	139	44	48	17
3-yr max. absolute change in NI	168	44	230	74	88	27
No. of firms	413		234		179	

The sample consists of 413 firms selected uniformly from the 1,000 largest firms on Compustat, ranked by market value of equity on December 31, 1995. The descriptive statistics are reported for the fiscal year ending December, 1997. MV Equity is common shares outstanding at year-end multiplied by stock price at year-end (Compustat #24 $\times$ Compustat #25). Assets is the book value of assets at year end (Compustat #6). Three-year avg. (x) is the average of variable x using data for the three years leading up to fiscal year-end 1997, when firms' derivatives positions are taken from the Form 10-K filings. CFO is cash from operating activities (Compustat #308). NI is net income before extraordinary items (Compustat #18). Cash + mkt. Securities is cash and short-term investments at year-end (Compustat #1). Investing CF is cash flows from investing activities (Compustat #311). Interest Expense is interest expense (Compustat #15). Firms with no interest expense in the year leading up to the date of derivatives measurement (i.e., no interest-bearing debt in year t) are excluded under the assumption that these firms have no reason to use derivatives to hedge interest expense in year t. Absolute Change in CFO is the change in annual CFO (Compustat #308). Absolute Change in NI is income before extraordinary items (Compustat #18). For these latter two variables, three annual absolute changes are calculated using four annual CFO observations leading up to the date of derivatives measurement. Max. Absolute Change in CFO and Max. Absolute Change in NI are the maximum absolute changes in annual CFO and NI, respectively, among the three annual changes leading up to fiscal year-end 1997.

management pertains to derivatives users. While the average market value of $5.9 billion for the aggregate sample is large because of our sample selection criterion, the derivatives users are the relatively larger firms with an average market value of $8.6 billion, compared to $2.4 billion for the non-users. Market value as well as all other variables in Table 1 exhibit right skewness.

The flow variables in Table 1 are three-year annual averages using data from 1995 to 1997. The descriptive statistics suggest derivatives users generally have large positive operating cash flows, net incomes, and investment cash flows. Mean (median) annual cash flows from operations for the derivatives users is $735 million ($178 million) and mean (median) annual investing cash flows is $637 million ($178 million). The firms are highly profitable in that derivatives users' mean (median) average annual net income is $318 million ($74 million). As an indication of the cash flow shocks the derivative users experience, we report the three-year average absolute change in annual cash flow from operations and net income, as well as the maximum absolute change in annual cash flow from operations and net income during the years 1995 to 1997. The average (maximum) absolute change in cash flow from operations (CFO) is \$194 million (\$349 million) for the derivatives users and the corresponding numbers for net income changes are \$139 million (\$230 million).

3.3. Derivatives data and descriptive statistics

Table 2 presents descriptive statistics on the notional principals of the derivatives positions as reported in the firms' Form 10-K filings at the 1997 fiscal year-end. The information applies only to the 234 derivatives users. We partition the derivatives into foreign exchange, interest rate, and commodity instruments. In each category, we further partition the instruments by type, e.g., swaps, forwards, and options. For each firm, we sum the notional principals for each type of security held in each category. The first column in Table 2 reports the number of firms that hold each type of security, and the next seven columns provide descriptive statistics for the outstanding notional principals calculated using data for the firms that hold those securities. The last two columns provide the mean and standard deviation of time-to-maturity for each category of securities held by the firms. Note that these descriptive statistics describe the reported derivatives positions held by the firms at fiscal year-end and may differ somewhat from the average derivatives positions held by the firms during the year.

Consistent with the findings in previous research, Table 2 reveals that foreign exchange (FX) and interest rate (IR) derivatives constitute the bulk of the activity both in terms of the number of users and the notional amount of derivatives used. Within the FX derivatives category, 124 of the 143 users have positions in forwards and futures, whereas only 33 firms hold FX swaps and 27 hold FX options. The median notional principal of FX forwards and futures is \$64.4 million and the range is from \$0.6 million to \$9.5 billion. The median notional principals are substantially greater for FX swap and option users, at \$243 million and \$203 million, respectively. Of the 143 firms that hold IR derivatives, swaps are the most popular securities (137 users), whereas IR caps and forwards are used by only a handful of firms (24 users).[4] The median firm's IR swap position, however, is only \$180 million of notional principal. Thirty-six firms use commodity derivatives with a median notional principal of \$40 million across all three instruments, forwards and futures, swaps, and options.[5] The four largest derivatives users in our sample, based on notional

[4] In a plain vanilla currency swap, the parties to the swap exchange interest payments in two foreign currencies each period and swap back the principal payments in the two foreign currencies at the maturity of the swap. Therefore, the sensitivity of the annual cash flows from a foreign currency swap to a given change in exchange rates depends on the size of the interest payment and the magnitude of the change in exchange rates. To avoid underestimating FX sensitivities or IR sensitivities, we include these derivatives as both FX swaps and IR swaps.

[5] For reporting purposes, certain types of commodity positions are not considered derivative instruments. For example, long-term purchase or sales contracts that fix commodity prices are not considered derivatives for reporting purposes if they can be settled in units of the commodity as opposed to cash.

Table 2
Descriptive statistics on derivative positions

Type of derivative	No. of users	Notional principal ($million) Mean	Std. Dev.	Min.	Q1	Median	Q3	Max.	Maturity (years) Mean	Std. Dev.
FX derivatives										
FX forwards/futures	124	419.6	1,079.0	0.6	12.0	64.4	371.5	9,511.0	1.2	0.6
FX swaps	33	428.1	625.7	0.7	65.0	243.1	441.0	2,874.0	4.8	4.2
FX options	27	290.5	387.4	6.0	42.8	202.9	354.7	1,537.0	1.4	0.8
All FX derivatives	143	517.4	1221.8	0.6	19.1	112.0	481.3	9,561.0	2.4	2.8
IR derivatives										
IR swaps	137	474.8	697.2	3.8	100.0	180.0	495.0	3,678.0	5.0	5.6
IR caps	15	205.0	255.2	17.7	80.0	100.0	200.0	1,003.4	4.7	5.2
IR forwards	9	367.8	458.7	50.0	85.0	200.0	350.0	1,500.0	1.1	0.2
All IR derivatives	143	499.5	746.4	3.8	100.0	200.0	500.0	3,678.0	5.4	6.2
Commodity derivatives										
Commodity forwards/futures	25	128.9	186.8	0.5	21.2	39.4	200.0	679.0	1.9	1.4
Commodity swaps	13	189.3	278.6	2.2	23.3	50.0	205.8	974.0	1.8	1.2
Commodity options	8	123.5	223.9	1.4	6.4	41.9	112.9	664.0	1.5	0.8
All Commodity derivatives	36	190.6	243.5	0.5	21.2	39.9	275.9	974.0	2.3	2.0

The sample consists of 234 firms that report derivatives use for hedging purposes at fiscal year-end 1997. This sample is obtained from a sample of 413 firms selected uniformly from the 1,000 largest firms on Compustat, ranked by the market value of equity on December 31, 1995. Notional principal is the stated dollar amount of the derivatives positions. Maturity is the remaining time to maturity of the derivatives positions.

principal, are Dow Chemical, Johnson & Johnson, International Paper, and Intel, with total notional principal holdings of $12.4 billion, $7.7 billion, $4.7 billion, and $4.6 billion, respectively (primarily in FX forwards and swaps and IR swaps).

The average time-to-maturity of the FX and IR swaps is about five years compared to about one to two years for commodity derivatives, FX forwards and options, and IR forwards and options. This is not surprising because swap contracts are typically designed to hedge periodic cash flows over long horizons (e.g., bond interest payments), whereas long-horizon forwards and options contracts are extremely illiquid or non-existent.

4. Results: derivative positions' market value and cash flow sensitivities

In this section, we present evidence on the cash flow and market value sensitivities of derivatives positions to extreme changes in the underlying asset prices. We begin by describing how we calculate the sensitivities for each derivative security. We then examine the extent to which the derivatives positions can potentially hedge firms' market values or operating flows in the event of extreme asset price movements. At the end of this section we explore whether the sensitivities of the derivatives positions are relatively larger for subsamples of firms with greater expected incentives to hedge. We also examine whether additional variables chosen to proxy for agency and contracting incentives to hedge (e.g., earnings smoothing, managerial risk-aversion and hedging in a multi-divisional firm) explain cross-sectional variation in the intensity of firms' derivatives activities.

4.1. Estimation procedure for derivative sensitivities

We estimate the cash flow and market value sensitivities of each firm's aggregate derivatives portfolio at 1997 fiscal year-end. Cash flow sensitivity is defined as the change in the annual cash flow resulting from each derivative security in the portfolio for a three standard deviation annual change in the price of the underlying asset (i.e., change in interest rates, exchange rates, or commodity prices). Similarly, we define market value sensitivity as the change in the value of each derivative security for a three standard deviation annual change in the prices of the underlying assets. We recognize that shocks to asset prices are not necessarily normally distributed, and as such, the probability of a three standard deviation change can be greater than that suggested by the normal distribution. Our choice of three standard deviations is simply intended to represent a low probability event. We assume that the cash flow sensitivities and market value sensitivities are perfectly positively correlated within each class of derivative security (i.e., none of the positions are offsetting). Graham and Rogers (2002) report that, on average, after netting out offsetting long and short IR and FX derivatives positions, a firm's net notional principal is only about 70% of its gross notional principal. This finding suggests our measures of firms' gross derivatives sensitivities are likely to substantially overstate firms' net derivatives sensitivities. We estimate cash flow (market value) sensitivities for each firm as the sum of the cash flow (market value) sensitivities across all the derivative securities in the portfolio.

