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How fair-value accounting can influence firm hedging

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Abstract The potential influence of accounting regulations on hedging strategies and the use of financial derivatives is a research topic that has attracted little attention in both the finance and the accounting literature. However, recent surveys suggest that company hedging can be substantially influenced by the accounting for financial instruments. In this study, we illustrate not only why but also *how* the accounting regulations may affect hedging behavior. We find that under mark-to-market accounting, most firms concerned with earnings smoothness adopt myopic hedging strategies relative to the benchmark, cash flow hedging. The specific influence of the accounting regulations depends on market and firm-specific characteristics, but, in general, the firms dramatically reduce the extent of hedging addressing price risk in future accounting periods. We illustrate that the change in hedging behavior significantly dampens the increase in earnings volatility stemming from fair value accounting of derivatives. However, the adjusted hedging strategies may substantially increase the firms' cash flow volatility.

Keywords Cash-flow hedging · Earnings hedging · Earnings volatility · Unhedgeable risk · Hedgeable risk · Fair value accounting.

JEL Classification G18 · G19 · M41 · M48

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1 Introduction

Prior to International Accounting Standard (IAS) 39 and Statement of Financial Accounting Standards (SFAS) 133, most derivative instruments were not reflected in the financial statements, and the disclosures (if any) in the footnotes were not uniform (Li and Stammerjohan 2005). The introduction of IAS 39 and SFAS 133 standardized the accounting treatment for derivatives and other financial instruments (Finnerty and Grant 2002). However, IAS 39 and SFAS 133 are controversial accounting standards. A popular claim has been that the accounting standards may affect hedging behavior, in particular for companies concerned with earnings volatility (see, e.g., Zhang 2009). Nonetheless, as noted by Glaum and Klöcker (2011), there is not much evidence on the influence of these regulations on risk management strategies. Glaum and Klöcker (2011) apply data from exchange-listed German and Swiss non-financial companies, and their survey results do indeed suggest that IAS 39 (and SFAS 133)[1] influences firms' hedging behavior; "…some even report that accounting fully determines it" (p. 484). Motivated by the recent survey evidence of Glaum and Klöcker (2011) and Lins et al. (2011), as well as the current efforts to reform the accounting for financial instruments (FASB 2010; IASB 2010), we analyze firms' hedging strategies when their major concern is to increase earnings smoothness.

Glaum and Klöcker's 2011 survey is binary in the sense that they only examine *whether* hedging behavior is affected by the hedge accounting regulations; their focus is not on *how* the rules may affect behavior. In our theoretical study, we complement the study of Glaum and Klöcker (2011) by focusing on the specific influence that a fair-value oriented accounting regime may have on companies' hedge portfolios. We turn to the most basic theory of hedging to identify the expected influence of accounting regulations on the hedging strategies of different non-financial firm types. Ruling out speculative behavior and selective hedging (Brown et al. 2006; Stulz 1996), we analyze a set of firms generating random cash flows, the magnitudes of which depend on hedgeable as well as unhedgeable risk, over a two-period hedging horizon. We illustrate that, compared to a base case with cash flow hedging, a firm concerned with earnings smoothness will typically respond to a fair-value accounting regime by adopting myopic hedging strategies. Specifically, the firm will generally substantially reduce the extent of hedging addressing price risk in future accounting periods. We supplement the theoretical analysis with a simulation study to further illustrate the empirical consequences of the findings, based on price data from the platinum market. In accordance with survey evidence from Lins et al. (2011) and Glaum and Klöcker (2011), the simulation study instructively shows that the specific influence of the accounting standards is very much dependent on firm-specific characteristics. However, the simulations illustrate that firms in general will experience a significant increase in earnings volatility following a change in the accounting regime from deferral hedge accounting to mark-to-market (fair value) accounting. Firms may be able to

[1] IAS 39 is part of IFRS (International Financial Reporting Standards), whereas SFAS 133 is part of US GAAP (Generally Accepted Accounting Principles). The IFRS are the most widely used accounting regulations throughout the world, followed by the US GAAP. IAS 39 and SFAS 133 are, for all practical purposes, similar for the particular questions addressed in this study.

dampen the effect of mark-to-market accounting on earnings volatility by adjusting the hedging strategies, but the reduction in earnings volatility comes at the expense of increased cash flow volatility.

The majority of empirical studies analyzing the influence of IAS 39 and SFAS 133 on firm hedging do so indirectly by studying earnings volatility rather than firms' actions. For example, Singh (2004) and Park (2004) find no significant increase in earnings volatility and thus conclude that the impact of SFAS 133 may not be as considerable as has been claimed. A similar conclusion is reached by Li and Stammerjohan (2005). However, when companies are asked directly, a different story unfolds. Glaum and Klöcker (2011) report that over half of companies using hedge accounting indicate that the accounting rules influence their hedging behavior. In another survey on corporate financial and risk management policies conducted in 2005 with 330 companies from 39 countries, 40 % of all responding companies have been affected by the accounting standards in at least one area of risk management (Lins et al. 2011). Zhang (2009) contends that "it is important to differentiate the effect on short-term earnings volatility assuming firms' risk-management behavior remains unchanged and the effect of SFAS 133 on firms' risk management behavior" (p. 245). If the increase in earnings volatility is material and costly and a firm adjusts its derivatives portfolio in anticipation of this potential cost, we may not observe any significant increase in earnings volatility after the adoption of SFAS 133 and IAS 39.

The lack of a clear-cut theory on how firms concerned with earnings volatility are expected to respond to fair-value accounting is a major obstacle to understanding how the accounting regulations influence firms' hedging strategies "because we cannot perceive facts without a theory" (Friedman 1953, p. 34). Beatty (2007) contends that, in general, there is little research on changes in economic behavior following an accounting change. Moreover, she maintains that the evidence on which economic incentives give rise to these changes is even more limited. We believe that the degree to which accounting rules influence actual firm behavior, in this case firm hedging, is a question of utmost importance, and we seek to advance the state of financial hedging knowledge by presenting a model that explains why and how such influences may occur. The mere fact that the Lins et al. (2011) study was published in a top-tier finance journal is a testimony to the wide-reaching influence of SFAS 133 and IAS 39. Obviously, if firms' hedging strategies are optimal prior to an accounting change, the change itself is potentially detrimental to firm value.

The rest of this paper is structured as follows. Section 2 briefly explains why some firms are concerned with earnings volatility and summarizes the most important principles of SFAS 133 and IAS 39. Section 3 analyzes, using cash flow hedging as the benchmark, how firms concerned with earnings volatility may respond to mark-to-market accounting. Section 4 develops a simulation study and discusses the empirical consequences of the analytical results, and Section 5 concludes.

2 Hedging earnings under SFAS 133 or IAS 39: Background

Discussing the design of an effective risk management strategy, Smith (2008) claims that "there is apparent disagreement on how one should measure a firm's risk exposures: Should management focus on cash flows, firm value, or reported earnings? Discovering why a firm hedges has direct implications for how one should measure these corporate exposures" (p. 541). In a survey and follow-up field interviews conducted by Graham et al. (2005, 2006, 2007), the traditionally cash-flow-oriented finance literature is severely challenged. CFOs believe that earnings, not cash flows, are the key metric considered by outsiders. An overwhelming majority of CFOs prefer smooth earnings; a surprising 78 % of the surveyed CFOs would even give up economic value in exchange for smooth earnings. Earnings, not cash flows, are king. Their study unveils a divergence between financial theory and practice with potentially important implications for corporate hedging behavior. Because existing theories on corporate hedging (Aretz and Bartram 2010; Bartram et al. 2009) pay little attention to earnings smoothing, we analyze how the overwhelming emphasis on smooth earnings reported by Graham et al. (2005, 2006, 2007) can influence firm hedging.

The claim that reported earnings can be a legitimate part of a firm's hedging strategy is supported in the literature, which could explain why 96.9 % of the surveyed CFOs in the study of Graham et al. (2005, p. 44) prefer smooth earnings. The demand for earnings stability can, for instance, be driven by contracting purposes (Asquith et al. 2005; Beatty et al. 2002; Gaver et al. 1995), and managing earnings risk can also be potentially rewarding from an asset-pricing perspective. Francis et al. (2003) document higher price-earnings multiples for firms with smooth earnings, whereas Michelson et al. (2000) show that U.S. earnings smoothers have a higher cumulative abnormal return than non-smoothers. These findings could indirectly be linked to dividend smoothing. Kasanen et al. (1996) find evidence of dividend-driven earnings management arising from an implicit managerial contract to pay out a smooth stream of dividends to the owners, whereas Ap Gwilym et al. (2000) suggest that managers signal a low exposure to systematic risk to investors in terms of stable dividends. Both ideas are supported by Chen et al. (2012), who find that aggregate dividends have been significantly smoothed in the postwar period. Chen and Wu (1999) present empirical evidence consistent with both signaling and smoothing motives (see also Goddard et al. 2006; Aivazian et al. 2006).

