Corporate Risk Management and Hedge Accounting under the scope of IFRS 9

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Abstract Accounting for derivatives has stirred important debate among academics, international standard setters and practitioners over the past decade. On the one hand, standard accounting with fair value measurement makes the use of derivatives more transparent, giving clear insights of the firm's underlying risk exposure. On the other hand, if derivatives qualify for the hedge accounting treatment, the timings mismatch associated with standard accounting is alleviated, so that the temporary income statement volatility may be significantly reduced, and the firm's risk management policy will be better reflected in financial statements. Under IFRS, hedge accounting has been covered by IFRS 9 from January 1, 2018.
In this chapter, we study the implications of IFRS 9 hedge accounting requirements from the perspective of non-financial firms that use commodity derivatives. After describing the main advances of IFRS 9, we present appropriate methods to estimate hedge ratios and measure hedge effectiveness. We show that time-varying hedge ratios could be used to rebalance hedges and maximize the benefits of hedge accounting. Finally, we use an illustrative case study to explain how a power firm can report carbon hedges in respect of IFRS 7 disclosure requirements to provide transparent and relevant information in financial statements.

KEYWORDS: Risk Management; Hedge accounting; IFRS 9; Hedge effectiveness; Carbon derivatives.

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1 Introduction

An important function of a corporate treasury is to protect cash flow margins and earnings generated from the underlying business against external market forces such as commodity price fluctuations, changes in the interest rates and in the exchange rates. In practice, corporates may implement hedging strategies in order to protect against the associated (volatility) risk exposures by using derivative financial instruments. Remarkably, the World Federation of Exchanges (WFE) has estimated that the amount of exchange-traded commodity derivatives has increased fivefold over the past decade to reach 5.8 billion contracts in 2017 (WFE, 2018).

Hedging strategies of corporates using derivatives are strongly influenced by accounting standards (Gumb et al., 2018). On the one hand, prior research provides evidence that accounting for derivatives at fair value could make their use more transparent and favor prudent risk management (Hairston and Brooks, 2019). On the other hand, sound hedging strategies may be suboptimal under fair value accounting (Melumad et al., 1999). Because fair value accounting implies that the respective gains and losses on the hedged item and the hedging (derivative) instrument are not accounted for simultaneously in the income statement, hedging relationships may generate an increase in earnings volatility, which decreases the utility of hedging in terms of (volatility) risk reduction. Instead, hedge accounting can reduce this artificial increase in earnings volatility to a large extent.

The International Financial Reporting Standards (IFRS) rules for hedge accounting previously were previously defined in IAS 39 but they were often criticised as being too restrictive and not sufficiently aligned with corporates' risk management strategies.

IFRS 9 that has replaced IAS 39 from November 2013 offers three main advantages over IAS 39. A first main benefit is the removal of the arbitrary 80%-125% boundaries for hedge ratios. A second main benefit is the abandonment of retrospective tests to assess hedging effectiveness that were required by IAS 39.[1] Instead, the hedge effectiveness tests are only prospective. A third main improvement is that IFRS 9 allows companies to maintain their hedges by means of rebalancing without discontinuing the hedging relationship as is the case with IAS 39, driven by the objective to enhance the linkages between hedge accounting and corporate risk management activities.[2] Because hedge accounting with IFRS 9 remains optional, corporates should assess the costs and benefits of its implementation.[3]

This chapter examines the relevance of the new hedge accounting model of IFRS 9 from the perspective of commodity derivatives. The motivations of this chapter are threefold.

Our main objective is to show that the IFRS 9 principles are relevant for firms that use commodity derivatives because they are aligned with their risk management objectives. For that purpose, we consider the particularly interesting case of the European carbon derivatives.