The cash flow sensitivity measure is useful in gauging the importance of derivatives for risk management if firms use derivatives to hedge cash flows or income. For example, firms may use derivatives to dampen cash flow volatility and thereby reduce the likelihood that they incur the costs of accessing external capital markets to undertake valuable investment opportunities. The market value sensitivity measure is relevant to assessing the derivatives portfolio's importance for risk management if firms use derivatives to hedge firm value. For example, risk-averse managers may wish to mitigate stock price exposure to changes in interest rates, exchange rates, or commodity prices to reduce the volatility of their stock-based wealth.

We illustrate our estimation of the cash flow and market value sensitivities below using FX forwards and then summarize the estimation of IR and commodity derivative sensitivities. We provide complete estimation details for other FX derivatives, e.g., swaps and options, and for IR and commodity derivatives in Appendix B.

4.1.1. Cash flow and market value sensitivity of FX forwards

The cash flow sensitivity (market value sensitivity) of FX derivatives to exchange rate movements is measured as the estimated change in FX derivatives' annual cash flows (value) for a simultaneous, perfectly positively correlated 33% change in the currency exchange rates underlying the FX derivatives. We use 33% because it equals three times the average of the historical standard deviations of annualized percentage changes in the US dollar exchange rates for the ten most heavily weighted currencies in the Federal Reserve's Nominal Major Currencies Dollar Index. We compute the annualized standard deviations using quarterly observations over the ten-year period from 1988 through 1997. To annualize the exchange rate, interest rate, and commodity price standard deviations, we multiply the quarterly standard deviations by the square root of four. This procedure assumes independence across the quarterly changes. Empirically, the autocorrelations across quarterly changes are small, ranging from -0.12 for our commodity price time series to $+0.14$ for the interest rate time series.

We estimate the cash flow sensitivity of an FX forward contract to a three standard deviation change in the currency exchange rate as (\$ notional principal) $\times$ 33%. Because most FX forwards have a maturity of a year or less, we assume the market value and cash flow sensitivities to be the same. For forward contracts that mature in less than one year, we use the full 33% rate change in estimating the sensitivities. For longer-duration derivatives, such as FX swaps, IR swaps, and IR caps and options, our estimates of market value sensitivities are different from those of cash flow sensitivities, often substantially so (see Appendix B).

4.1.2. Interest rate and commodity derivatives

We measure market value (cash flow) sensitivities of IR derivatives to interest rate movements as the estimated change in the IR derivatives' value (annual cash flow) for a 3.4 percentage point change in the 6-month yield on T-bills. The choice of 3.4 percentage points reflects a three standard deviation change in the annualized percentage point change in the 6-month T-bill yield using quarterly observations over the ten-year period from January 1988 through December 1997.

We estimate commodity derivatives' sensitivities with respect to a 37% change in the underlying commodity price. For our sample firms, a majority of the commodity derivatives are written over a fuel-related resource, e.g., petroleum or natural gas (the remaining derivatives are written over commodities, such as metals, that are generally no more volatile than fuels). The choice of 37% reflects a three standard deviation change in the annualized percentage return of the quarterly Producer Price Index for Fuel over the ten-year period from January 1988 through December 1997. An alternative choice for the commodity index would be a more general index, such as the Producer Price Index for All Commodities. However, because this general index reflects a portfolio of commodity prices, its volatility is far lower than the volatility of a single commodity index. For example, the annualized standard deviation of the All Commodities Index is 2% versus 12.5% for the Fuel Index, although the correlation between these two indexes is high at 0.81. Therefore, we choose the more volatile Fuel Index to avoid underestimating the sensitivity of the commodity derivatives positions.

4.2. Descriptive statistics on sensitivities

Table 3 reports descriptive data on cash flow and market value sensitivities for the derivatives users' derivatives portfolios by type of derivative security and in aggregate. The mean and median aggregate cash flow sensitivities are $108 million and $15 million, respectively. The corresponding mean and median market value sensitivities are $154 million and $30 million, respectively. The disparity between the mean and median values underscores the influence of a relatively few intensive derivatives users (e.g., the largest market value and cash flow sensitivities are $3.4 billion and $3.2 billion, respectively). At the median, FX derivatives' contribution to cash flow sensitivity is about 25% greater than that of IR derivatives. However, because the average time to maturity for IR derivatives is considerably longer than that of FX derivatives, the contribution of IR derivatives to market value sensitivity is about 25% greater than that of FX derivatives. For most firms, commodity derivatives contribute substantially less sensitivity than either FX or IR derivatives.

In interpreting the sensitivities reported in Table 3, note that we make the following assumptions to ensure that we do not underestimate the estimated aggregate sensitivities:

(i) For each firm, we assume all derivative securities of the same type have payoffs that are perfectly positively correlated. For example, if a firm holds ten different FX contracts on ten different currencies, the value of all the contracts are assumed to

Table 3
Cash flow and market value sensitivities of firms' derivatives portfolios at the end of 1997

Type of derivative	Mean	Std. Dev.	Minimum	Q1	Median	Q3	Maximum
Cash flow sensitivity (*$million*)							
FX derivatives	86.0	281.1	0.0	0.0	2.9	40.3	3,140.0
IR derivatives	11.6	26.3	0.0	0.0	2.3	10.3	244.8
Commodity derivatives	9.9	41.2	0.0	0.0	0.0	0.0	360.4
All derivatives	107.5	294.8	0.2	4.4	14.9	80.6	3,238.8
Market value sensitivity (*$million*)							
FX derivatives	104.4	325.6	0.0	0.0	3.4	61.0	3,155.1
IR derivatives	39.4	88.9	0.0	0.0	4.2	34.1	676.0
Commodity derivatives	10.5	42.7	0.0	0.0	0.0	0.0	360.4
All derivatives	154.3	368.6	0.2	8.3	30.2	125.6	3,422.9

The sample consists of 234 firms that report derivatives use for hedging purposes at fiscal year-end 1997. The cash flow sensitivity of a firm's derivatives position is the change in the annual cash flow resulting from each derivative security in the portfolio for a given change in the price of the underlying asset (i.e., change in interest rates, exchange rates, or commodity prices). The market value sensitivity of a firm's derivatives position is the change in the value of each derivatives security in the portfolio for a given change in the prices of underlying assets. The sum of the cash flow sensitivities or market value sensitivities across all the derivatives securities yields the cash flow sensitivity and market value sensitivity for the entire derivatives portfolio under the assumption that prices of all the underlying assets simultaneously experience the assumed change (i.e., three standard deviations of annual changes). Details on this procedure are provided in Appendix B.

move in unison with the assumed shock to exchange rates. Similarly, if a firm holds a combination of IR swaps, caps, and forwards, we assume the values of all these securities move together with interest rates. As noted above, Graham and Rogers (2002) find that firms hold a substantial quantity of offsetting derivative positions.

(ii) We assume all options and option-like securities are deep in the money, and therefore we assume the maximum sensitivity. In Brown's (2001) case study of a large industrial firm's foreign exchange hedging program, the year-end notional principal of FX option and forward contracts totals \$3 billion. He also reports that this firm's derivatives program decreases the standard deviation of annual cash flow by only \$5 million. In contrast, if this firm were included in our sample, our method would yield a cash flow sensitivity of \$1 billion (i.e., \$3 billion $\times$ 0.33). If Brown's sample firm is typical, it suggests that the cash flows from derivatives contracts used in foreign exchange hedging programs are not highly correlated and/or a substantial amount of the FX option contracts are purchased out-of-the-money and finish out-of-the-money. To avoid underestimating cash flow and market value sensitivities, we assume that all option-like contracts are deep in-the-money with maximum sensitivity to changes in asset prices.

(iii) The aggregate sensitivity is an estimate of the change in the value of a firm's derivative securities assuming a three standard deviation shock occurs simultaneously for interest rates, exchange rates, and commodity prices. Further, we assume that the cash flow and value implications of all three shocks are perfectly positively correlated across all types of derivatives held.

To determine the likely implications of this third assumption for our results, we examine the correlation structure across interest rate, exchange rate and commodity (PPI) price indexes for the period January 1988 to December 1997. The indexes exhibit moderate cross-correlations, ranging from −0.40 to 0.23. To explore the extent to which our assumption of perfect positive correlation across the indexes overstates the sensitivities in Table 3, we estimate the expected change in any two of the indexes when the third index experiences a three standard deviation change. To do this, we first standardize the three time series to have the same standard deviation in price changes and then estimate pair-wise regressions between each of the indexes. The regression coefficients reflect the expected change in an index (measured in standard deviations) for a one standard deviation change in another index. Extrapolating these coefficients to a three standard deviation change yields the following table:

Three standard deviation change in:	Expected change in interest rates (in standard deviations)	Expected change in exchange rates (in standard deviations)	Expected change in commodity prices (in standard deviations)
Interest rates	3.0	0.8	0.4
Exchange rates	0.8	3.0	1.0
Commodity prices	0.4	1.0	3.0

The above table suggests that the probability of a simultaneous three standard deviation change in all three indexes is much less likely than a three standard deviation change in any one index. Further, conditional on a three standard deviation change in one index, the expected change in the other two indexes is considerably smaller than three standard deviations. This analysis suggests that our estimates substantially overestimate the aggregate cash flow and market value sensitivities of the derivatives positions in the event of a large shock to any one of the underlying asset prices.