Because hedging programs can influence the stability of both earnings and dividends, accounting methods may influence hedging decisions. Prior to SFAS 133 and IAS 39, the accounting treatment of derivatives was incomplete and inconsistent (Zhang 2009). As a result of large-scale derivatives-related losses by companies such as Gibsons Greetings, Metallgesellschaft, Orange County, and Procter and Gamble, regulatory bodies such as the FASB and the IASB came under increased pressure to develop a comprehensive and consistent set of rules for the reporting of the corporate use of derivatives (Barnes 2001). SFAS 133 and IAS 39 require that all derivatives be recognized as either assets or liabilities at fair value on the balance sheet and that changes in the fair value are recognized as unrealized gains or losses in the income statement. This basic principle, often referred to as fair-value or mark-to-market accounting (Barnes 2001; Comiskey and Mulford 2008), can create a mismatch between the timing of the recognition of gains and losses on derivative instruments entered into for hedging purposes and those of the hedged items. This mismatch could distort the income statement and the balance sheet as measures of firm performance and enterprise value, respectively. Consequently, fair-value accounting can potentially distort the hedging strategies of firms that manage the risk of their reported earnings more than their cash flows or firm value.[2]

The response to the distortion offered by the FASB and IASB is hedge accounting. Hedge accounting allows companies to override the normal accounting treatment for derivatives by reporting the effects of the derivatives and the risk being hedged in the same period. If the criteria for hedge accounting are met, the companies can recognize gains and losses on the hedging derivatives in the income statement in the same period as offsetting gains and losses on the hedged item. Therefore, the fair value changes are not recorded in the income statement until the hedged transaction affects profits or losses. Instead, changes in the fair value of the derivatives are recognized as a "hedging reserve" in equity. Hedge accounting is optional, and the management must weigh the costs and benefits when considering whether to use it. The criteria for hedge accounting demand that management must identify, document, and test the effectiveness of those transactions for which it wishes to use hedge accounting. IAS 39 and SFAS 133 require the hedging to be "highly effective", meaning that the hedge effectiveness must fall within a range of 80–125 % over the life of the hedge as measured by "the dollar offset method" or greater than or equal to 80 % as measured by the regression method.[3] However, even if the hedge's effectiveness is sufficient to qualify for hedge accounting, the ineffective part of the hedge must still be recorded in the income statement. In current efforts to reform the accounting for financial instruments, both the IASB and the FASB have proposed to simplify the hedge accounting regulations and lower the threshold for applying hedge accounting (FASB 2010; IASB 2010). Specifically, the FASB suggests that the effectiveness requirement is reduced to "reasonably effective" and that the highly complex, quantitative hedging requirements are replaced by more qualitative-based assessments (FASB 2010). The IASB proposes that the rigid "highly effective" criterion is eliminated and replaced by an objective-based hedge effectiveness assessment, where the purpose is to ensure that the hedging relationship minimizes expected hedge ineffectiveness (IASB 2010).

3 Hedging earnings under fair value accounting: Model analysis

Assuming that earnings targets are closely related to earnings expectations and that firms adhere to linear hedging strategies, we demonstrate that a mark-to-market (M2M) accounting regime can significantly change a firm's earnings risk exposure. Next, we analyze how firms concerned with earnings volatility adapt their hedging strategies under mark-to-market accounting. Finally, we discuss the implications of these findings.

[2] The designations of derivatives for accounting purposes are either fair-value hedges or cash flow hedges. Whereas a cash flow hedge results when derivatives are employed to hedge the exposure to expected future cash flows, a fair-value hedge protects the fair value of recognized assets and liabilities or firm commitments (Comiskey and Mulford 2008). This study focuses exclusively on cash flow hedging, and a premise for the analysis presented is that a cash flow hedge differs fundamentally from a fair-value hedge.

[3] IAS 39 and SFAS 133 do not endorse a specific testing methodology to be applied to qualify for hedge accounting; see the discussion in Finnerty and Grant (2002).

3.1 Hedging and earnings measurement

Consider a firm with a hedging horizon that covers two accounting periods facing the random cash flows $\widetilde{CF_1}$ equal to

$$\widetilde{CF_1} = \tilde{S}_1\tilde{Q}_1 - c\tilde{Q}_1 - C + a_1\left[\tilde{S}_1 - F_{0,1}\right] \tag{1}$$

where $\tilde{S}_1$ and $\tilde{Q}_1$ denote the random spot price and the random quantity produced in period 1, respectively, c the constant marginal cost, C fixed costs, $F_{0,1}$ the forward price at $t = 0$ with maturity at time 1, and a_1 the number of long positions in forward contracts with delivery at time 1 entered into at $t = 0$. Under a deferral accounting regime (DA), in which derivatives are kept off the balance sheet, hedging cash flows is equivalent to hedging earnings; therefore, $\widetilde{CF_1} = \widetilde{EARN}_1^{DA}$. Therefore, under the deferral hedge accounting approach, typically applied prior to SFAS 133 and IAS 39, there was no divergence between hedging cash flows and hedging earnings.[4] In contrast, under the main principle of SFAS 133 and IAS 39, i.e., mark-to-market accounting, the earnings of period one (the current accounting period) are now given as

$$\widetilde{EARN}_1^{M2M} = \tilde{S}_1\tilde{Q}_1 - c\tilde{Q}_1 - C + a_1\left[\tilde{S}_1 - F_{0,1}\right] + a_2\left[\tilde{F}_{1,2} - F_{0,2}\right] \tag{2}$$

A third random variable now influences the firm's earnings in addition to $\tilde{S}_1$ and $\tilde{Q}_1$: $\tilde{F}_{1,2}$, the random price at $t = 1$ of a forward contract with delivery in period two. If the firm qualifies for hedge accounting (HA), only the ineffective portion of the hedge will be recorded in current earnings, and, setting retrospective hedge ineffectiveness equal to prospective hedge ineffectiveness for simplicity, the earnings can be expressed as

$$\widetilde{EARN}_1^{HA} = \tilde{S}_1\tilde{Q}_1 - c\tilde{Q}_1 - C + a_1\left[\tilde{S}_1 - F_{0,1}\right] + a_2\left[1 - HEM\right]\left[\tilde{F}_{1,2} - F_{0,2}\right] \tag{3}$$

HEM is a hedge effectiveness measure, meaning that [1-HEM] denotes the ineffective portion of the hedge. Under SFAS 133 and IAS 39, hedge accounting is only allowed if HEM exceeds 80 % (as measured with the regression method). If HEM is below this level, hedge accounting is not allowed, and we are left with (2). Although neither the FASB nor the IASB specifies a concrete threshold of HEM for hedge accounting to be allowed in the future, it follows from the exposure drafts (FASB 2010; IASB 2010) that the HEM threshold is likely to be reduced. [5] Irrespective of the specific level of the future HEM threshold, the optimal hedging behavior of a firm concerned with earnings

4 Accruals unrelated to the hedging instrument are disregarded in this model.

5 In its exposure draft, the IASB recognizes no ineffectiveness for "under-hedges" (IASB 2010), i.e., where the cumulative change in the fair value of the hedging instrument is less than the cumulative change in the fair value of the hedged item.

smoothness will fall in the range from the optimal solution under cash flow hedging to the optimal solution under mark-to-market accounting. A higher HEM leads the optimal solution to be closer to the optimal cash flow hedge. If the HEM requirement is lowered, more firms will qualify for hedge accounting, but the optimal hedge for these "new" firms will be closer to the mark-to-market solution than the optimal hedge for companies qualified for hedge accounting under the current regulations of SFAS 133 and IAS 39. In the rest of this study, we devote our attention to the cash flow solution and the mark-to-market solution, as these optimal hedging behaviors define limits that any optimal hedging behavior under hedge accounting will fall within.[6]

3.2 Optimal hedging

A firm minimizing its cash exposure for each period within the hedging horizon will minimize the variance of expression (1), i.e., solve the problem $\min_{a_t}\left[\operatorname{var}\left(C\tilde{F}_t\right)\right]$ for each future year. It is straightforward to show that the solution of this problem is $a_t^{CF} = -\operatorname{cov}\left(\tilde{S}_t\tilde{Q}_t, \tilde{S}_t\right)/\sigma^2_{\tilde{S}_t} + c\rho_{\tilde{S}_t,\tilde{Q}_t}\sigma_{\tilde{Q}_t}/\sigma_{\tilde{S}_t}$ for arbitrary assumptions about the joint distribution of the random variables (RVs) $\widetilde{S}_t$ and $\widetilde{Q}_t$; see "Appendix A" for details. This is the number of contracts that minimizes the firm's cash flow volatility. However, it is also the number of contracts that minimizes the firm's earnings volatility in each period under a deferral accounting regime. Following Eq. (13) in Bohrnstedt and Goldberger (1969) or Lemma 2 in Sévi (2006), this general solution reduces to

$$a_t^{CF} = -\mu_Q - (\mu_S - c)\,\rho_{\tilde{Q}_t,S_t}\frac{\sigma_{\tilde{Q}_t}}{\sigma_{\tilde{S}_t}} \tag{4}$$

when the random variables $\widetilde{S}_t$ and $\widetilde{Q}_t$ are bivariately normally distributed. Here, hedging demand is the sum of a "naive hedging strategy" (sell expected production forward) and a term that accounts for "natural hedging" ($\rho_{\tilde{Q}_t,S_t} < 0$) or "risk compounding" ($0 < \rho_{\tilde{Q}_t,S_t}$). These well-known results, cf. Proposition 1 in Sévi (2006) and the references therein, now serve as benchmarks for the hedging behavior of firms concerned with earnings smoothness under a mark-to-market accounting regime. Because no cash flows to or from each forward contract until the year when the contract matures, every future year can be hedged independently. Therefore, expression (4) is general and denotes the optimal number of forward contracts for all future years.