Similar to any other commodity derivatives traded on exchanges, European carbon futures are subject to vagaries posed by the timing of compliance events that cause high price volatility risks (Medina and Pardo, 2013; Ibikunle et al., 2016). Also, carbon prices are influenced by the fuel-switching decisions of power firms (Chevallier, 2012) that have the most important carbon emissions exposure to be hedged (Schopp and Neuhoff, 2013). By bringing the amount of their hedging carbon costs on to their balance sheet, a connection between the amount of carbon emissions and the firm value has emerged (Lovell et al., 2013) or its financial performance (Qian and Schaltegger, 2017). However, the absence of a commonly accepted

[1] The prospective (*resp.* retrospective) hedge effectiveness test is a forward-looking (*resp.* backward-looking) evaluation of whether or not the changes in the fair value or cash flows of the hedging item are expected to be highly effective in offsetting the changes in the fair value or cash flows of the hedged item over the term of the relationship (*resp.* since the date of designation).

[2] Rebalancing allows firms to adjust their hedge ratio i.e., adjust the quantities of the hedged item or the hedging instrument. As rebalancing does not result in de- (or -re) designation of a hedge, the hedging relationship is maintained while hedge ineffectiveness is recognised immediately before adjusting the hedge relationship.

[3] Banks are obliged to comply with the provisions of IFRS 9 from January 1, 2018 while non-financial firms may adopt IFRS 9 voluntarily for reporting financial instruments including derivatives.

accounting standard has led to the use of various methods to account for carbon hedging instruments (Haupt and Ismer, 2013) and restrain the willingness of power firms to disclose them. If it raises concerns about the comparability of their financial statements, the ability to inform on their cost of complying with their objective of carbon emission reductions may also be hindered. Lovell et al. (2013) attribute this lack of transparency to a diversity in reporting practices used and to the difficulty in applying hedge accounting under IAS 39. As a solution to this impasse, the Climate Disclosure Board and the International Energy Trading Association (2013) have called European emitting (non-financial) firms to apply the IFRS 9 principles to report carbon hedge using derivatives.

In this chapter, we underscore their relevance to account for carbon hedges under IFRS 9 on the basis of its above-mentioned benefits, which are: (*i*) the removal of the arbitrary 80%-125% boundaries for the hedge ratios; (*ii*) the abandonment of retrospective tests of hedge effectiveness; (*iii*) the possibility of rebalancing in order not to discontinue hedge relationships.

To qualify for hedge accounting under IFRS 9, the hedge must be 'highly effective', so hedge effectiveness tests for qualifying derivatives as hedging instruments must be carried out. Nevertheless, neither IFRS 9 nor its predecessor IAS 39 have specified any bright line test to identify highly effective hedging relationships.

The second aim of this chapter is therefore to provide relevant and easy to implement methods to conduct hedge effectiveness tests under IFRS 9.

The issue of measuring hedge effectiveness has been largely explored in energy markets but to a lesser extent in carbon markets probably due to its newness. In a minimum variance framework, Feng et al. (2016) show that carbon hedging strategies are increasingly efficient even if optimal hedge ratios are estimated at lower levels compared to energy and more mature markets. By contrast, Fan et al. (2014) estimate optimal hedge ratios using European Allowances (EUAs) futures, with values ranging from 0.5 to 1.0 using a 1-year horizon, in line with estimations found for more mature financial markets. In terms of hedge effectiveness, they find that OLS carbon hedges often provide the greatest variance reduction in comparison to time-varying carbon hedges based on a GARCH structure (VECM-GARCH and CCC GARCH). In contrast, Philip and Shi (2016) provide evidence of the superiority of time-varying Markov regime switching (MRS-LR-DCC) hedge.[4] In a Value at Risk (VaR) framework, Feng et al. (2012) use the Extreme Value Theory (EVT) to estimate optimal hedge ratios and to assess effectiveness of hedging strategies as Kleindorfer and Li (2011) recommend for power companies.[5] Their results indicate that the EVT VaR is a more effective tool to evaluate the hedging effectiveness than the minimum variance reduction measure (Harris and Shen, 2006).