4.3. Scaled sensitivities

4.3.1. Sensitivities scaled by firm characteristics

If derivatives securities are an important component of risk-management programs, the potential change in the value of a firm's derivatives positions should be economically significant when compared to potential hedging objectives, such as firm value, operating flows, and/or the firm's underlying risk exposures. Since the appropriate comparison depends upon the objective of the risk-management program and the theories of risk management, we report results comparing the sensitivities of firms' derivatives positions to a variety of firm characteristics.

Table 4 scales cash flow and market value sensitivities of firms' aggregate derivatives portfolios by the sample characteristics detailed in Table 1.[6] In interpreting the scaled sensitivities, we assume that the derivative securities' value is perfectly negatively correlated with the scaling variable, i.e., the derivatives are perfect hedges. In Brown's (2001) case study of a large industrial firm's foreign exchange hedging program, the correlation between changes in earnings and derivative profits and losses is −0.39. To the extent that the derivatives are not a perfect hedge (and it is inconceivable that they are a perfect hedge for all of the scaling variables), the reported scaled sensitivities overstate the potential impact of the derivatives positions on the firms' risk-management program. Also, note that, unlike the numerators in the scaled sensitivities, the data in the denominators are simply taken from the three most recent years, 1995 through 1997, and are not selected to reflect extreme realizations. Further, some of the scaling variables, such as changes in cash flows and earnings, are influenced by the cash flow realizations from firms' derivatives positions (e.g., in Brown's (2001) case study, the standard deviations of hedged annual cash flow and earnings are 10% to 15% smaller than the unhedged values). The extent to which our scaling variables reflect "normal" years and are affected by realizations from derivatives positions depends in part on whether movements in interest rates, exchange rates, and commodity prices were

[6] The scaling variables measure firm characteristics that could *potentially* be targeted for hedging and are not direct measures of firms' risk exposures. It is possible that many of the firms' assets and cash flows are not highly sensitive to changes in IR, FX, and commodity prices. For such firms, the derivatives sensitivities are expected to be small relative to the firm characteristics, even if the firms are using derivatives to fully hedge their core IR, FX, and commodity price exposures. However, in these cases, one would still conclude that derivatives use is not an economically important component of the firms' overall risk profile.

Table 4

Scaled cash flow and market value sensitivities of firms' derivatives portfolios at the end of 1997

Cash flow sensitivities are scaled by operating flow variables and market value sensitivities are scaled by the market value of equity or the firm's book value of assets

	Mean	Std. Dev.	Min.	Q1	Median	Q3	90th %	Max.
CF sensitivity/3-yr avg. annual CFO	0.45	2.26	0.00	0.03	0.10	0.27	0.62	25.41
CF sensitivity from IR derivatives only/3-yr avg. interest expense	0.35	1.07	0.00	0.05	0.12	0.25	0.70	11.37
CF sensitivity/3-yr avg. cash + mkt. securities	1.14	2.62	0.00	0.06	0.28	1.21	2.49	27.37
CF sensitivity/3-yr avg. annual investing CF	0.34	0.75	0.00	0.03	0.09	0.33	0.77	5.88
CF sensitivity/3-yr avg. absolute chg. in annual CFO	0.81	1.46	0.01	0.10	0.32	0.87	2.16	14.02
CF sensitivity/3-yr max. absolute chg. in annual CFO	0.46	0.75	0.00	0.06	0.17	0.53	1.12	6.29
CF sensitivity/3-yr avg. absolute chg. in annual NI	1.05	1.65	0.00	0.14	0.39	1.24	2.67	10.81
CF sensitivity/3-yr max. absolute chg. in annual NI	0.63	0.94	0.00	0.09	0.24	0.72	1.81	6.46
Market value sensitivity/MV equity	0.03	0.05	0.00	0.00	0.01	0.03	0.07	0.39
Market value sensitivity/assets	0.03	0.04	0.00	0.00	0.02	0.04	0.07	0.50

The cash flow sensitivity of a firm's derivatives position is the change in the annual cash flow resulting from each derivative security in the portfolio for a given change in the price of the underlying asset (i.e., change in interest rates, exchange rates, or commodity prices). The market value sensitivity of a firm's derivatives position is the change in the value of each derivatives security in the portfolio for a given change in the prices of underlying assets. The sum of the cash flow sensitivities or market value sensitivities across all the derivatives securities yields the cash flow sensitivity and market value sensitivity for the entire derivatives portfolio under the assumption that prices of all the underlying assets simultaneously experience the assumed change (i.e., three standard deviations of annual changes). Details on this procedure are provided in Appendix B. Three-year avg. (x) is the average of variable x using data for the three years leading up to fiscal year-end 1997 when firms' derivatives positions are taken from the Form 10-K filings. CFO is cash from operating activities (Compustat #308). NI is net income before extraordinary items (Compustat #18). Interest Expense is interest expense (Compustat #15). Firms with no interest expense in the year leading up to the date of derivatives measurement (i.e., no interest bearing debt in year t) are excluded under the assumption that these firms have no reason to use derivatives to hedge interest expense in year t. Cash + Mkt. Securities is cash and short-term investments at year-end (Compustat #1). Investing CF is cash flows from investing activities (Compustat #311). Three annual absolute changes in CFO and NI are calculated using four annual CFO and NI observations from the period 1994 through 1997. Max. absolute change in CFO and Max. absolute change in NI are the maximum absolute changes in annual CFO and NI, respectively, among the three annual changes leading up to fiscal year-end 1997. MV Equity is common shares outstanding at year-end multiplied by stock price at fiscal year-end 1997 (Compustat #24 $\times$ Compustat #25). Assets is book value of assets at fiscal year-end 1997 (Compustat #6).

"unusual" during the 1995 through 1997 period. An analysis comparing price movements during the 1995 through 1997 period with those during the longer 1988 through 1997 period indicates that the 1995 through 1997 period was not unusual. Interest rate, exchange rate and commodity price volatilities were slightly lower during 1995 through 1997 compared to 1988 through 1997, and the 1997 levels of these asset prices were not substantially different from the 1995 levels.

The results in Table 4 suggest that for most firms, the estimated sensitivities are not a large fraction of the scaling variables. Although average values of the cash flow sensitivities as a fraction of the firms' operating flow variables are quite large (e.g., 0.45 when we scale by three-year average CFO), the means are driven by extreme observations (e.g., the maximum is 25.41 when we scale by three-year average CFO), which generally result from small denominators, i.e., low three-year average flow values. The median scaled values are between 0.10 and 0.30 for most of the flow variables. For example, at the median, the estimated cash flow from the derivatives portfolio would be 9% of the three-year average investing cash flow in the event of extreme movements in the underlying asset prices. For an alternative perspective on the potential hedging ability of the derivatives positions, we scale cash flow sensitivity by three-year average absolute changes in operating cash flow (median = 0.32), and three-year maximum absolute change in operating cash flow (median = 0.17). We also scale the sensitivities by average absolute and average maximum changes in net income and obtain similar results. Considered in isolation, and in light of the upward-biased assumptions we make in estimating the sensitivities, these increments to firms' cash flows appear small and unlikely to prevent substantial alterations in firms' investment policies in the event of unfa-vorable circumstances.

The market value sensitivity as a fraction of book value of assets (market value of equity) averages 0.03 (0.03); the median is 0.02 (0.01) and the 75th percentile is 0.04 (0.03).[7] Thus, for three-quarters of the sample firms, in the event of extreme simultaneous movements in interest rates, exchange rates, and commodity prices, the estimated change in the value of the firms' aggregate derivatives portfolios is no greater than 4% of the book value of assets. Overall, the evidence suggests that on average, derivatives are unlikely to have an economically large effect on the volatility of the sample firms' cash flows or values. These findings call into question empirical

[7] Market value sensitivities scaled by operating flow variables might also provide a relevant benchmark for assessing the importance of the derivatives positions because firms can often monetize market value gains or losses on derivatives into current cash flow by closing out the contracts. However, under the hypothesis that firms enter into derivative positions for hedging purposes, firms that use multi-year derivatives positions likely have multi-year risk exposures (e.g., a long-term interest rate swap or foreign sales contract). That is, for firms with multi-year derivatives positions, we expect shocks to interest rates, exchange rates, or commodity prices to have an effect on both current and future cash flows. If our assumption is correct, scaling the monetized cash flows from the derivatives position by current cash flow requirements overestimates the extent of hedging by the sample firms because the denominator in this measure excludes the cash flow effects of a current price shock on future cash flows. In the next section, we estimate the effect of a price shock on the present value of future cash flows using exposure coefficients from regressions of stock returns on changes in interest rates and exchange rates. We then construct measures of monetized cash flows from the derivatives positions scaled by a capitalized measure of the expected future operating cash flows that result from a price shock.

findings that the magnitudes of derivatives positions held by broad samples of non-financial firms are sufficient to have an economically large effect on firm-level volatility or firm value. For example, our results are difficult to reconcile with the conclusion by Allayannis and Weston (2001) that, for a broad sample of firms, the use of foreign currency derivatives increases firm value by as much as 4.87%, on average. In the absence of private information about asset prices, derivatives can increase firm value by reducing the costs associated with volatility. That is, hedging theory predicts that derivatives can increase firm value through their second-moment effects as opposed to their first moment effects. Our evidence suggests that even if derivative-using firms had private information about directional movements in interest rates, exchange rates, and commodity prices, most of the derivative positions appear much too small to increase firm value by 4.87%.