We use a similar approach to analyze the optimal hedging for companies concerned with earnings volatility under a mark-to-market accounting regime. Our behavioral assumption is consistent with the view that "CFOs equate the idea of smooth earnings with the desire to avoid negative earnings surprises (relative to earnings targets)" (Graham et al. 2005, p. 50). The firm will now minimize the variance of expression (2), i.e., solve the problem $\min_{a_1,a_2}\left[\operatorname{var}\left(\widetilde{EARN_1^{M2M}}\right)\right]$. Before we turn to the specific

[6] In general, as changes in derivatives' value in any case is part of "other comprehensive earnings", the hedge accounting regulations offer no solution for companies concerned with the smoothness of *comprehensive* earnings.

solution of the problem, a major difference to cash flow hedging should be noted: the earnings variance of period two cannot be managed at $t = 0$ because gains and losses from all forward positions that accrue between $t = 0$ and $t = 1$ are booked in the income statement of period one. Fair value accounting effectively increases the number of hedging instruments that can be used to manage the earnings of period one by removing the very same instrument as a means of hedging the risk exposure of the earnings of period two from $t = 0$ to $t = 1$.

"Appendix A" develops the optimal hedging strategy for firms concerned with minimizing earnings volatility under a mark-to-market accounting regime. As illustrated by Proposition 1, the firms will no longer adhere to the hedging strategies pursued under cash flow hedging:

Proposition 1 *Assume that firms minimize the volatility of the next period's earnings. Under multivariate normally distributed random variables, the optimal numbers of forward contracts are given by Eqs. (5) and (6).*

$$a_1^{M2M} = -\mu_{\tilde{Q}_1} - \left(\mu_{\tilde{S}_1} - c\right) \frac{\sigma_{\tilde{Q}_1}}{\sigma_{\tilde{S}_1}} \left[\frac{\rho_{\tilde{Q}_1,\tilde{S}_1} - \rho_{\tilde{Q}_1,\tilde{F}_{1,2}} \rho_{\tilde{S}_1,\tilde{F}_{1,2}}}{1 - \rho^2_{\tilde{S}_1,\tilde{F}_{1,2}}} \right] \tag{5}$$

$$a_2^{M2M} = -\left(\mu_{\tilde{S}_1} - c\right) \frac{\sigma_{\tilde{Q}_1}}{\sigma_{\tilde{F}_{1,2}}} \left[\frac{\rho_{\tilde{Q}_1,\tilde{F}_{1,2}} - \rho_{\tilde{Q}_1,\tilde{S}_1} \rho_{\tilde{S}_1,\tilde{F}_{1,2}}}{1 - \rho^2_{\tilde{S}_1,\tilde{F}_{1,2}}} \right] \tag{6}$$

Corollary 1 *The hedging demand under cash flow hedging, a_t^{CF}, is the sum of a "naive hedging strategy" (sell the expected production forward) and a term that accounts for "natural hedging" ($\rho_{\tilde{Q}_t,S_t} < 0$) or "risk compounding" ($0 < \rho_{\tilde{Q}_t,S_t}$). A shift to mark-to-market accounting does not affect the first term for period-one forwards but can scale the second term up or down depending on the risk exposure characteristics or firm type. The same change of accounting regime eliminates the "naive hedging strategy" part for period-two forwards and distorts the second term.*

Corollary 2 *There is no unique solution to a firm's volatility-minimizing objective when the forward price, $\widetilde{F_{1,2}}$, is perfectly correlated with the spot price, $\widetilde{S_1}$. In this case, the forward contracts with delivery in period one and period two, respectively, are equally beneficial as hedging instruments for the earnings of period one. Consequently, a firm could choose to set the number of forward contracts with delivery in period one equal to the number of contracts under cash flow hedging, i.e., $a_1^{M2M} = a_1^{CF}$, and the number of forward contracts with delivery in period two equal to zero.*

Corollary 3 *Assume that $\rho_{\tilde{Q}_1,\tilde{F}_{1,2}} = k\rho_{\tilde{Q}_1,\tilde{S}_1}$ for $0 \leq k < 1, 0 \leq \rho_{\tilde{S}_1,\tilde{F}_{1,2}} < 1$, and $\sigma_{\tilde{F}_{1,2}} = sam\sigma_{\tilde{S}_1}$ for $0 \leq sam : \mathbb{R}^n \to \mathbb{R}_+$. Then, the optimal numbers of forward contracts are given by Eqs. (7) and (8). Note that $a_1^{M2M} = a_1^{CF}$ and $a_2^{M2M} = 0$ for $k = \rho_{\tilde{S}_1,\tilde{F}_{1,2}}$, i.e., a zero partial correlation coefficient between $\tilde{F}_{1,2}$ and $\tilde{Q}$, the same solution as the special case of Corollary 2.*

$$a_1^{M2M} = -\mu_{\tilde{Q}_1} - \left(\mu_{\tilde{S}_1} - c\right) \rho_{\tilde{Q}_1,\tilde{S}_1} \frac{\sigma_{\tilde{Q}_1}}{\sigma_{\tilde{S}_1}} A, \quad A = \frac{1 - k\rho_{\tilde{S}_1,\tilde{F}_{1,2}}}{1 - \rho^2_{\tilde{S}_1,\tilde{F}_{1,2}}} \geq 0 \tag{7}$$

$$a_2^{M2M} = -\left(\mu_{\tilde{S}_1} - c\right) \rho_{\tilde{Q}_1,\tilde{S}_1} \frac{\sigma_{\tilde{Q}_1}}{\sigma_{\tilde{S}_1}} B, \quad B = \frac{1}{sam} \left(\frac{k - \rho_{\tilde{S}_1,\tilde{F}_{1,2}}}{1 - \rho^2_{\tilde{S}_1,\tilde{F}_{1,2}}} \right) \tag{8}$$

It follows from Proposition 1 and Eq. (4) that a_1^{M2M} and a_2^{M2M} generally differ from a_1^{CF} and a_2^{CF}, respectively. However, if the RVs $\widetilde{S}_1$ and $\widetilde{S}_2$ as well as $\widetilde{Q}_1$ and $\widetilde{Q}_2$ are i.i.d., that is, if firms face repeated sampling from the same underlying distributions, they will be indifferent between choosing a_2^{CF} and zero forward contracts with delivery in period two at $t = 0$ under cash flow hedging. Hedging the cash flow of period two may then be postponed to $t = 1$; therefore, the difference between the number of forward contracts with delivery in period two under mark-to-market earnings hedging and cash flow hedging at $t = 0$ is given by a_2^{M2M} for the i.i.d. case.

The influence of mark-to-market accounting appears to differ more across firm types with non-i.i.d. RVs. The smaller the expected contribution margin $\mu_{\tilde{S}_1} - c > 0$, the closer $\sigma_{\tilde{Q}_1}$ is to zero (market completeness), and, under the assumptions of Corollary 2, as $\rho_{\tilde{Q}_1,\tilde{S}_1}$ approaches zero, the closer is a_1^{M2M} to a_1^{CF} as both approach $-\mu_{\tilde{Q}_1}$, and vice versa. At the same time, a_2^{M2M} approaches zero while a_2^{CF} approaches $-\mu_{\tilde{Q}_2}$, the equivalent of a 100 % reduction in the number of forward contracts with delivery in period two. The influence on the extent of hedging in future accounting periods is dramatic; mark-to-market accounting effectively forces myopia on most types of firms.

3.3 Implications

Our theoretical analysis complements the few existing empirical studies on the influence of accounting regulations on hedging behavior, such as the surveys by Glaum and Klöcker (2011) and Lins et al. (2011). Glaum and Klöcker (2011) examine whether companies are affected by accounting for hedging instruments and relate the answers to firm characteristics such as company size, leverage, growth opportunities, and the perceived importance of reduced earnings volatility (cf. Lins et al. 2011). Although our study differs fundamentally in terms of research methodology, several of the findings of Glaum and Klöcker (2011) can be related to our model. For instance, Glaum and Klöcker (2011) find that hedging behavior is related to the perceived importance of earnings volatility. Our model suggests that this is the factor actually driving firm behavior; the preference for smooth earnings is a necessary condition for accounting regulations to have an influence on hedging behavior.

However, with its focus on price and production characteristics as well as the two-period orientation, our model also supplements the findings of Glaum and Klöcker (2011) and Lins et al. (2011). Overall, our analysis suggests that substituting mark-to-market earnings hedging for cash flow hedging may significantly change firms' hedge portfolios. The specific influence of mark-to-market accounting on firm hedging designed to reduce earnings volatility varies across risk exposure characteristics, as well as between current and future accounting periods. For instance, markets characterized by low persistence in prices such as agricultural commodities, electricity, and crude oil are likely to be affected differently than markets with persistent prices, including markets for metals, such as silver, gold, and platinum (cf. Bessembinder et al. 1995; Lucia and Schwartz 2002). This is evident from the influence of the function *sam*, which represents the relation between spot price and forward price volatility. However, firm-specific characteristics such as unhedgeable quantity risk, the correlation between quantity and prices, and the expected contribution margin can lead to variations even within the same industry. Nevertheless, as the "anchor" of the second hedging period ($\mu_{\tilde{Q}_2}$) is no longer included in the optimal number of forward contracts, most types of firms turn myopic under earnings hedging in a mark-to-market accounting regime; i.e., they significantly reduce the extent of hedging addressing price risk in future accounting periods.

For most companies, it is reasonable to assume that the correlation between produced quantity and spot price is limited. Due to production constraints, a shorter time horizon indicates a more reasonable assumption. For instance, within an accounting year, the absolute value of $\rho_{\tilde{Q}_t, S_t}$ is likely to be low, meaning that the firm faces small prospects of natural hedging or risk compounding. Under this assumption, we can state the following hypothesis:

A firm facing limited prospects of natural hedging or risk compounding will only make small adjustments to its hedging of risk exposures in the current accounting period in response to a shift from cash flow hedging to earnings hedging in a mark-to-market accounting regime. However, the same firm will eliminate or almost eliminate its hedging of risk exposures in future accounting periods.