Building on this prior literature, we focus on proven empirical methods to estimate optimal hedge ratios and associated hedging effectiveness. We proceed in three steps. First, we consider that the large EU ETS companies use rollover strategies to cover their long-term hedging needs (Schopp and Neuhoff, 2013) so that we choose 1-year hedging horizon as in Fan et al. (2013). Second, we estimate hedge ratios using two static models (OLS, VECM) and two time-varying models (VECM-GARCH and VECM-GJR GARCH). Our results indicate that hedge ratios sometimes fall outside the range of 80%-125% especially for hedging strategies based on CER derivatives. Third, we propose two optimisation methods to estimate hedge effectiveness: variance reduction (Ederington, 1979) and the VaR measure (Harris and Shen, 2006). We find that time-varying VECM-GJR GARCH hedges deliver superior hedging effectiveness in terms of variance reduction and VaR reduction for both EUA and CER

[4] The MRS-LR-DCC model leads to an estimate of a long run relationship between spot and futures prices and DCC-GARCH errors to connect to the idea of a disequilibrium measured by a lagged basis with this of uncertainty modelled by DCC-GARCH, across market regimes.

[5] Kleindorfer and Li (2011) model portfolio strategies of power firms that choose a portfolio of electricity and carbon derivatives to maximise their expected profit under the constraint of minimizing its VaR exposure.

derivatives. Interestingly, these time-varying ratios may be used to rebalance carbon hedges and more generally to rebalance commodity hedges.

The third objective of this chapter is to give operating guidelines to disclose cash flow hedges using commodity derivatives in financial statements under IFRS 7. In fact, whenever IFRS 9 rules for hedge accounting are applied by non-financial firms, they must follow the disclosure requirements of IFRS 7. These disclosures shall provide detailed information about: (*i*) the risk management strategy of a given corporate and its style of managing risks; (*ii*) how its hedges can influence the amount, timing and uncertainty of its future cash flows; (*iii*) the effect that hedge accounting has had on its financial statements.

In the final part of this chapter, we thus propose a case study that illustrates how a given power company can use IFRS 7 rules to disclose a cash flow hedge using carbon futures in its financial statements provided that the IFRS 9 requirements have been met.

The remainder of the chapter is organised as follows. Section II describes the hedge accounting requirements of IFRS 9 and its main advances from the perspective of non-financial firms. Next, proven methodologies to estimate static or time-varying hedge ratios and associated hedge effectiveness tests are outlined in Section III. Section IV is devoted to the presentation of a case study that explains how a carbon hedge qualified under IFRS 9 must be disclosed in the financial statements according to IFRS 7. Section V concludes.

2 Hedge Accounting with IFRS 9 and Corporate Risk Management: Toward a Greater Alignment

This section examines the provisions of IFRS 9 in terms of hedge accounting and their possible effect on corporate risk management strategies. We proceed in two steps. First, the key conditions of accounting for derivatives under IFRS 9 are discussed in comparison to those of IAS 39. Second, we focus on the case of carbon derivatives to show the relevance and usefulness of the IFRS 9 principles to account for commodity hedges using derivatives.

2.1 Accounting for financial instruments with IFRS 9: Background information

Derivatives contracts are financial instruments that derive their value from an underlying asset but not from the contract itself. Although derivatives have existed in various forms, reporting these instruments presents challenges owing to the complexity of initial and ongoing valuations (Hairston and Brooks, 2019). Since EU listed companies have applied IFRS to their consolidated financial statements from 2005, the International Accounting Standards Board (IASB hereafter) has promoted a fair value accounting approach that implies the superiority of market prices to value derivatives. Proponents of fair value accounting contend that fair value measurements are more relevant to shareholders because they reflect the current value of assets and liabilities. By contrast, their opponents argue that the corporates' hedging strategies are made suboptimal since the hedged item and the hedging instrument are not accounted for simultaneously, which generates an economically non-justifiable increase of earnings volatility.