For a small fraction of the firms, the estimated scaled sensitivities are quite large. To better understand the characteristics of these firms, we examine in greater detail the eight separate firms that are associated with either the top-five largest market value sensitivities scaled by assets or the top-five largest cash flow sensitivities scaled by three-year average cash flow. Four of these firms have large seemingly offsetting positions (e.g., three firms had both fixed-to-floating and floating-to-fixed IR swaps, and two firms disclose that their foreign currency derivatives portfolio contains contracts to both buy and sell US dollars). Two firms hold large option contracts (in excess of $1 billion) that are out-of-the-money as of year-end 1997 (our computations assume these options are deep in-the-money). Three of the firms with large scaled cash flow sensitivities had extremely small realized average cash flow values in the ratio's denominator (i.e., three-year average cash flow of less than 1% of assets). This investigation suggests that at least some of the large scaled sensitivities are due to upwardly-biased measurement errors in our estimates.

4.3.2. Sensitivities scaled by estimated exposures

The preceding analysis examines derivatives portfolios' sensitivities as a fraction of contemporaneous firm characteristics that proxy for the potential hedging needs of a firm. For another perspective on this issue, we directly estimate the exposure of firms' market values to interest rates and currency exchange rates, and examine the extent to which firms' derivatives portfolios potentially hedge these exposures. Because many sample firms hold multi-year derivatives positions, we expect shocks to interest rates, exchange rates, or commodity prices to affect both current and future cash flows. To assess the extent to which firms' derivatives portfolios potentially hedge these multi-year exposures, we estimate the effects of interest rate and exchange rate shocks on the present value of future cash flows using exposure coefficients from firm-specific regressions of stock returns on changes in interest rates and exchange rates. We then compare the estimated effects of interest rate and exchange rate shocks on the present value of cash flows from the derivatives positions (i.e., market value sensitivities) with the estimated effects of the shocks on the present value of firms' future operating cash flows (i.e., the regression-based exposures). We report estimated market-based exposures in Table 5 and scaled sensitivities in Table 6. The analysis below excludes exposures to commodity prices

Table 5
Descriptive statistics on stock return based exposures

	Mean	Std. Dev.	Median
Interest rate exposure (% of market value of equity)	33%	29%	24%
Interest rate exposure (dollars of market value of equity)	$2,939 mil	$8,258 mil	$825 mil
Exchange rate exposure (% of market value of equity)	25%	25%	17%
Exchange rate exposure (dollars of market value of equity)	$1,748 mil	$3,988 mil	$458 mil
Stock-return volatility (annualized percentage standard deviation of monthly returns)	30%	15%	26%
Stock-return volatility (expected annualized standard deviation of the market value of equity)	$2,068 mil	$4,746 mil	$627 mil

The regression model for estimating interest rate and exchange rate exposures is $R_{it} = a + b_1 \Delta$ T−Bill rate$_t$ $+ b_2\% \Delta FX_t + b_3 R_{mt} + \varepsilon_{it}$. Interest rate and exchange rate exposures are reported only for those firms holding IR and FX derivatives, respectively. Interest rate exposure in percent of the market value of equity is the absolute value of the coefficient from a three-year regression of monthly stock returns on the monthly percentage change in the 6-month T-bill rate (b_1 in the regression model) multiplied by a 3.4% change in the 6-month T-bill rate. Interest rate exposure in dollars of the market value of equity is the interest rate exposure in percent of the market value multiplied by the market value of equity at the end of 1997. Exchange rate exposure in percent of the market value of equity is the absolute value of the coefficient from a three-year regression of monthly stock returns on the monthly percent change in the trade-weighted exchange index (b_2 in the regression model) multiplied by a 33% change in the trade-weighted exchange index. Exchange rate exposure in dollars of the market value of equity is the exchange rate exposure in percent of market value multiplied by the market value of equity at the end of 1997. Stock return volatility measured as the annualized standard deviation of monthly returns is computed over the three years leading up to December, 1997. Stock return volatility measured as the expected annualized standard deviation of the market value of equity is the three-year annualized standard deviation of monthly returns multiplied by the market value of equity at the end of 1997.

Table 6
Market value sensitivities of firms' derivative portfolios scaled by return-based exposures

	Mean	Std. Dev.	Min.	Q1	Median	Q3	90th%	Max.
Market value sensitivity/interest rate exposure	0.29	1.53	0.00	0.01	0.03	0.12	0.39	17.08
Market value sensitivity/exchange rate exposure	0.91	4.51	0.00	0.01	0.06	0.22	0.80	44.17
Market value sensitivity/stock return volatility	0.10	0.17	0.00	0.01	0.04	0.12	0.25	1.11

The market value sensitivity of a firm's derivatives position is the change in the value of each derivatives security in the portfolio for a given change in the prices of the underlying assets. The sum of the market value sensitivities across all the derivative securities yields the market value sensitivity for the entire derivatives portfolio under the assumption that prices of all the underlying assets simultaneously experience the assumed change (i.e., three standard deviations of annual changes). Details on this procedure are provided in Appendix B. Interest rate exposure, exchange rate exposure, and stock return volatility are the interest rate exposure in dollars of the market value of equity, exchange rate exposure in dollars of the market value of equity, and the stock return volatility measured as the expected annualized standard deviation of the market value of equity as described and summarized in Table 5.

because a relatively small fraction of the sample firms uses commodity derivatives and because firms do not consistently report the commodity prices to which they face risk exposure.

Table 5 reports both sample firms' market-based exposures to interest rates and exchange rates, and the volatility of the market value of equity. To estimate interest rate and exchange rate exposures, we regress monthly stock returns on monthly changes in the 6-month T-bill yield, monthly percentage changes in the Federal Reserve's Nominal Major Currencies Dollar Index, and monthly returns on the CRSP value-weighted market index (for similar procedures, see Guay, 1999; Wong, 2000; and Hentschel and Kothari, 2001). We estimate the regressions separately for each sample firm using data for the three years ending December 1997. We define estimated interest rate exposure as the product of the absolute value of the regression coefficient on the interest rate variable multiplied by a 3.4 percentage point change in the 6-month T-bill yield, which serves as an extreme change in the interest rate. Because we estimate the exposure coefficients using firms' stock returns as the dependent variable, the exposures calculated as above are denominated in percentages of the market value of equity, i.e., stock returns. Similarly, the exchange rate exposure is the absolute value of the regression coefficient on the exchange rate variable multiplied by a 33% change in the Federal Reserve's Nominal Major Currencies Dollar Index. In addition to return exposures, we also report dollar exposures. Dollar exposures are equal to the return exposures multiplied by the market value of equity at the end of December 1997.

Results in Table 5 reveal that the sample firms' median market-based exposure to a three standard deviation change in interest rates is quite substantial at 24%, or in dollar terms, $825 million. The firms' exchange rate exposures are smaller than the interest rate exposures, but nevertheless quite substantial. The median exchange rate exposure is 17% of the market value of equity, or $458 million. Note that because the estimates of interest rate and exchange rate exposures are net of the hedging consequences of the firms' derivatives portfolios, our measures underestimate the firms' core exposures to interest rates and exchange rates. We recognize that our tests may suffer from estimation errors in our measures of interest rate and exchange rate exposures. To examine the severity of this problem, we perform two untabulated sensitivity tests; in one, we use only firms with statistically significant interest rate and exchange rate exposure coefficients, whereas in the other, we use only firms with exposure coefficients that are in the top quartile with respect to the precision of the estimates (i.e., regression coefficients with standard errors in the lowest quartile). The inference from these sensitivity tests is the same as that from the reported results.

We define firms' stock return volatility as the annualized standard deviation of firms' monthly stock returns over the three-year period ending December 1997. The dollar stock return volatility is the annualized standard deviation of monthly returns multiplied by the market value of equity at December 1997. Table 5 shows that the median sample firm's annualized stock return volatility is 26%, or $627 million.

Table 6 reports both the market value sensitivities of the firms' derivative securities scaled by the estimated dollar exposures to interest rates and exchange rates, and the dollar standard deviation of the market value of equity. The scaled sensitivities reflect the fraction of the change in stockholder value that would be offset by derivatives in the event of a shock to asset prices. For the scaled interest rate measure, the numerator includes only the market value sensitivity from IR derivatives. Similarly, for the scaled exchange rate measure, the numerator includes only the market value sensitivity from FX derivatives. The market value sensitivity for all derivative securities is included in the numerator of the scaled market value of equity volatility measure. The median scaled sensitivities to interest rate dollar exposures, exchange rate dollar exposures, and the dollar standard deviation of stock returns are 0.03, 0.06, and 0.04, respectively.

These findings suggest that derivative securities are unlikely to have a significant impact on entity-level interest rate exposures, exchange rate exposures, or stock return volatility. The results also suggest that it is unlikely that risk-averse executives with rational expectations use derivatives to lower the stock price volatility inherent in their stock and option portfolios, at least within broad samples of non-financial firms.

Note that our inference is with respect to *entity-level* exposures as opposed to *transaction-level* exposures. Entity-level risk exposures subsume transaction-level exposures but also include operational risk exposures such as supply, demand, and competitive effects related to changes in interest rates or exchange rates. We make no statements about the portion of a particular type of transaction-based exposure that is hedged, such as the fraction of foreign sales hedged with FX derivatives or the portion of variable rate debt that is hedged with IR derivatives. It is possible that contracting costs and/or the desire to qualify for hedge accounting treatment drive some firms to engage in transaction-level hedging. Our results in Table 6 simply suggest that if firms do hedge a large portion of these transaction-level exposures, then the transaction-level exposures make up a relatively small fraction of firms' overall market value exposures to interest rates, exchange rates, and commodity prices. For example, Allayannis and Weston (2001) use the notional amount of foreign currency derivatives scaled by foreign sales as a proxy for the amount of exchange rate exposure hedged by their sample firms. They find that this ratio averages 22%. Our results suggest that this hedge ratio overstates the amount of total exchange rate risk that firms hedge with FX derivatives, in large part because foreign sales fail to capture important elements of entity-level exchange rate exposure. As a further point, if hedging transaction-level exposures *is* an important objective of firms' derivatives programs, an interesting and unanswered question is *why* firms spend considerable effort and resources to hedge this relatively small component of their overall risk profile.