We can be even more specific under the assumption of Corollary 3, where a particularly interesting result emerges if k is set equal to $\rho_{\tilde{S}_1, \tilde{F}_{1,2}}$. This assumption implies that the partial correlation between $\widetilde{Q}_1$ and $\tilde{F}_{1,2}$ is zero; in other words, the correlation between $\widetilde{Q}_1$ and $\tilde{F}_{1,2}$ is implied by the correlation between $\widetilde{Q}_1$ and $\tilde{S}_1$ for non-zero $\rho_{\tilde{S}_1, \tilde{F}_{1,2}}$. Once again, the assumption is reasonable. For instance, the assumption holds for all markets with a deterministic relation between spot and forward prices (e.g., the markets for foreign currencies and most storable commodities). Corollary 3 and $k = \rho_{\tilde{S}_1, \tilde{F}_{1,2}}$ imply that there is no difference in the number of forward contracts for period 1 between cash flow hedging and mark-to-market earnings hedging. However, for period 2, the number of forward contracts reduces to zero under mark-to-market earnings hedging. This situation is displayed in Fig. 1, which also illustrates the general finding from the previous section: even if the influence of a mark-to-market accounting regime may be limited for the current accounting period, most firms substantially reduce the hedging of the price risk of future accounting periods.

4 Earnings and cash flow volatility with two-period rollover hedging

In this section, we present the results of a simulation study based on real price data. Specifically, we apply platinum prices to investigate changes in earnings and cash flow volatility following a shift from cash flow hedging to mark-to-market earnings hedging under the assumptions of Corollary 3 and $k = \rho_{\tilde{S}_1, \tilde{F}_{1,2}}$. We accomplish this

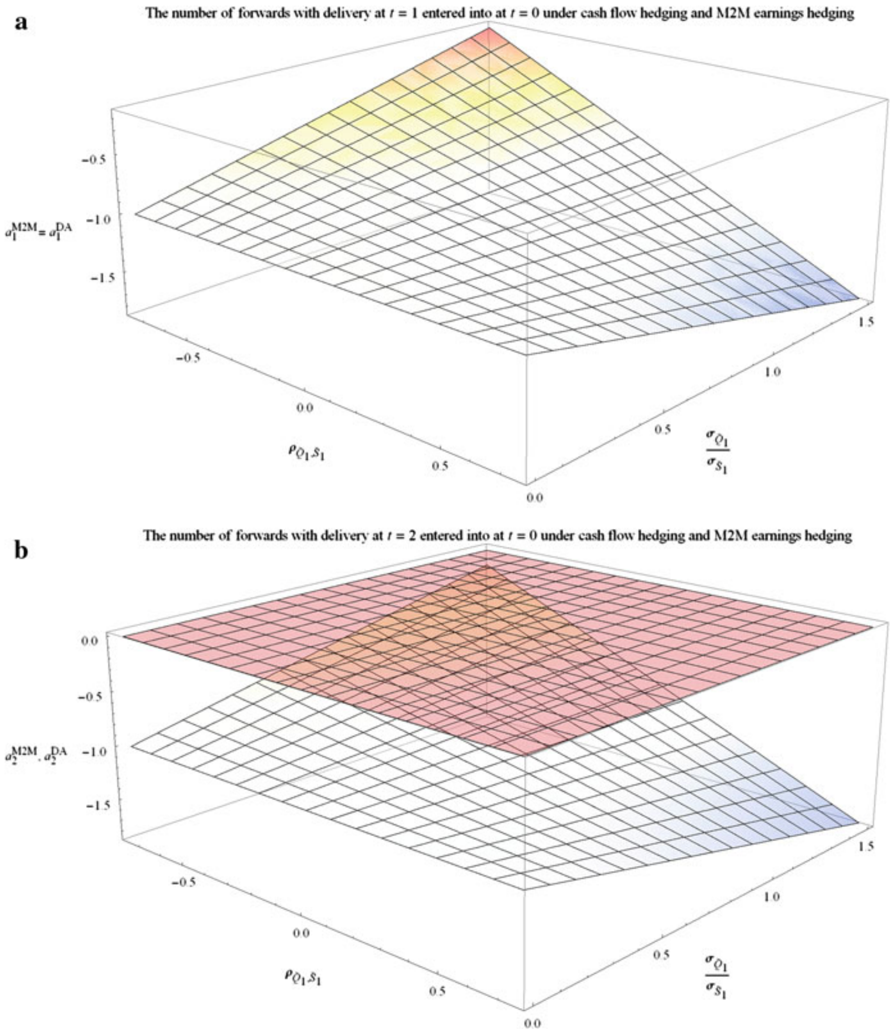

Fig. 1 Corollary 3 illustrated for $\rho_{\tilde{S}_1, \tilde{F}_{1,2}} = 0.95$, $k = \rho_{\tilde{S}_1, \tilde{F}_{1,2}}$ and $c = 0.25$. The *upper figure* illustrates that there is no change in the number of forward contracts with delivery in period one. The *lower figure* illustrates that these firms adopt myopic hedging strategies under SFAS 133 and IAS 39: the *upper* (*lower*) surface represents hedging at $t = 0$ using forward contracts with delivery at t = 2 under mark-to-market earnings hedging (cash flow hedging)

by simulating platinum price paths for the period 2012–2021 and recording earnings and cash flow volatility in each sample assuming two-period rollover hedging.

4.1 The dynamics of the yearly average platinum spot price and other sources of risk

We now assume that the yearly average platinum spot price dynamics can be represented by an ARMAX model that takes the form $S_t = \mathbf{X}_t \boldsymbol{\beta} + S_t^*$, where $\mathbf{X}_t$ is a row vector of exogenous variables and S_t^* a covariance stationary term that follows an ARMA process. The term $\mathbf{X}_t\boldsymbol{\beta}$ represents the mean of S_t conditional on $\mathbf{X}_t$, but not conditional on lagged values of S_t (Davidson and MacKinnon 2004, p. 566). The term $\mathbf{X}_t\boldsymbol{\beta}$ can, for instance, represent the influence of a deterministic time trend, which we will denote as $T_t(\Phi)$ in the following. If the RV $\varepsilon_t \sim N\left(0, \sigma_\varepsilon^2\right) \forall t$ is the innovation representing the unpredictable part in the evolution of S_t^* and, consequently, the spot price S_t, the next period's forward price on a one-period forward contract may be represented as

$$F_{t+1,t+2} = E_{t+1}\left[S_{t+2}\right] \times \xi_{t+1} \text{ given } \xi_t \sim \mathrm{N}\left(1, \sigma_\xi^2\right) \text{ and } \rho_{\varepsilon_t,\xi_t} = 0\ \forall t \tag{9}$$

This specification may be given several interpretations. First, equation (9) may be reorganized as $\ln(E_{t+1}[\tilde{S}_{t+2}]/F_{t+1,t+2}) = -\ln(\xi_{t+1}) \equiv \pi_{t+1}$, in which case the market place is characterized by random relative risk premia π. Second, the RV ξ could be perceived as a representation of trading noise arising from "animal spirits" in the market place (French and Roll 1986). Third, the multiplicative noise term could be seen as a parsimonious representation of the combined effect of time-varying and possibly stochastic risk premia and stochastic convenience yields net of storage costs (Gibson and Schwartz 1990; Hilliard and Reis 1998; Schwartz 1997).

Closed form solutions for key input under AR(1) spot price dynamics are as follows:[7]

$$S_t^* = S_t - T_t(\Phi) \tag{10}$$

$$S_t^* = \varphi S_{t-1}^* + \varepsilon_t \tag{11}$$

$$\sigma^2_{\tilde{F}_{1,2}}(t) = \varphi^2\left(\varphi^2 S_t^{*2}\sigma_\xi^2 + \sigma_\varepsilon^2\left(1+\sigma_\xi^2\right)\right) \tag{12}$$

$$\rho_{\tilde{S}_1,\tilde{F}_{1,2}}(t) = \frac{\sigma_\varepsilon}{\sqrt{\varphi^2 S_t^{*2}\sigma_\xi^2 + \sigma_\varepsilon^2\left(1+\sigma_\xi^2\right)}} \tag{13}$$

$$E_t\left[\tilde{S}_{t+1}\right] = T_{t+1}(\Phi) + \varphi S_t^* \tag{14}$$

$$E_t\left[\tilde{S}_{t+2}\right] = T_{t+2}(\Phi) + \varphi^2 S_t^* \tag{15}$$

$$a_{2,t}^{CF} = -\mu_{\tilde{Q}_2} - \left(T_{t+2}(\Phi) + \varphi^2 S_t^* - c_{t+2}\right)\rho_{\tilde{Q}_2,\tilde{S}_2}\frac{\sigma_{\tilde{Q}_2}}{\left(1+\varphi^2\right)\sigma_\varepsilon} \tag{16}$$

Based on raw data for yearly platinum prices obtained from Datastream for the period 1976–2011, i.e., the CYA#(PLATFRE,I) series, using MLE, we estimate that $S_t^* = 0.88S_{t-1}^* + \varepsilon_t$, $T_t(\Phi) = -77{,}224.09 + 39.09t$ and $\hat{\sigma}_S = \hat{\sigma}_{S^*} = \hat{\sigma}_\varepsilon = 138.2$. Next, we assume that the estimated model represents the true data-generating process and simulate 10,000 discrete price paths for platinum over the years 2012–2021. We

[7] The *AIC* and the *BIC* information criteria for selecting an *ARMAX* model among the four alternatives AR(1), AR(2), ARMA(1,1), and ARMA(2,2) both preferred the AR(1) representation of S_t^*, given a linear time trend. The correlations $\rho_{\tilde{Q}_1,\tilde{S}_1}$, $\rho_{\tilde{Q}_2,\tilde{S}_2}$ and $\rho_{\tilde{Q}_1,\tilde{F}_{1,2}}$ must be pinned down from other sources.

fix the expected quantity produced in each year at unity, assuming that the yearly deviations from unity are i.i.d. but possibly correlated with the unpredictable part of the price process (following the procedure described by Hull (1997, p. 363) for generating bivariately normally distributed RVs). All simulations are performed with a fixed seed to make the findings comparable. A detailed account of the simulation assumptions is provided in "Appendix B".