As an alternative to fair value accounting, hedge accounting aims to better reflect the hedging results by reporting the effects of the hedging instrument (i.e., the derivative) and the risk being hedged in the same period. Hedge accounting may significantly reduce the P&L mismatch of fair value accounting by considering both the hedging instrument and the hedged item as a single item. Thus, the gains and losses from the hedged item and the hedging instrument are reported in the same period so that the changes in their valuation are offset, leading to reduce corporates' earnings volatility.

Hedge accounting is a privilege and has to be earned. Corporates can only adopt hedge accounting if they meet the IAS 39 requirements. However, the complexity of IAS 39 *Financial instruments : Recognition and Measurement* constrain its usage by corporates to account for hedges (IASB, 2010) notably those associated with commodity derivatives.

Therefore, the IASB has undertaken a reform of IAS 39 from 2009 through a new International Financial Reporting Standard entitled IFRS 9: *Financial Instruments*. In December 2010, the IASB issued an Exposure Draft (ED) Hedge Accounting, which contains the proposals for the third part of IFRS 9 related to hedge accounting. On 19 November 2013, after receiving comments on the ED, the IASB issued a new version of IFRS 9 *Financial Instruments*: *Hedge Accounting and amendments to IFRS 9, IFRS 7 and IAS 39* (IASB, 2013) introducing a new hedge accounting model, with the ambition to provide relevant information about risk management activities using derivatives. Interestingly, most significant benefits may be by non-financial firms since hedge accounting will be permitted for components of non-financial items such as commodities, provided certain criteria can be satisfied.

Fig.1 displays the sequence of steps for designating a hedging relationship that consists of eligible hedging instruments (i.e., derivatives) and eligible hedged items (i.e., underlying assets) under IFRS 9. Unlike IAS 39, IFRS 9 proposes three types of hedging relationships: a fair value hedge, a cash flow hedge or a hedge of a net investment in a foreign operation. To qualify for hedge accounting, the hedging relationship must meet all of these requirements:

- There is an economic relationship between the hedged item and the hedging instrument;
- Companies must provide a formal designation and documentation on the hedging relationship at inception of the hedging relationship;
- The value changes related to this economic relationship that could impact both the hedging instrument and the hedged item are not dominated by the credit risk effect; [6]
- The hedging relationship resulting from the quantity of hedged item actually hedged is identical to this resulting from the quantity of the hedging instrument used by the firm actually to hedge the quantity of the hedged item.

The first requirement implies that the hedging instrument and the hedged item should move in opposite directions as a result of a variation in the hedged risk. When the critical terms of the hedging instrument and hedged item are not closely aligned, which is often the case for commodities, IFRS 9 suggests that "*it might only be possible for an entity to conclude [that there is an economic relationship] on the basis of a quantitative assessment*." If IFRS 9 does not specify a method for quantitative assessment, a possible method is a statistical (regression) analysis in order to obtain a suitable hedge ratio. The third requirement is that this hedge ratio, which is the ratio between the amount of hedged item and the amount of hedging instrument used for hedge accounting shall be identical to this used for risk management objectives.[7]

[Fig. 1 is inserted about here]

Like in IAS 39, the decision to apply hedge accounting remains optional for non-financial firms so that their management should consider the costs and benefits when deciding whether or not to use it. For instance, power firms will have to consider their commodity hedging activities and existing hedge accounting or why hedge accounting has not been achieved in the past in order to assess the benefits of the IFRS 9 requirements. This assessment encompasses operational aspects (such as the hedge effectiveness test) as well as the eligibility of items (such as risk components of non-financial items) that can be designated in hedging relationships.

Table 1 stresses the advantages and drawbacks of the IFRS 9 principles against IAS 39 rules in terms of hedge accounting. In a preliminary study, Onali and Ginesti (2014) show that if most of IFRS non-financial firms welcome IFRS 9 improvements, they also expect that the use of hedge accounting will be extended to non-financial items including commodities.

[6] The credit risk can take the form of either the counterparty's credit risk or the company's credit risk.

[7] For a hedging relationship with a correlation between the hedged item and the hedging instrument that differs from the 1:1 relationship, risk managers will generally adjust the hedge ratio to improve its effectiveness.