4.4. Risk-management theories and cross-sectional variation in scaled sensitivities

In this section we examine cross-sectional variation in the intensity of derivatives use. Evidence in the preceding sections indicates that most firms' derivatives positions are unlikely to significantly reduce the volatility of firm value or cash flows. However, it is possible that the intensity of derivatives use is economically large for large firms with the greatest incentives to hedge according to risk-management theories. We therefore analyze the relation between variables that proxy for the determinants of hedging and firms' scaled cash flow and market value sensitivities. We also entertain the possibility that firms use derivatives for other purposes, such as to smooth income and/or to reduce contracting costs between the firm and risk-averse employees. An important feature of our inference that differs from previous research is that we emphasize the magnitude, not the statistical significance, of the relation between derivatives use and determinants of hedging.

4.4.1. Proxy variables for the determinants of hedging

Based on the risk-management theories discussed in Section 2, we expect cash flow volatility, growth opportunities, and leverage to proxy for firms' incentives to hedge. We measure cash flow volatility as the average absolute change in the ratio of annual cash flow from operations to assets from 1994 through 1997. We also use an earnings-based volatility measure, calculated similar to the cash-flow-based measure, on the premise that earnings represent a forecast of a firm's future cash flow generating ability (see, e.g., Dechow et al., 1998). We use the market-to-book ratio of assets as a proxy for firms' growth opportunities. Leverage is calculated as the ratio of the book value of debt to the market value of assets and serves as a proxy for the probability of financial distress.

In addition to the above measures, we also examine firm size, segment diversification, and geographic diversification. Firm size, measured as the book value of assets, proxies for the potentially greater benefits of hedging for smaller firms because the direct costs of distress do not increase proportionately with firm size (Warner, 1977). In addition, previous research shows that small firms' earnings and cash flows are more volatile than those of large firms. Segment and geographic diversification are crude proxies for the degree of diversification of the firm's sources of cash flows, suggesting a negative correlation between these variables and the demand for hedging. We estimate segment diversification with an entropy measure of total product diversification, calculated from data on the Compustat Industry Segments File and defined as $\Sigma P_i \ln(1/P_i)$ where P_i is dollar sales of principal product i scaled by total firm sales. Geographic diversification is also an entropy measure, calculated from data on the Compustat Geographic Segments File and equal to $\Sigma G_i \ln(1/G_i)$, where G_i is dollar sales represented by geographic segment i scaled by total firm sales. We also include the cash and marketable securities variable described in Table 2; substantial holdings of cash and marketable securities can act as alternative means of risk management by providing the firm with a buffer against cash shortfalls.

Firm size, segment diversification, and geographic diversification might also generate demand for derivatives by managers because of contracting-related reasons. Large, diversified firms are more likely to be multi-divisional. At the divisional level, variation in profits or revenues due to variation in financial prices may be uninformative about manager performance. If the costs of writing contracts to remove this variation are large, firms might rationally allow lower-level managers to smooth their divisional performance by hedging with derivatives, even though these positions are not large enough to significantly hedge entity-level risk. Thus, whereas diversified sources of cash flows for these firms would suggest less intensive demand for derivatives, agency considerations predict that these firms would use derivatives more intensively.

A related contracting argument also applies to top executives such as the CEO. Optimal contracts written between firms and their executives often impose risk on the executive through stock-based and accounting-based performance measures. The cost of these contracts to the firm increases with the noise in the performance measures. To reduce contracting costs, firms may allow executives to remove uncontrollable market risks through hedging with derivatives. We use two proxies to capture executives' incentives to mitigate uncontrollable market risks. The first variable is a measure of stock-based incentives computed as the sensitivity of the value of a CEO's stock and option portfolio to a 1% change in stock price. We estimate this sensitivity following the method described in Core and Guay (2002), using data from the Execucomp database and from proxy statements for firms not listed on Execucomp. The second variable is a measure of a CEO's incentives from annual bonuses. This variable is defined as the total cash bonus paid to the CEO over the previous three years as a fraction of the CEO's total pay over the same period. Total pay includes cash pay plus grants of restricted stock, options and other annual compensation, and is calculated using data from the Execucomp database and from proxy statements for firms not listed on Execucomp. We recognize that this variable measures managers' incentives to smooth earnings with error because it does not incorporate the influence of non-linearities in the shape of the bonus scheme.

4.4.2. Evidence on cross-sectional variation in hedging intensity

To explore how the intensity of derivatives use varies with hypothesized determinants, we partition derivatives users into quintiles based on the proxy variables described above. Table 7 reports median scaled sensitivities for the first, third, and fifth quintiles of the proxy variables. Although we report results for only three of the scaled sensitivities (i.e., market value sensitivity scaled by assets, cash flow sensitivity scaled by three-year average investing cash flows, and cash flow sensitivity scaled by the largest absolute change in cash flow during the previous three years), the results are similar for the remaining scaled sensitivity measures.

Table 7 indicates that the scaled sensitivities are not large for most of the quintile rankings. In no quintile does the median firm's market value sensitivity exceed 3% of assets. In the remaining columns, where hedging intensity is defined as scaled cash flow sensitivity, the median values are generally small, in most cases less than 30%. Table 7 also shows that some of the hedging proxy variables are correlated with derivatives intensity in the direction predicted by theory. For example, hedging intensity increases with the ratio of market-to-book value of assets across the quintiles. However, while a positive correlation between hedging intensity and proxies for the incentives to hedge is consistent with risk-management theory, such a finding is not sufficient to conclude that derivatives securities are an economically important component of firms' risk profiles.

The largest median scaled cash flow sensitivity reported in Table 7 is 0.43, which occurs in the quintile of firms with the greatest geographic diversification when the scaling variable is the largest absolute change in cash flow during the previous three years. Geographic diversification exhibits a strong and consistent positive relation with derivatives intensity across the columns in Table 7. A potentially confounding issue in interpreting the results for geographic diversification is that firm size also exhibits consistent positive relations with both derivatives intensity and diversification. In Table 8, we rank firms first into quintiles by size, and then within each size quintile by above- and below-median geographic diversification, to explore whether firm size influences the observed relation between diversification and derivatives-use intensity. The results suggest that geographic diversification is more strongly positively related to derivatives intensity than size. In each size quintile, firms with above-median geographic diversification exhibit significantly higher derivatives intensity, and in several cases, the magnitude of the median firm's derivatives intensity is quite large.

Table 9 reports multivariate regressions of derivatives intensity on the proxies for hedging incentives. The first two columns report regressions using cash flow and market value sensitivities scaled by assets as the dependent variables. Note, the three-year average absolute change in annual net income scaled by assets is excluded from the regression because of its high correlation with the three-year average absolute change in annual cash flow from operations scaled by assets. The coefficients on the market-to-book assets ratio and the cash and marketable securities variable are in the predicted directions and are marginally significant, thus providing some support for the hypotheses that derivatives use is related to growth and cash constraints. Consistent with the findings in Tables 7 and 8, the coefficients on geographic diversification are positive and significant in both regressions. Further, unreported results show that the significance of geographic diversification is attributable to firms holding FX derivative positions. In an expanded regression that includes the geographic diversification variable as a main effect and the geographic diversification variable interacted with a dummy variable for FX derivatives users, only the latter is statistically significant. The significance of the geographic diversification variable interacted with the FX derivatives-user dummy suggests corporations with multinational operations hedge foreign currency transaction exposure. None of the other coefficients in Table 9 are significantly different from zero.

Alternative regression specifications that use other scaled sensitivities from Table 4 as the dependent variable generally yield similar results. The results are also similar for a Tobit specification that includes the non-derivatives users as a way to control for self-selection issues. When the interest rate and exchange rate exposures reported in Table 5 are included as independent variables, their coefficients are generally *negative* and marginally significant, suggesting that firms with greater exposure to interest rates and exchange rates use derivatives less intensively. However, none of the other results are altered when these variables are included.