4.2 Simulated earnings volatility

We study three types of earnings representations: (1) earnings under deferral accounting with cash flow hedging ("before"), (2) earnings under fair-value accounting with cash flow hedging ("after, same strategy") and (3) earnings under fair-value accounting with an adapted hedging strategy ("after, new strategy"). In each of a total of $M = 10,000$ replications, we calculate the earnings volatility over the period 2012–2021 of the one- and two-year earnings targets. In brief, the three different earnings representations are calculated as follows:

- **"Before"**: The earnings under deferral accounting are calculated as the sum $\widetilde{CF_t} = \widetilde{NP}_t^{NoHedge} + \widetilde{FCP}_{1,t}^{DA} + \widetilde{FCP}_{2,t}^{DA}$, where FCP denotes "forward contract payoff" and the DA-superscript marks that the hedging strategy addresses earnings volatility under a deferral accounting regime (cash flow hedging). $\widetilde{NP}_t^{NoHedge}$ is the net profit of year t without a hedging strategy, $\widetilde{FCP}_{1,t}^{DA}$ is the derivative payoff in year t due to the position in one-year forwards entered into one year earlier, and $\widetilde{FCP}_{2,t}^{DA}$ is the profit or loss realized at $t-1$ from closing a position in two-year forwards entered into at $t-2$.
- **"After, same strategy"**: With a shift from a deferral to a fair-value accounting regime, the profit or loss realized at $t-1$ from closing a position in two-year forwards entered into at $t-2$ is now booked in the income statement of year $t-1$, not year t. Therefore, the earnings under mark-to-market accounting and cash flow hedging are defined as the sum $\widetilde{Earn}_t^{CF} = \widetilde{NP}_t^{NoHedge} + \widetilde{FCP}_{t,1}^{DA} + F\left(\widetilde{FCP}_{t,2}^{DA}\right)$, with F being the forward lag operator.
- **"After, new strategy"**: With a shift from a deferral to a fair-value accounting regime and a hedging strategy adapted to the new accounting regime (cf. Sect. 3), earnings are defined as the sum $\widetilde{Earn}_t = \widetilde{NP}_t^{NoHedge} + \widetilde{FCP}_{1,t}^{M2M} + \widetilde{FCP}_{2,t}^{M2M}$. The hedging horizon does not extend beyond the current accounting period, although forward contracts settled in the subsequent period may be useful for managing the current period's earnings volatility.

Define $RMSE_k^{\tilde{j}_{t\in\Theta}}$ as the root mean squared error over the M = 10,000 replications from the earnings target $\hat{j}$ formed k years earlier over the period $\Theta = \{t : t \in \{2012, \ldots, 2021\}\}$ spanning $N = 10$ years. In each year $t \in \Theta$, the deviation between actual earnings $\tilde{j}$ and the prediction formed k years earlier is squared. Summing the squared deviations over the N years and dividing by N yields the average squared deviation from the targets over the 2012–2021 period for the given replication.

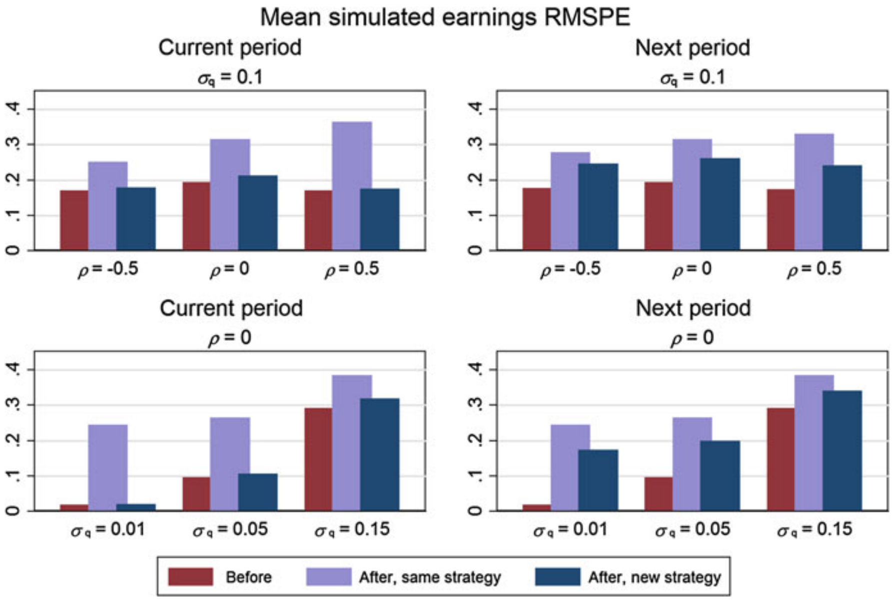

Fig. 2 Mean simulated earnings RMSPE over the period 2012–2021 under the assumptions of Corollary 3 with $\sigma_\xi = 0$, $k = \rho_{\tilde{S}_1, \tilde{F}_{1,2}}$, $S_t^* = 0.88 S_{t-1}^* + \varepsilon_t$, $T_t(\Phi) = -77, 224.09 + 39.09t$, $\hat{\sigma}_S = \hat{\sigma}_{S*} = \hat{\sigma}_\varepsilon = 138.2$ variable costs $c_t = c^* T_t\ (\Phi)$, fixed costs $C_t = C^* T_t\ (\Phi)$ with $c^* = 0.25$, and $C^* = 0.4$. More details are available in "Appendix B" (Color figure online)

Summing these numbers across all the 10,000 different replications and dividing by $M = 10,000$ yields the average squared deviation from the targets formed k years earlier, that is, the targets formed over the periods 2011–2020 and 2010–2019 for $k = 1$ and $k = 2$, respectively. Expressed as a percentage deviation from the target, the root mean squared percentage error is defined as follows:

$$RMSPE_k^{\widehat{j}_{t\in\Theta}} = \frac{1}{M}\sum_{i=1}^{M}\sqrt{\frac{1}{N}\sum_{t\in\Theta}\left(\frac{\widetilde{j_{t,i}} - \widehat{j_{t-k,t,i}}}{\widehat{j_{t-k,t,i}}}\right)^2}\ \forall\ k = 1, 2;$$
$$j = \widetilde{CF}, \widetilde{Earn}^{CF}, \widetilde{Earn} \tag{17}$$

Figure 2 presents the earnings volatility (RMSPE) under the three earnings representations discussed above, using various assumptions on firm-specific quantity risk and the correlation between quantity and price. The figure illustrates that a shift from deferral hedge accounting to mark-to-market accounting dramatically increases earnings volatility for most firm types (compare the red and light blue bars). Even the firms that apparently experience the lowest increase in the earnings volatility according to Fig. 2 may experience an increase in this volatility of 50–100 %.

For many firms, the dramatic increase in earnings volatility will be unacceptable (cf. Graham et al. 2005, 2006, 2007). However, firms may adjust the hedging strategy to minimize their earnings volatility, in accordance with the framework developed in Sect. 3. Such risk management will substantially reduce the earnings volatility compared to a strategy designed to minimize the cash flow risk. Therefore, if earnings stability matters, firms may adapt their hedging strategies to the prevailing accounting regime to dampen the effects of the accounting regulations. A shift from cash flow to earnings hedging will, in all the displayed cases, cause a significant drop in earnings volatility, given that the hedge portfolio is to be marked-to-market (compare light blue and dark blue bars).

Figure 2 shows that the effect of a mark-to-market accounting regime on earnings volatility is larger in period 2, even after firms have adapted to the new regulations. This finding also applies to a multi-period setting. The reason is simply that the earnings risk of all accounting periods succeeding period 1 can no longer be managed at $t = 0$. The value change of all derivatives that mature after period 1 must be recorded in the financial report of period 1 and does not affect the future period until they are settled.

It should be noted that for some firms, the increase in earnings volatility is relatively moderate following a shift from deferral hedge accounting to mark-to-market accounting if the companies adapt their risk management strategies to the accounting change. Most empirical research on the influence of accounting regulations on hedging strategies has studied changes in earnings volatility following the change in accounting regulations. However, Fig. 2 illustrates the important point observed by Zhang (2009); such indirect studies of the change in risk management strategies may be weak tests. If companies immediately adapt to the new accounting rules to minimize earnings volatility, it may be difficult document statistically significant differences in earnings volatility for many companies, at least in the short run.

4.3 Simulated cash-flow volatility

The starting point and benchmark for our analysis is cash flow volatility minimization. If an accounting change induces companies to implement adjusted hedging strategies, the cash flow volatility will be affected. This is illustrated in Fig. 3.

The red bars show the cash flow volatility when the cash flow risk is minimized. Obviously, the cash flow volatility is not affected by the accounting change if firms do not alter their risk management strategies. However, if the increase in earnings volatility is unacceptable and the firms adjust their hedging strategies, the cash flow volatility will be influenced, as illustrated by the blue bars. In all cases, the cash flow volatility increases because the firms no longer adhere to cash flow risk minimization. As before, the long-run effect is the most pronounced.