Under IAS 39, a substantive requirement to qualify for hedge accounting is that two hedge effectiveness assessment tests must be performed and repeated once the hedge relationship is subjected to important changes, throughout the life of the hedge.

The first test relates to how the hedge is expected to perform, prospectively, and the second one indicates how the hedge has performed, retrospectively. A possible approach to conducting these tests is to calculate a dollar offset ratio (DOR hereafter), whereby the gains or losses of the hedging derivative (the numerator) are compared to the gains or losses of the hedged item (the denominator). Offsetting in this context means that if one of the market values of hedged item or hedging instrument decreases the other will increase, and vice versa. This implies a risk symmetry with respect to the variations of the hedged item and those of the hedging instrument.

The IASB has decided that the DOR metric must fall between two acceptable boundaries [4/5 ; 5/4] or [80% ; 125%] as a qualifying criterion. Nonetheless, both theory and practice have highlighted that these boundaries are too restrictive or even inoperative for two reasons at least. A first reason is that the DOR falls too frequently outside the boundaries in periods with little price changes. In these periods, the DOR denominator (gains or losses of the hedged item) approaches zero, so it reaches values well above the 125% maximum. Consequently, corporates may find that hedge accounting is unfairly disallowed during periods when price changes have limited economic effect (Kawaller, 2015). A second reason is the inconsistency of results from the single-period DOR that may (*resp.* may not) fall within the acceptable boundaries while those from the cumulative DOR that may not (*resp.* may).

Because the IAS 39 requirement for hedge effectiveness was operationally onerous and suboptimal preventing many well-designed hedging relationships from qualifying for hedge accounting, the IASB decided with IFRS 9 to remove the arbitrary 80-125% thresholds and to require only prospective tests of hedge effectiveness.

In addition to the above decision, the alignment of the corporate risk management strategy with its objective is fundamental under IFRS 9. To qualify for hedge accounting under IFRS 9, a detailed documentation of the hedge ratio calculation and of the potential sources of ineffectiveness must be provided. For instance, firms must report 25% of ineffectiveness in the P&L if the hedge was 75% effective at the end of a reporting period. To avoid discontinuation, IFRS 9 allows firms to rebalance i.e., to refine their hedge ratio in order to reduce this source of ineffectiveness due to changes in the relationship between the hedged item and the hedging instrument. Rebalancing can be achieved by: (i) increasing (or decreasing) the volume of the hedged item or (ii) increasing (or decreasing) the volume of the hedging instrument.

[Table 1 is inserted about here]

In view of the advances made by IFRS 9, Kawaller (2015) argues that the hedging part of IFRS 9 is a more ambitious and less prescriptive approach than that of its US GAAP equivalent: FAS 133. First, IFRS 9 allows benchmark hedging for commodities as well as for interest rates. Therefore, if a commodity price is tied to a benchmark price and if the derivative depends on this benchmark price, the hedge may be expected to perform with zero ineffectiveness. Second, IFRS removes the 80-125% threshold for qualifying hedge relationships. By contrast, FAS 133 imposes that the hedging strategy must be "highly effective" meaning that the hedge ratio must fall within the boundaries of 80%-125%, otherwise this precludes hedge accounting in that period. Third, FAS 133 imposes a repetition of prospective effectiveness tests at least on a quarterly basis whereas IFRS 9 only enforces a prospective test that must be conducted at the start of the hedge relationship and on an ongoing basis. Fourth, retrospective tests of hedge effectiveness are required under FAS 133, while they are abandoned in IFRS 9. For all of these reasons, the application of the more liberal IFRS 9 model is expected to boost the use of hedge accounting by non-financial firms using financial instruments such as commodity derivatives (see also Onali and Ginesti, 2014).

2.2 *Accounting for financial instruments with IFRS 9: the case of carbon derivatives*

Accounting for financial instruments has been subject to much controversy in terms of accounting for commodity derivatives including energy derivatives held for hedging purposes (Lopes, 2007). More specifically, the case of European carbon derivatives is an enlightening example of the difficulty to adopt a commonly international standard for hedge accounting.