For comparison with previous research, the last column in Table 9 reports regression results using total notional principal scaled by assets as the dependent variable. In contrast to the results in the first two columns, the coefficients on firm size, the sensitivity of CEO wealth to stock price, and cash holdings are now

Table 7
Median scaled cash flow and market value sensitivities for first, third, and fifth quintiles of firm-year observations ranked independently on proxy variables for hedging determinants

Proxy variables for hedging determinants	Median (market value sensitivity/assets)			Median (CF sensitivity/3-yr avg. annual investing CF)			Median (CF sensitivity/maximum absolute Chg. in annual CFO from previous three years)		
	Ql	Q3	Q5	Ql	Q3	Q5	Q1	Q3	Q5
Leverage	0.017	0.015	0.021	0.144	0.090	0.069	0.148	0.188	0.167
Market-to book assets	0.015	0.015	0.022	0.052	0.111	0.171	0.166	0.200	0.211
3-yr avg. absolute change in annual (NI/assets)	0.011	0.019	0.018	0.053	0.124	0.141	0.164	0.247	0.171
3-yr avg. absolute change in annual (CFO/assets)	0.012	0.018	0.020	0.081	0.115	0.256	0.411	0.172	0.114
Fraction of total pay as bonus	0.010	0.016	0.012	0.054	0.112	0.085	0.118	0.241	0.154
3-yr avg. [(cash + marketable securities) assets]	0.013	0.017	0.011	0.058	0.079	0.121	0.178	0.166	0.112
Sensitivity of wealth to stock price	0.014	0.017	0.018	0.067	0.108	0.130	0.141	0.169	0.254
Assets	0.013	0.014	0.017	0.092	0.095	0.130	0.139	0.162	0.391

Segment diversification	0.014	0.018	0.013	0.074	0.140	0.106	0.247	0.186	0.166
Geographic diversification	0.010	0.009	0.030	0.045	0.071	0.239	0.113	0.108	0.429

The table reports median values of the scaled sensitivities listed in the column headings for the first, third, and fifth quintiles ranked by the hedging determinant listed in the row heading. The market value sensitivity of a firm's derivatives position is the change in the value of each derivatives security in the portfolio for a given change in the prices of underlying assets. The cash flow sensitivity of a firm's derivatives position is the change in the annual cash flow resulting from each derivative security in the portfolio for a given change in the price of the underlying asset (i.e., change in interest rates, exchange rates, or commodity prices). The sum of the cash flow sensitivities or market value sensitivities across all the derivatives securities yields the cash flow sensitivity and market value sensitivity for the entire derivatives portfolio under the assumption that prices of all the underlying assets simultaneously experience the assumed change (i.e., three standard deviations of annual changes). Details on this procedure are provided in Appendix B. Leverage is the book value of liabilities divided by the book value of assets at fiscal year-end 1997. Market-to-Book assets is the market value of equity plus the book value of liabilities divided by the book value of assets at fiscal year-end 1997. Three-year avg. absolute change in annual (NI/assets) and absolute change in annual (CFO/assets) are the average annual absolute changes in CFO and NI calculated using four annual CFO and NI observations from the period 1994–1997. Fraction of total pay as bonus is the total cash bonus paid to the CEO over the previous three years divided by total pay to the CEO over the three years ending with 1997. Three-year Avg. [(Cash + Marketable Securities)/Assets] is average cash and short-term investments (Compustat #1) divided by assets over the three years ending 1997. The Sensitivity of wealth to stock price is the estimate sensitivity of the value of a CEO's stock and option portfolio to a 1% change in stock price at fiscal year-end 1997. Assets is book value of assets at fiscal year-end 1997 (Compustat #6). Segment diversification is an entropy measure of total product diversification calculated from data on the Compustat Industry Segments file and is equal to $\sum P_i \ln(1/P_i)$ where P_i, is dollar sales of principal product i scaled by total firm sales. Geographic diversification is an entropy measure of geographic diversification calculated from data on the Compustat Geographic segments File and is equal to $\sum G_i \ln(1/G_i)$ where G_i, is dollar sales represented by geographic segment i scaled by total firm sales. The scaling variable three-year average investing CF is the average cash flows from investing activities (Compustat #311) using data for the three years leading up to fiscal year-end 1997. The scaling variable/ maximum absolute change in CFO from previous three years is the maximum absolute change in annual CFO among the three annual changes leading up to fiscal year-end 1997.

Table 8
Discriminating between firm size and geographic diversification as determinants of cash flow and market value sensitivities

	Median (market value sensitivity/assets)		Median (CF sensitivity/ 3-year average annual investing CF)		Median (CF sensitivity/ 3-year average absolute change in annual CFO)		Median (CF sensitivity/ max. absolute change in annual CFO from previous three years)	
Geographic diversification:	Below median	Above median	Below median	Above median	Below median	Above median	Below median	Above median
Asset quintile								
Smallest	0.01	0.01	0.07	0.16	0.12	0.36	0.10	0.19
2	0.02	0.02	0.05	0.14	0.43	0.64	0.21	0.42
3	0.01	0.02	0.05	0.15	0.21	0.26	0.16	0.16
4	0.01	0.02	0.03	0.20	0.13	0.52	0.08	0.28
Largest	0.01	0.03	0.06	0.30	0.22	1.02	0.14	0.51

Firms are ranked first into quintiles based on total assets and then ranked within each size quintile into above- and below-median geographic diversification. Assets is book value of assets at fiscal year-end 1997 (Compustat #6). Geographic Diversification is an entropy measure of geographic diversification calculated from data on the Compustat Geographic Segments File and is equal to $\sum G_i \ln(1/G_i)$ where G_i is dollar sales represented by geographic segment i scaled by total firm sales. The table reports median values of the scaled sensitivities listed in the column headings. The market value sensitivity of a firm's derivatives position is the change in the value of each derivatives security in the portfolio for a given change in the prices of underlying assets. The cash flow sensitivity of a firm's derivatives position is the change in the annual cash flow resulting from each derivative security in the portfolio for a given change in the price of the underlying asset (i.e., change in interest rates, exchange rates, or commodity prices). The sum of the cash flow sensitivities or market value sensitivities across all the derivatives securities yields the cash, flow sensitivity and market value sensitivity for the entire derivatives portfolio under the assumption that prices of all the underlying assets simultaneously experience the assumed change (i.e., three standard deviations of annual changes). Details on this procedure are provided in Appendix B. The scaling variable investing CF is cash flows from investing activities (Compustat #311). The scaling variable three-year average investing CF is the average cash flows from investing activities (compustat #311) using data for the three years leading up to fiscal year-end 1997. The scaling variable maximum absolute change in CFO from previous three years is the maximum absolute change in annual CFO among the three annual changes leading up to fiscal year-end 1997.

Table 9
Regressions of cash flow and market value sensitivities on determinants of derivatives use

Independent variables	Predicted sign	Dependent variable (%)		
		Cash flow sensitivity/ assets	Market value sensitivity /assets	Total notional principal/ assets
Intercept		1.12	1.01	22.75
		(0.64)	(0.64)	(2.67)
Leverage	+	−0.85	1.78	5.47
		(−0.66)	(1.55)	(0.87)
Market-to-book assets	+	0.31	0.36	0.57
		(1.44)	(1.88)	(0.55)
Log(assets)	−	−0.04	−0.21	−2.59
		(−0.17)	(−1.12)	(−2.52)
Segment diversification	+/−	0.10	0.23	0.15
		(0.22)	(0.59)	(0.07)
Geographic diversification	+/−	1.33	1.44	0.18
		(2.33)	(2.82)	(0.06)
Fraction of total pay as bonus	+	−1.25	−0.82	−5.58
		(−0.84)	(−0.61)	(−0.76)
Sensitivity of wealth to stock price	+	0.10	0.16	1.72
		(0.56)	(1.00)	(2.01)
3-yr avg. [(cash + marketable securities)/assets]	−	−2.44	−2.63	−22.69
		(−1.16)	(−1.39)	(−2.20)
3-yr avg. absolute chg. in annual (CFO/assets)	+	5.15	4.00	−10.19
		(0.76)	(0.66)	(−0.31)
No. of observations		223	223	223
Adjusted R-squared		2.2%	5.7%	2.3%

The sample consists of 234 firms that report derivatives use for hedging purposes at fiscal year-end 1997. The cash flow sensitivity of a firm's derivatives position is the change in the annual cash flow resulting from each derivative security in the portfolio for a given change in the price of the underlying asset (i.e., change in interest rates, exchange rates, or commodity prices). The market value sensitivity of a firm's derivatives position is the change in the value of each derivatives security in the portfolio for a given change in the prices of underlying assets. The sum of the cash flow sensitivities or market value sensitivities across all the derivatives securities yields the cash flow sensitivity and market value sensitivity for the entire derivatives portfolio under the assumption that prices of all the underlying assets simultaneously experience the assumed change (i.e., three standard deviations of annual changes). Details on this procedure are provided in Appendix B. Notional principal is the stated dollar amount of the derivatives positions. Leverage is the book value of liabilities divided by the book value of assets as fiscal year-end 1997. Market-to-book assets is the market value of equity plus the book value of liabilities divided by the book value of assets at fiscal year-end 1997. Log(assets) is the logarithm of book value of assets at fiscal year-end 1997 (Compustat #6). Segment diversification is an entropy measure of total product diversification calculated from data on the compustat industry segments file and is equal to $\sum P_i \ln(1/P_i)$ where P_i is dollar sales of principal product i scaled by total firm sales. Geographic Diversification is an entropy measure of geographic diversification calculated from data on the Compustat Geographic Segments File and is equal to $\sum G_i \ln(1/G_i)$ where G_i is dollar sales represented by geographic segment i scaled by total firm sales. Fraction of Total Pay as Bonus is the total cash bonus paid to the CEO over the previous three years divided by total pay to the CEO over the three years ending with 1997. The Sensitivity of Wealth to Stock Price is the estimate sensitivity of the value of a CEO's stock and option portfolio to a 1% change in stock price at fiscal year-end 1997. Three-year avg. [(cash + marketable securities)/assets] is average cash and short-term investments (compustat #1) divided by assets over the three years ending 1997. Three-year avg. absolute change in annual (CFO/assets) is the average annual absolute change in CFO calculated using four annual CFO observations from the period 1994–1997. The t-statistics are reported in parentheses.

of the predicted sign and are statistically significant, and the coefficients on geographic diversification and market-to-book are insignificant. The substantially different results in the notional principal regression suggest that further investigation into the determinants of derivatives use using richer proxies for the magnitude of firms' derivatives use may be fruitful. However, an important caveat in interpreting these results is that we have intentionally constructed upward-biased measures of cash flow and market value sensitivities so as to avoid underestimating the importance of firms' derivatives positions. In future research, regressions estimated using unbiased estimates of cash flow and market value sensitivities may yield better specified tests of the determinants of firms' derivatives use.