Once again, we note that the specific increase in volatility is dependent on firm-specific characteristics. Therefore, there is no reason to believe that an accounting change will affect all companies identically, a finding consistent with Glaum and Klöcker (2011) and Lins et al. (2011). For some firm types, the increase in cash flow volatility is modest. For others, it is dramatic. For instance, for companies with zero correlation between the price and quantity and low quantity uncertainty, a change in the risk management strategy will induce a large increase in the cash flow risk. Zero price/quantity correlation and low production uncertainty characterize many

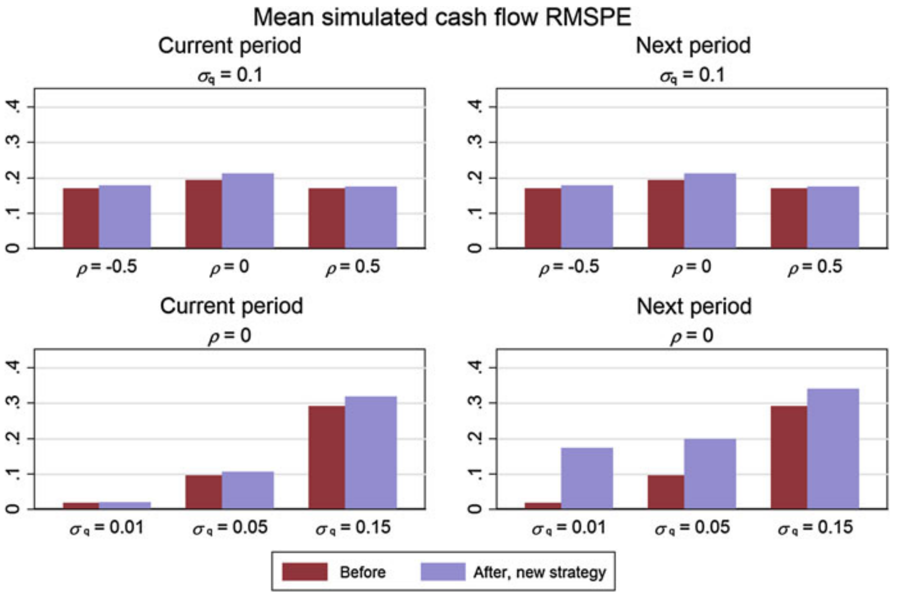

Fig. 3 Mean simulated cash flow RMSPE over the period 2012–2021 under the assumptions of Corollary 3 with $\sigma_\xi = 0, k = \rho_{\tilde{S}_1, \tilde{F}_{1,2}}, S_t^* = 0.88 S_{t-1}^* + \varepsilon_t, T_t(\Phi) = -77,224.09 + 39.09t, \hat{\sigma}_S = \hat{\sigma}_{S^*} = \hat{\sigma}_\varepsilon = 138.2, \hat{\sigma}_S = \hat{\sigma}_{S^*} = \hat{\sigma}_\varepsilon = 138.2$ variable costs $c_t = c^* T_t\,(\Phi)$, fixed costs $C_t = C^* T_t\,(\Phi)$ with $c^* = 0.25$ and $C^* = 0.4$. More details are available in "Appendix B" (Color figure online)

industries. For example, in the petroleum industry, the production level is often relatively constant throughout the year, and there is little uncertainty about the quantity produced. When the producers are small, the correlation between price and quantity is typically close to zero. Similar characteristics are found in commodity production, such as gold mining.

Overall, Fig. 3 illustrates that for companies with strong preferences for earnings stability, an accounting change has the potential to alter companies' derivatives portfolios in ways that can induce dramatic increases in the cash flow volatility. If earnings volatility affects company value, as suggested by Michelson et al. (2000), among others, the change in hedging strategies could be rational in an economic sense. However, if the preference for stable earnings documented by Graham et al. (2005, 2006, 2007) is more or less irrational or based on temporary market inefficiencies (cf., e.g., the classical study of Sloan (1996), who documents that investors in the short run tend to "fixate" on earnings), the change in risk management is more problematic. In such cases, the deviation from optimal cash flow hedging will increase the expected deadweight costs and thus be detrimental to firm value (cf. Aretz and Bartram 2010). Until recently, this issue has been neglected by the finance literature, but more recent studies will hopefully motivate more research on the important topic. Needless to say, the topic should also be of interest to accounting standard setters, whose regulations have the potential to be value destroying.

5 Concluding remarks

Both the IASB and the FASB have been moving toward a fair-value regime in the accounting for financial instruments. Survey evidence (Glaum and Klöcker 2011; Lins et al. 2011) suggests that firms' hedging behavior is directly affected by accounting regulations. We analyze the implications of fair-value accounting on firm hedging when firms are ultimately concerned with earnings volatility. Our theoretical analysis supplements and extends the survey evidence of, for instance, Lins et al. (2011) by focusing on the exact changes in firm behavior that can be expected from a significant change in the accounting regime. Specifically, our study illustrates how price and product characteristics influence hedging behavior in a two-period setting. The most general finding from the study is that the influence of the mark-to-market principle of SFAS 133 and IAS 39 differs across risk-exposure characteristics but that for the vast majority of firms, it entails less hedging in future accounting periods. If firms are truly concerned with earnings volatility, as suggested by Graham et al. (2005, 2006, 2007), firms will adopt myopic hedging strategies, either in the form of abandoned hedging programs or in terms of significantly reduced positions in hedging instruments with payoffs dependent on prices in future accounting periods. Realizing that they are unable to influence the volatility of earnings beyond the current period in a mark-to-market regime, firms adopt myopic hedging strategies designed to decrease the earnings volatility of this period, leaving subsequent periods unmanaged.

In contrast to the mark-to-market accounting of SFAS 133 and IAS 39, the deferral hedge accounting approach typically applied prior to SFAS 133 and IAS 39 did not create a mismatch between the timing of the recognition of gains and losses on derivative instruments entered into for hedging purposes and those of the hedged items. Therefore, cash flow hedging was equivalent to earnings hedging. We do not have a similar equivalence under the hedge accounting regulations of SFAS 133 and IAS 39; both SFAS 133 and IAS 39 require the ineffective portion of the hedge to be measured on a mark-to-market basis. The distortion in the current period's earnings may be considerable, especially for firms with a hedging horizon covering several future accounting periods. Therefore, even if qualifying for hedge accounting, firms concerned with earnings smoothness will have incentives to move away from the optimal cash flow hedging *in the direction of* the optimal earnings hedging under fair value accounting. For these firms, the hedge accounting regulations offer only a partial solution.

Because the requirements for hedge accounting have been widely criticized for being overly rigid and complex (Corman 2006), the FASB and the IASB both suggest that the thresholds for hedge accounting be lowered. However, companies that in the future are allowed to substitute hedge accounting for mark-to-market accounting, will, on average, have a more ineffective hedging strategy than the companies that currently have adapted to the hedge accounting regulations. If, for instance, a reasonably effective criterion is implemented, where reasonably effective is interpreted as having a minimum of 60 % hedge effectiveness, a firm with minimum hedge effectiveness will only shield 60 % of the future changes in the market value of a derivatives portfolio ex-ante. The 40 % ineffective part will still influence earnings, and the effect can be dramatic if the hedging extends beyond the next accounting period. Therefore, if earnings smoothness matters, the incentives to let the hedging (at least partly) be influenced by the mark-to-market of derivatives remain.[8] Much of the controversy over SFAS 133 and IAS 39 can be attributed to the concern that earnings as a measure of firm performance have eroded under mark-to-market accounting and, unfortunately, that hedge accounting in its present form is no universal remedy for excessively myopic behavior by firms, relative to the cash flow hedging benchmark.

Appendix A: Proof of proposition 1

Let $\tilde{S}_t$ and $\tilde{Q}_t$ denote the random spot price and the random quantity produced in period t, respectively, c the constant marginal cost, C fixed costs, $F_{0,t}$ the forward price at $t = 0$ with maturity at time t, and a_t the number of long positions in forward contracts with delivery at time t entered into at $t = 0$. A firm faces random cash flows $\widetilde{CF_1}$ equal to

$$\widetilde{CF_1} = \tilde{S}_1 \tilde{Q}_1 - c\tilde{Q}_1 - C + a_1 \left[\tilde{S}_1 - F_{0,1} \right] \tag{18}$$

The variance of the cash flow is equal to

$$\begin{aligned} \operatorname{var}\left(C\tilde{F}_1\right) = \operatorname{var}\left(\tilde{S}_1 \tilde{Q}_1\right) + c^2 \operatorname{var}\left(\tilde{Q}_1\right) + a_1^2 \operatorname{var}\left(\tilde{S}_1\right) \\ -2c \operatorname{cov}\left(\tilde{S}_1 \tilde{Q}_1, \tilde{Q}_1\right) + 2a_1 \operatorname{cov}\left(\tilde{S}_1 \tilde{Q}_1, \tilde{S}_1\right) - 2a_1 c \operatorname{cov}\left(\tilde{S}_1, \tilde{Q}_1\right) \end{aligned} \tag{19}$$

A firm minimizing the volatility of the cash flow solves the following condition (interior solution):

$$\frac{d \operatorname{var}\left(\widetilde{CF}_1\right)}{da_1} = 0 \tag{20}$$

Under bivariate normality, it follows from Lemma 2 in Sévi (2006) that the optimal number of forward contracts for period 1 is equal to

$$a_1^{CF} = -\mu_Q - (\mu_S - c)\, \rho_{\tilde{Q}_1, S_1} \frac{\sigma_{\tilde{Q}_1}}{\sigma_{\tilde{S}_1}} \tag{21}$$

Because forward contracts covering future periods do not affect cash flows in the previous periods, this expression for the optimal number of forward contracts is general and holds for any random year t.