5. Summary and conclusions

In this paper, we examine the hypothesis that financial derivatives are an economically important component of corporate risk management. While previous research explores whether the corporate use of derivatives is consistent with theories of hedging, none of the previous studies document large-sample evidence on the magnitude of a firm's risk exposure hedged by financial derivatives. Absent such evidence, it is difficult to assess the importance of corporations' financial derivatives portfolios in managing risk.

For a random sample of 234 large non-financial corporations, we present detailed evidence on the cash flow and market value sensitivities of financial derivative portfolios to extreme changes in the underlying assets' prices. That is, for simultaneous extreme changes in interest rates, exchange rates, and commodity prices, we estimate an upper bound on both the dollar amount of cash flow that a firm would derive from its derivatives portfolio, and the change in the market value of the firm's derivatives portfolio. The median (75th percentile) firm's cash flow sensitivity to extreme changes in the underlying assets' prices is $15 ($81) million, and the market value sensitivity is $30 ($126) million. For most of the sample firms, these cash flow and market value sensitivities are small relative to the magnitude of traditional measures of economic exposures, or to operating and investing cash flow measures. For example, the median firm holds derivative securities that, even under very generous assumptions, could hedge only 3% to 6% of its aggregate interest rate and currency exchange rate exposures. Our inferences in this respect are broadly consistent across a variety of economic measures that capture different aspects of firms risk exposures.

Our results suggest that the magnitude of the derivatives positions held by most firms is economically small in relation to their entity-level risk exposures. However, we assume firms perceive that the benefits of their derivatives programs exceed the costs. Evidence in Brown's (2001) case study suggests that the cost of initiating and maintaining a derivatives program is not trivial. He estimates the annual costs to maintain the foreign currency hedging program for his large multinational case study firm to be $3.8 million, of which $1.5 million are operating costs and $2.3 million are transactions costs (the notional principal of outstanding derivatives contacts stood at $3 billion at year-end 1997). Brown estimates the net effect of this program on operating cash flows and earnings is to reduce annual changes by about $5 million and suggests that traditional risk-management theory is unlikely to fully explain the motivation for this derivatives program. Although the median firm in our sample is smaller than Brown's large case-study corporation and, likewise, uses smaller quantities of derivatives, we expect that firms consider similar trade-offs between the costs and benefits of initiating and maintaining a derivatives program. Maintaining a derivatives program that has a relatively small effect on entity-level risk, as observed for our sample of large firms, is potentially consistent with firms: (i) Using derivatives to ''fine-tune'' their overall risk-management program which likely includes other means of hedging (e.g., operational hedges through diversified manufacturing sites); (ii) Making decentralized decisions on derivatives use (e.g., divisional decision making) for internal budgeting or performance evaluation purposes; or, (iii) Using derivatives for purposes other than those predicted by traditional risk-management theory, such as to speculate on asset prices or to mitigate the likelihood that changes in asset prices increase analyst forecast errors (e.g., Brown, 2001).

Appendix A

Intel Corporation, Footnotes to Financial Statements for 1997 Derivative financial instruments

Outstanding notional amounts for derivative financial instruments at fiscal year-ends were as follows:

(In millions)	1997	1996
Swaps hedging investments in debt securities	$ 2,017	$ 900
Swaps hedging investments in equity securities	$ 604	$ 918
Swaps hedging debt	$ 155	$ 456
Currency forward contracts	$ 1,724	$ 1,499
Currency options	$ 55	$ 94
Options hedging investments in marketable equity securities	$ –	$ 82

While the contract or notional amounts provide one measure of the volume of these transactions, they do not represent the amount of the Company's exposure to credit risk. The amounts potentially subject to credit risk arising from the possible inability of counterparties to meet the terms of their contracts are generally limited to the amounts, if any, by which the counterparties' obligations exceed the obligations of the Company. The Company controls credit risk through credit approvals, limits and monitoring procedures. Credit rating criteria for off-balance-sheet transactions are similar to those for investments.

Swap agreements. The Company utilizes swap agreements to exchange the foreign currency, equity and interest rate returns of its investment and debt portfolios for floating US dollar interest rate based returns. The floating rates on swaps are based primarily on US dollar LIBOR and are reset on a monthly, quarterly or semiannual basis.

Pay rates on swaps hedging investments in debt securities match the yields on the underlying investments they hedge. Payments on swaps hedging investments in equity securities match the equity returns on the underlying investments they hedge. Receive rates on swaps hedging debt match the expense on the underlying debt they hedge. Maturity dates of swaps match those of the underlying investment or the debt they hedge. There is approximately a one-to-one matching of swaps to investments and debt. Swap agreements remain in effect until expiration.

Weighted average pay and receive rates, average maturities and range of maturities on swaps at December 27, 1997 were as follows:

	Weighted average pay rate	Weighted average receive rate	Weighted average maturity	Range of maturities
Swaps hedging investments in US dollar debt securities	6.1%	5.8%	0.9 years	0–3 years
Swaps hedging investments in foreign currency debt securities	6.3%	5.9%	1.0 years	0–3 years
Swaps hedging investments in equity securities	N/A	5.7%	0.6 years	0–2 years
Swaps hedging debt	5.9%	5.2%	1.6 years	0–4 years

Note: Pay and receive rates are based on the reset rates that were in effect at December 27, 1997.

Other foreign currency instruments. Intel transacts business in various foreign currencies, primarily Japanese yen and certain other Asian and European currencies. The Company has established revenue and balance sheet hedging programs to protect against reductions in value and volatility of future cash flows caused by changes in foreign exchange rates. The Company utilizes currency forward contracts and currency options in these hedging programs. The maturities on these instruments are less than 12 months. Deferred gains or losses attributable to foreign currency instruments are not material.

Fair values of financial instruments

The estimated fair values of financial instruments outstanding at fiscal year-ends were as follows.

	1997		1996	
(In millions)	Carrying amount	Estimated fair value	Carrying amount	Estimated fair value
Cash and cash equivalents	$ 4,102	$ 4,102	$ 4,165	$ 4,165
Short-term investments	$ 5,561	$ 5,561	$ 3,736	$ 3,736
Trading assets	$ 195	$ 195	$ 87	$ 87
Long-term investments	$ 1,821	$ 1,821	$ 1,418	$ 1,418
Non-marketable instruments	$ 387	$ 497	$ 119	$ 194
Swaps hedging investments in debt securities	$ 64	$ 64	$ (12)	$ (12)
Swaps hedging investments in equity securities	$ 8	$ 8	$ (27)	$ (27)
Options hedging investments in marketable equity securities	$ –	$ –	$ (25)	$ (25)
Short-term debt	$ (212)	$ (212)	$ (389)	$ (389)
Long-term debt redeemable within one year	$ (110)	$ (109)	$ –	$ –
Long-term debt	$ (448)	$ (448)	$ (728)	$ (731)
Swaps hedging debt	$ –	$ (1)	$ –	$ 13
Currency forward contracts	$ 26	$ 28	$ 5	$ 18
Currency options	$ 1	$ 1	$ –	$ –

Appendix B

For simultaneous extreme changes in interest rates, exchange rates, and commodity prices, we estimate for each sample firm both the dollar amount of cash flow that a firm would derive from its derivatives portfolio, referred to as the cash flow sensitivity, and the change in the market value of the firm's derivatives portfolio, referred to as the market value sensitivity. We describe this estimation procedure below for each class of derivative security.

FX derivatives: For FX derivatives, an extreme change is defined as a 33% change in the currency exchange rate. A 33% change equals three times the average historical standard deviation of annualized percentage changes in the US dollar exchange rate for the ten most heavily weighted currencies in the Federal Reserve's Nominal Major Currencies Dollar Index. The annualized standard deviations are computed using quarterly observations over the ten-year period from 1988 through 1997.

FX forwards: The cash flow and market value sensitivities of an FX forward/ contract to a 33% change in the currency exchange rate are estimated as: [$ notional principal × 33%]. Because most FX forwards have a maturity of a year or less, we assume the market value and cash flow sensitivities to be the same. For forward contracts that mature in less than one year, the assumed 33% change likely overstates a three standard deviation shock to exchange rates.

FX options: The market value sensitivity and cash flow sensitivity of an FX option to a 33% change in the currency exchange rate is estimated as: [$ notional principal × 33%]. Again, because FX options tend to have maturities of a year or less, we assume the market value and cash flow sensitivities to be the same.

Our sensitivity measure overestimates the actual sensitivity of most of the options because the computation assumes that all options are deep-in-the-money (i.e., have an option delta of one). For example, if the option is substantially out-of-the-money, the dollar sensitivity of the option value to exchange rate movements is very small. The sensitivity of an option approaches the sensitivity of a forward contract (i.e., sensitivity of one) in the limit as it moves deep-in-the-money. Because the strike price is rarely disclosed in the Form 10-K footnotes, it is not possible to precisely estimate the option sensitivity with public data. While the time to maturity of the options is sometimes disclosed, this information alone is not sufficient to accurately estimate option sensitivity. Therefore, we assume all options have the maximum possible sensitivity.

FX swaps. Market value sensitivity of an FX swap to a 33% change in the currency exchange rate is estimated as: [$ notional principal × 33%]. The rationale is as follows. From Hull (1997),

$$\text{Value of swap} = (S \times B_{\text{F}}) - B_{\text{D}} \tag{B.1}$$

where S is the spot exchange rate expressed as the number of units of domestic currency per unit of foreign currency, B_{F} the value of the foreign-denominated bond underlying the swap, measured in the foreign currency, and B_{D} the value of the US dollar bond underlying the swap. Therefore, assuming

$$B_{\text{F}} = B_{\text{D}} = \text{notional principal of the swap in \$US}, \tag{B.2}$$

then the market value sensitivity of an FX swap equals: [$ notional principal × 33%].

This should roughly be true when the firm first enters into the swap since the interest rates on swaps are likely to be set so that each bond trades at par. However, as exchange rates and interest rates change over time, the above assumption will no longer be valid for all firms, although it might still hold approximately, on average.

The cash flow sensitivity of an FX swap to a 33% change in the currency exchange rate is estimated as: [$ notional principal × 8% × 33%]. In a plain vanilla currency swap, the parties to the swap exchange interest payments in two foreign currencies each period and then swap back the principal payments in the two foreign currencies at the maturity of the swap. Therefore, the sensitivity of the annual cash flows from an FX swap to a given change in exchange rates depends on the size of the interest payment and the magnitude of the change in exchange rates. Because the interest rate underlying currency swaps is rarely disclosed in the 10-K report, we assume that foreign currencies are swapped by all firms at an interest rate of 8%. This interest rate is larger than the interest rates on Treasury bills and five-year US bonds in effect at December 31, 1997 (or at any time in the three-year period leading up to this date), and therefore is not likely to underestimate the cash flow sensitivity of FX swaps held by the sample firms.

We include FX/IR swaps in this group. These are currency swaps that swap fixed-for-floating interest rates and vice versa, in addition to the swap of currencies. For these swaps, the estimated exchange rate sensitivity is like a comparative static as it measures the sensitivity of the swap's value to exchange rates holding interest rates constant. The sensitivity of this swap to exchange rates is computed just like the standard FX swaps above. Note, since the value and cash flows of this type of swap are also sensitive to changes in interest rates, we include them in the interest rate sensitivity computations below as well.

IR derivatives. We measure the market value (cash flow) sensitivity of IR derivatives to interest rate movements as the estimated change in IR derivatives' value (annual cash flow) for a 3.4 percentage point change in the 6-month yield on T-bills. The choice of 3.4 percentage points reflects a three standard deviation change in the annualized percentage point change in the 6-month T-bill yield using quarterly observations over the ten-year period from 1988 through 1997.

IR swaps. The cash flow sensitivity of an IR swap to a 3.4% change in interest rates is estimated as: [$ notional principal $\times$ 3.4%]. In a plain vanilla IR swap, each party either pays or receives a cash flow equal to a floating interest rate times the notional principal of the swap. Therefore, when interest rates change, the change in periodic cash flows equals the notional principal multiplied by the change in interest rates.

The market value sensitivity of an IR swap to 3.4% change in interest rates is estimated as follows. From Hull (1997),

$$\text{Value of swap} = B_{\text{floating}} - B_{\text{fixed}}, \tag{B.3}$$

where B_{floating} is the value of the floating-rate bond underlying the swap, and B_{fixed} the value of the fixed-rate bond underlying the swap.

We assume $B_{\text{floating}} = B_{\text{fixed}} =$ notional principal of the swap because: (i) B_{floating} always equals the notional principal immediately after a payment date; and (ii) since the swap normally has a value of zero at initiation, B_{fixed} should be equal to notional principal at initiation. Of course, this equality will generally not be true during the life of the swap, although it might still hold approximately, on average. Given this assumption, the market value sensitivity of an IR swap equals the change in B_{fixed} for a 3.4% change in interest rates.

To compute this market value sensitivity, we must assume the fixed coupon rate that underlies the swap and the prevailing interest rates that should be used to discount the bond's cash flows. A random sampling of 150 companies reveals that 40% of the sample firms provide information about the interest rates underlying their swaps. In these cases, the coupon rates almost always fall between 5.5% and 6.5%.

We assume that the coupon rate and discount rate are both equal to 6% for all swaps, all firms, and all maturities. We then perturb the discount rate by $\pm 3.4\%$, to 2.6% and 9.4%, and compute the aggregate value of each firm's swaps at each of these discount rates. The average absolute value of the outstanding swaps computed at these two discount rates is taken to be the interest rate sensitivity of the derivatives.

While most firms disclose the time to maturity of their swaps, some disclose a range of maturities and others make no disclosure at all. For the firms that report a range of maturities, we take the midpoint of the range as the time to maturity. For companies that do not disclose any maturity information, we assume a time to maturity of five years, which is the average swap maturity for the firms that do provide disclosure.

We also include the IR/FX swaps when computing interest rate sensitivities. As indicated above, these are IR swaps that also swap currencies. As with the FX/IR swap, the IR sensitivity is like a comparative static as it measures the sensitivity to interest rates holding exchange rates constant. The sensitivity of this swap to interest rates is computed just like the standard IR swaps above. Since this type of swap is also sensitive to changes in exchange rates, we include them in the exchange rate sensitivity computations above.

IR forwards. We assume each forward contract is written on a five-year Treasury note with notional principal equal to the disclosed notional principal. We assume the firm holds the five-year note and we estimate the cash flow sensitivity of the forward as the change in the value of the note as a result of a 3.4% change in interest rates. Similar to our computations for IR swaps, we assume that the initial discount rate on the note is 6% for all IR forwards. The initial value of the note is assumed to be equal to [\$ notional principal / $(1.06)^5$]. We then perturb the interest rate by $\pm 3.4\%$, to 2.6% and 9.4%, and compute the change in the value of the note at each of these discount rates. The average absolute change in value for the notes computed at these two discount rates is taken to be the interest rate sensitivity of the IR forward derivatives. Because IR forwards held by our sample firms mature almost invariably within a year, we assume the market value and cash flow sensitivities to be the same.

We include the three sample firms with IR options in this group as well. As with the forwards, we assume the options are written on a five-year Treasury note. As with the FX options, this sensitivity measure should overestimate the "true" sensitivity because our computation is appropriate only for options that are deep-in-the-money.

IR caps, *IR floors*, *IR collars*. Caps, floors, and collars are similar to swaps except that the swap payments occur only when interest rates are above (caps and collars) or below (floors and collars) some pre-specified interest rate. To compute an upper bound on the cash flow sensitivity, we assume that all caps and floors are deep-in-the-money and that all collars have the maximum sensitivity. Under this assumption, if the interest rate changes by 3.4%, the annual cash flow from the derivative changes by [\$ notional principal $*$ 3.4%]. As such, we estimate the cash flow sensitivity of the cap, floor, or collar as [\$ notional principal $*$ 3.4%]. The estimation of the market value sensitivity is more complicated because caps, floors, and collars are generally bundles of options that have staggered times to maturity. For example, a five-year cap might be made up of 20 caplet options that expire each quarter. To compute an upper bound on the market value sensitivity, we again assume that all the caplets are deep-in-the-money and that the annual cash flow from the cap changes by [$ notional principal $*$ 3.4%] when interest rates change by 3.4%. Thus, the market value sensitivity of the cap is the present value of an annuity, where the cash flow is equal to [$ notional principal $*$ 3.4%] and the length of the annuity is the time to maturity of the cap, floor, or collar. While a collar is the combination of a put option and a call option and specifies an upper and lower interest rate, only one of the options, either the put or the call, can be deep in-the-money at a given time. Therefore, the method used for caps and floors is a reasonable upper bound on the sensitivity of collars.

Commodity derivatives. The cash flow sensitivity of commodity derivatives to commodity price movements is measured as the estimated change in commodity derivatives' annual cash flows for a 37% change in the underlying commodity price. A majority of the commodity derivatives used by our sample firms are written over some form of fuel-related resource, e.g., crude oil or natural gas. The choice of 37% reflects a three standard deviation change in the annualized percentage return on the quarterly Producer Price Index for Fuel over the ten-year period from January 1988 through December 1997. An alternative choice for the commodity index would be a more general index, such as the Producer Price Index for All Commodities. However, because this index reflects a portfolio of commodity prices, its volatility is far lower than the volatility of a single commodity index. For example, the annualized standard deviation of the All Commodities Index from January, 1988 through December, 1997 is 2% versus 12.4% for the Fuel Index, though the correlation between these two indexes is high at 0.81. We choose the more volatile Fuel Index to avoid underestimating the sensitivity of the commodity derivatives positions.

Using the same logic described above for FX derivatives, the cash flow sensitivity of the commodity forwards and options for a 37% change in the price of the underlying commodity is estimated as: [$ notional principal $\times$ 37%]. Because the commodity forwards and options held by our sample firms tend to mature in less than one year, we assume that the market value sensitivity of these securities is the same as their cash flow sensitivities.

For commodity swaps, the disclosed notional principal is the total quantity of the commodity swapped over the duration of the swaps held. The cash flow sensitivity varies somewhat over time depending upon the total quantity of the commodity swapped during each fiscal period. For simplicity, we assume that the notional quantity swapped each year is equal to the total notional quantity swapped divided by the number of years remaining until all the swaps mature. Therefore, the cash flow sensitivity of commodity swaps is estimated as: [($ notional principal/years to maturity) $\times$ 37%].

Since the notional principal represents the total quantity of commodity swapped over the duration of the swap, the market value sensitivity is estimated as: [$ notional principal $\times$ 37%].

For approximately 35% of the sample firms that use commodity derivatives, the notional principal is stated in units of the underlying commodity instead of dollars. Some firms disclose units and price per unit, thus providing sufficient information to compute notional values. For cases in which only units are reported, we approximate the notional principal using commodity prices prevailing at the end of 1997.

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