[8] We stress that the ineffectiveness is caused by imperfect hedging instruments and not speculation. There is no speculation in our model. Speculative positions in derivatives should in any case be marked to market.

We now assume that we have a two-period setting. Under mark-to-market accounting, the earnings in period (year) 1 is equal to

$$\widetilde{EARN}_1 = \tilde{S}_1 \tilde{Q}_1 - c\tilde{Q}_1 - C + a_1 \left[\tilde{S}_1 - F_{0,1}\right] + a_2 \left[\tilde{F}_{1,2} - F_{0,2}\right] \quad (22)$$

The variance of earnings in period 1 equals

$$\begin{aligned} \operatorname{var}\left(\widetilde{EARN}_1\right) = {} & \operatorname{var}\left(\tilde{S}_1 \tilde{Q}_1\right) + c^2 \operatorname{var}\left(\tilde{Q}_1\right) + a_1^2 \operatorname{var}\left(\tilde{S}_1\right) + a_2^2 \operatorname{var}\left(\tilde{F}_{1,2}\right) \\ & -2c \operatorname{cov}\left(\tilde{S}_1 \tilde{Q}_1, \tilde{Q}_1\right) + 2a_1 \operatorname{cov}\left(\tilde{S}_1 \tilde{Q}_1, \tilde{S}_1\right) \\ & +2a_2 \operatorname{cov}\left(\tilde{S}_1 \tilde{Q}_1, \tilde{F}_{1,2}\right) - 2a_1 c \operatorname{cov}\left(\tilde{Q}_1, \tilde{S}_1\right) \\ & -2a_2 c \operatorname{cov}\left(\tilde{Q}_1, \tilde{F}_{1,2}\right) + 2a_1 a_2 \operatorname{cov}\left(\tilde{S}_1, \tilde{F}_{1,2}\right) \end{aligned} \quad (23)$$

A firm minimizing the volatility of earnings under mark-to-market accounting at $t = 0$ solves the following conditions (interior solution):

$$\begin{aligned} \frac{\partial \operatorname{var}\left(\widetilde{EARN}_1\right)}{\partial a_1} &= 0 \\ \frac{\partial \operatorname{var}\left(\widetilde{EARN}_1\right)}{\partial a_2} &= 0 \end{aligned} \quad (24)$$

Following Theorem 17.10 in Sydsaeter and Hammond (1995) and the fact that

$$\begin{aligned} \frac{\partial^2 \operatorname{var}\left(\widetilde{EARN}_1\right)}{\partial a_1^2} &= 2\sigma^2_{\tilde{S}_1} > 0 \\ \frac{\partial^2 \operatorname{var}\left(\widetilde{EARN}_1\right)}{\partial a_2^2} &= 2\sigma^2_{\tilde{F}_1} > 0 \\ \frac{\partial^2 \operatorname{var}\left(\widetilde{EARN}_1\right)}{\partial a_1 \partial a_2} &= \frac{\partial^2 \operatorname{var}\left(\widetilde{EARN}_1\right)}{\partial a_2 \partial a_1} = 0 \end{aligned} \quad (25)$$

the variance function is strictly convex. Therefore, the solutions of the two first-order conditions define the unique global minimum value (Theorem 17.11). Given Eq. (22), these two solutions are defined by the following two simultaneous equations:

$$a_1 = -\frac{\operatorname{cov}(\tilde{S}_1\tilde{Q}_1, \tilde{S}_1) + a_2 \operatorname{cov}\left(\tilde{S}_1, \tilde{F}_{1,2}\right) - c \operatorname{cov}\left(\tilde{Q}_1, \tilde{S}_1\right)}{\operatorname{var}\left(\tilde{S}_1\right)}$$

$$a_2 = -\frac{\operatorname{cov}(\tilde{S}_1\tilde{Q}_1, \tilde{F}_{1,2}) + a_1 \operatorname{cov}\left(\tilde{S}_1, \tilde{F}_{1,2}\right) - c \operatorname{cov}\left(\tilde{Q}_1, \tilde{F}_{1,2}\right)}{\operatorname{var}\left(\tilde{F}_{1,2}\right)} \tag{26}$$

Setting $a_1 = -\frac{A + a_2 C - cF}{B} = -\frac{A - cF}{B} - a_2\frac{C}{B}$ and $a_2 = -\frac{D + a_1 C - cG}{E} = -\frac{D - cG}{E} - a_1\frac{C}{E}$,

where $A = \operatorname{cov}(\tilde{S}_1\tilde{Q}_1, \tilde{S}_1)$, $B = \operatorname{var}\left(\tilde{S}_1\right)$, $C = \operatorname{cov}\left(\tilde{S}_1, \tilde{F}_{1,2}\right)$, $D = \operatorname{cov}(\tilde{S}_1\tilde{Q}_1, \tilde{F}_{1,2})$, $E = \operatorname{var}\left(\tilde{F}_{1,2}\right)$, $F = \operatorname{cov}\left(\tilde{Q}_1, \tilde{S}_1\right)$, and $G = \operatorname{cov}\left(\tilde{Q}_1, \tilde{F}_{1,2}\right)$ yields the solutions

$$a_1 = \frac{\frac{DC}{EB} - \frac{A}{B} + c\left(\frac{F}{B} - \frac{GC}{EB}\right)}{1 - \frac{C^2}{EB}} \tag{27}$$

$$a_2 = \frac{\frac{A}{B}\frac{C}{E} - \frac{D}{E} + c\left(\frac{G}{E} - \frac{FC}{BE}\right)}{\left(1 - \frac{C^2}{BE}\right)} \tag{28}$$

Reinserting the definitions of the constants yields the optimal number of forward contracts entered into at $t = 0$ under general distributional assumptions:

$$a_1^{M2M*} = -\frac{\operatorname{cov}(\tilde{S}_1\tilde{Q}_1, \tilde{S}_1)}{\sigma_{\tilde{S}_1}^2\left(1 - \rho_{\tilde{S}_1,\tilde{F}_{1,2}}^2\right)} + \frac{\operatorname{cov}(\tilde{S}_1\tilde{Q}_1, \tilde{F}_{1,2})}{\sigma_{\tilde{F}_{1,2}}\sigma_{\tilde{S}_1}}\frac{\rho_{\tilde{S}_1,\tilde{F}_{1,2}}}{1 - \rho_{\tilde{S}_1,\tilde{F}_{1,2}}^2} + c\left(\frac{\rho_{\tilde{Q}_1,\tilde{S}_1} - \rho_{\tilde{Q}_1,\tilde{F}_{1,2}}\rho_{\tilde{S}_1,\tilde{F}_{1,2}}}{1 - \rho_{\tilde{S}_1,\tilde{F}_{1,2}}^2}\right)\frac{\sigma_{\tilde{Q}_1}}{\sigma_{\tilde{S}_1}} \tag{29}$$

$$a_2^{M2M*} = -\frac{\operatorname{cov}(\tilde{S}_1\tilde{Q}_1, \tilde{F}_{1,2})}{\sigma_{\tilde{F}_{1,2}}^2\left(1 - \rho_{\tilde{S}_1,\tilde{F}_{1,2}}^2\right)} + \frac{\rho_{\tilde{S}_1,\tilde{F}_{1,2}}}{1 - \rho_{\tilde{S}_1,\tilde{F}_{1,2}}^2}\frac{\operatorname{cov}(\tilde{S}_1\tilde{Q}_1, \tilde{S}_1)}{\sigma_{\tilde{S}_1}\sigma_{\tilde{F}_{1,2}}} + c\frac{\left(\rho_{\tilde{Q}_1,\tilde{F}_{1,2}} - \rho_{\tilde{Q}_1,\tilde{S}_1}\rho_{\tilde{S}_1,\tilde{F}_{1,2}}\right)\frac{\sigma_{\tilde{Q}_1}}{\sigma_{\tilde{F}_{1,2}}}}{\left(1 - \rho_{\tilde{S}_1,\tilde{F}_{1,2}}^2\right)} \tag{30}$$

These optimal numbers of forward contracts collapse into the following equations under multivariate normality by using Lemma 2 in Sévi (2006)

$$a_1^{M2M} = -\mu_{\tilde{Q}_1} - \left(\mu_{\tilde{S}_1} - c\right) \frac{\sigma_{\tilde{Q}_1}}{\sigma_{\tilde{S}_1}} \left[\frac{\rho_{\tilde{Q}_1,\tilde{S}_1} - \rho_{\tilde{Q}_1,\tilde{F}_{1,2}} \rho_{\tilde{S}_1,\tilde{F}_{1,2}}}{1 - \rho^2_{\tilde{S}_1,\tilde{F}_{1,2}}} \right] \quad (31)$$

$$a_2^{M2M} = -\left(\mu_{\tilde{S}_1} - c\right) \frac{\sigma_{\tilde{Q}_1}}{\sigma_{\tilde{F}_{1,2}}} \left[\frac{\rho_{\tilde{Q}_1,\tilde{F}_{1,2}} - \rho_{\tilde{Q}_1,\tilde{S}_1} \rho_{\tilde{S}_1,\tilde{F}_{1,2}}}{1 - \rho^2_{\tilde{S}_1,\tilde{F}_{1,2}}} \right] \quad (32)$$

Appendix B: Detailed specification of the simulation assumptions of Section 4

1) Earnings targets (predictions at time t for the earnings of time t +1 and t+2)
Before:

$$\begin{aligned} \widehat{CF}_{t,t+1} &= \left(E_t\left[\tilde{S}_{t+1}\right] - c^* T_{t+1}(\Phi)\right)\mu_Q + \sigma_\varepsilon \sigma_{\tilde{Q}} \rho_{\tilde{Q},\tilde{S}} - C^* T_{t+1}(\Phi) \\ &\quad + a_{1,t}^{CF}\left(E_t\left[\tilde{S}_{t+1}\right] - F_{t,t+1}\right) + a_{2,t-1}^{CF}\left(F_{t,t+1} - F_{t-1,t+1}\right) \quad (33) \\ \widehat{CF}_{t,t+2} &= \left(E_t\left[\tilde{S}_{t+2}\right] - c^* T_{t+2}(\Phi)\right)\mu_Q + \sigma_\varepsilon \sigma_{\tilde{Q}} \rho_{\tilde{Q},\tilde{S}} - C^* T_{t+2}(\Phi) \\ &\quad + a_{2,t}^{CF}\left(E_t\left[\tilde{S}_{t+2}\right] - F_{t,t+2}\right) \quad (34) \end{aligned}$$

After, same strategy:

$$\begin{aligned} \widehat{Earn}^{CF}_{t,t+1} &= \left(E_t\left[\tilde{S}_{t+1}\right] - c^* T_{t+1}(\Phi)\right)\mu_Q + \sigma_\varepsilon \sigma_{\tilde{Q}} \rho_{\tilde{Q},\tilde{S}} - C^* T_{t+1}(\Phi) \\ &\quad + a_{1,t}^{CF}\left(E_t\left[\tilde{S}_{t+1}\right] - F_{t,t+1}\right) + a_{2,t}^{CF}\left(E_t\left[\tilde{S}_{t+2}\right] - F_{t,t+2}\right) \quad (35) \\ \widehat{Earn}^{CF}_{t,t+2} &= \left(E_t\left[\tilde{S}_{t+2}\right] - c^* T_{t+2}(\Phi)\right)\mu_Q + \sigma_\varepsilon \sigma_{\tilde{Q}} \rho_{\tilde{Q},\tilde{S}} - C^* T_{t+2}(\Phi) \quad (36) \end{aligned}$$

After, new strategy:

$$\begin{aligned} \widehat{Earn}_{t,t+1} &= \left(E_t\left[\tilde{S}_{t+1}\right] - c^* T_{t+1}(\Phi)\right)\mu_Q + \sigma_\varepsilon \sigma_{\tilde{Q}} \rho_{\tilde{Q},\tilde{S}} - C^* T_{t+1}(\Phi) \\ &\quad + a_{1,t}^{M2M}\left(E_t\left[\tilde{S}_{t+1}\right] - F_{t,t+1}\right) + a_{2,t}^{M2M}\left(E_t\left[\tilde{S}_{t+2}\right] - F_{t,t+2}\right) \quad (37) \\ \widehat{Earn}_{t,t+2} &= \left(E_t\left[\tilde{S}_{t+2}\right] - c^* T_{t+2}(\Phi)\right)\mu_Q + \sigma_\varepsilon \sigma_{\tilde{Q}} \rho_{\tilde{Q},\tilde{S}} - C^* T_{t+2}(\Phi) \quad (38) \end{aligned}$$

Other assumptions:

$$E_t\left[\tilde{S}_{t+1}\right] = T_{t+1}(\Phi) + \varphi S_t^* \tag{39}$$

$$E_t\left[\tilde{S}_{t+2}\right] = T_{t+2}(\Phi) + \varphi^2 S_t^* \tag{40}$$

$$c_t = c^* T_t(\Phi) \tag{41}$$

$$C_t = C^* T_t(\Phi) \tag{42}$$

Consistent with Brown and Toft's (2002, p. 1291) base case assumptions, we set $c^* = 0.25$ and $C^* = 0.4$. Note that both $\widehat{Earn}^{CF}$ and $\widehat{Earn}$ above represent earnings under fair-value accounting, the former using cash flow hedging and the latter using a hedging strategy designed to manage earnings risk under fair-value accounting.

2) Net profit decomposition under deferral accounting (FCP = forward contract payoff):

$$\widetilde{FCP}_{1,t}^{DA} = a_{1,t-1}^{CF}\left(\tilde{S}_t - F_{t-1,t}\right) \tag{43}$$

$$FCP_{2,t}^{DA} = a_{2,t-2}^{CF}\left(F_{t-1,t} - F_{t-2,t}\right) \tag{44}$$

$$\widetilde{NP}_t^{NoHedge} = \tilde{S}_t\tilde{Q}_t - c\tilde{Q}_t - C \tag{45}$$

$$\widetilde{CF}_t = \widetilde{NP}_t^{NoHedge} + \widetilde{FCP}_{1,t}^{DA} + \widetilde{FCP}_{2,t}^{DA} \tag{46}$$

3) Net profit decomposition under fair-value accounting and cash flow hedging: Let F be the forward lag operator. In this case,

$$\widetilde{Earn}_t^{CF} = \widetilde{NP}_t^{NoHedge} + \widetilde{FCP}_{t,1}^{DA} + F\left(\widetilde{FCP}_{t,2}^{DA}\right) \tag{47}$$

4) Net profit decomposition under fair-value accounting and a hedging strategy designed to manage earnings risk under fair-value accounting:

$$\widetilde{FCP}_{1,t}^{M2M} = a_{1,t-1}^{M2M}\left(\tilde{S}_t - F_{t-1,t}\right) \tag{48}$$

$$\widetilde{FCP}_{2,t}^{M2M} = a_{2,t-1}^{M2M}\left(F_{t,t+1} - F_{t-1,t+1}\right) \tag{49}$$

$$\widetilde{Earn}_t = \widetilde{NP}_t^{NoHedge} + \widetilde{FCP}_{1,t}^{M2M} + \widetilde{FCP}_{2,t}^{M2M} \tag{50}$$

5) Average root mean squared prediction errors in the sample of M = 10,000 replications over the N = 10 years 2012–2021:

Define $\Theta = \{t : t \in \{2012, \ldots, 2021\}\}$. In this case, root mean squared errors are defined as follows for one-year and two-year forecasts, respectively:

$$RMSE_{1YR}^{\widehat{CF_{t\in\Theta}}} = \frac{1}{M}\sum_{i=1}^{M}\sqrt{\frac{1}{N}\sum_{t\in\Theta}\left(\widetilde{CF}_{t,i} - \widehat{CF}_{t-1,t,i}\right)^2} \tag{51}$$

$$RMSE_{2YR}^{\widehat{CF_{t\in\Theta}}} = \frac{1}{M}\sum_{i=1}^{M}\sqrt{\frac{1}{N}\sum_{t\in\Theta}\left(\widetilde{CF}_{t,i} - \widehat{CF}_{t-2,t,i}\right)^2} \tag{52}$$

$$RMSE_{1YR}^{\widehat{Earn}_{t\in\Theta}^{CF}} = \frac{1}{M}\sum_{i=1}^{M}\sqrt{\frac{1}{N}\sum_{t\in\Theta}\left(\widetilde{Earn}_{t,i}^{CF} - \widehat{Earn}_{t-1,t,i}^{CF}\right)^2} \tag{53}$$

$$RMSE_{2YR}^{\widehat{Earn}_{t\in\Theta}^{CF}} = \frac{1}{M}\sum_{i=1}^{M}\sqrt{\frac{1}{N}\sum_{t\in\Theta}\left(\widetilde{Earn}_{t,i}^{CF} - \widehat{Earn}_{t-2,t,i}^{CF}\right)^2} \tag{54}$$

$$RMSE_{1YR}^{\widehat{Earn}_{t\in\Theta}} = \frac{1}{M}\sum_{i=1}^{M}\sqrt{\frac{1}{N}\sum_{t\in\Theta}\left(\widetilde{Earn}_{t,i} - \widehat{Earn}_{t-1,t,i}\right)^2} \tag{55}$$

$$RMSE_{2YR}^{\widehat{Earn}_{t\in\Theta}} = \frac{1}{M}\sum_{i=1}^{M}\sqrt{\frac{1}{N}\sum_{t\in\Theta}\left(\widetilde{Earn}_{t,i} - \widehat{Earn}_{t-2,t,i}\right)^2} \tag{56}$$

Percentage errors (relative to the targets) are obtained as in Eq. (17).

6) Procedure for generating the unhedgeable quantity innovations (Hull 1997, p. 363).

The unhedgeable quantity innovations are presumed to be i.i.d. and correlated (corr) with the innovation terms of the ARMAX price dynamics; that is, the quantity innovations are correlated with the ε-terms of the price process.

- *Step 1*: Scale each of the price innovations by multiplying ε with the ratio $\frac{\sigma_{\tilde{Q}}}{\hat{\sigma}_{\varepsilon}}$ ($\hat{\sigma}_{\varepsilon} = 125.1$). Denote this rescaled series of price innovations e_1.
- *Step 2*: Generate an independent set of normally distributed RVs with zero (expected) mean and standard deviation $\sigma_{\tilde{Q}}$. Denote this series e_2.
- *Step 3*: Generate a correlated set of bivariately normal innovations price and quantity innovations with zero mean and standard deviations equal to $\hat{\sigma}_{\varepsilon} = 125.1$ and $\sigma_{\tilde{Q}}$, respectively, by calculating the new series of $\tilde{Q}$-innovations as follows: corr * e_1 + sqrt(1 − corr^2) * e_2. This is the set of randomly generated quantity innovations.

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