In January 2005, the advent of the EU Emission Trading System (EU ETS) introduced European Allowances (EUAs) as a new class of financial assets (Medina and Pardo, 2013). All combustion installations exceeding 20 MW are affected by the EU ETS including different kinds of industries like metal, cement, paper, glass, etc., as well as refineries or coke ovens. In total, the EU-ETS system comprises 13,000 installations responsible for approximately 45% of EU's CO_2 emissions and has given birth to the world's largest GHG emissions trading system. Each EU Member State proposes a National Allocation Plan (NAP) including caps on greenhouse gas emissions for power plants and other large point sources that are then approved by the European Commission (EC hereafter). The EC evaluates and decides whether such NAP is or is not in line with what each Member State is expected to comply with. If the answer is positive, EU Member States are in charge of allocating the number of EUAs among the installations involved. In Phase I (2005-2007) and Phase II (2008-2012) of EU ETS, EUAs were granted free of charge for 98% of the total volume. Phase III (2013-2020) introduces the purchases of EUAs by means of auctions. On average, 20% of EUAs have been auctioned in 2013 with a gradual rise to 70% in 2020. The EU ETS forces companies to hold an adequate number of EUAs according to their carbon dioxide output. Failure to submit a sufficient amount of allowances resulted in sanction payments of 100 EUR per missing ton of CO_2 allowances in Phases II and III. Therefore, EU ETS companies develop dedicated risk management strategies to hedge against both the risks of sanction payments and of higher prices when they have to purchase additional EUAs if their carbon emissions are more than expected.

Whilst the EU ETS represents the most important tool to meet Kyoto obligations, other measures built around the 'Clean Development Mechanism' (CDM) have emerged. This mechanism allows EU ETS companies to earn 'Certified Emissions Reductions' (CERs) when they invest in low-carbon intensive projects. Each CER represents a successful emission reduction of one tonne of CO_2. With a limit of 13.4% of annual volume on average, CERs can be converted into EUAs by companies for compliance purposes (Trotignon and Leguet, 2009).

The emergence of EU ETS and CDM have given birth to a new class of traders since EUA and CER assets and related derivatives may be used for both hedging and speculative purposes (Berta et al., 2017).[8] They can trade either EUA and CER spot or derivatives contracts including futures, OTC forwards and options on dedicated exchanges like the European Climate Exchange (ECX). If 75% of EUA and CER trades are futures in Phase II, ECX monopolises the EU ETS exchange-based carbon trading with 92% market share (Ibikunle et al., 2016). Carbon traders prefer to hold long futures positions to hedge their long-term commitment to purchase EUAs especially in Phase III (Trück et al., 2016). They notably focus their attention on the December maturity representing 76% of the futures contracts traded on ECX from 2009 (Ibikunle et al., 2016). Kalaitzoglou and Ibrahim (2013) point out that OTC EUA forwards are fewer than EUA futures but with a larger size indicating a high proportion of informed traders. Similarly, Medina et al. (2013) estimate a large concentration of informed trading in the CER futures market. They also show that the contribution of CER futures to price discovery is overly large in Phase II of EU ETS given their share in trading volume in comparison to EUA futures.

[8] Berta et al. (2017) show that the distinction between hedging and speculation is irrelevant in the case of carbon derivatives. Every hedging position of EU ETS companies requires a speculative position to bear the risk as a counterparty; so every hedging transaction is simultaneously a speculative one. While speculation is regarded as necessary to help firms to hedge against price volatility, speculation creates price volatility. Accordingly, we consider derivatives used for either hedging or speculative purposes as financial instruments.

In 2004, the International Financial Reporting Interpretations Committee (IFRIC) released an interpretation dealing with accounting for *Emission Rights* (*IFRIC 3 'Emissions Rights'*). Nonetheless, IFRIC 3 was unable to address the accounting issues for EUAs held by non-EU ETS firms for investment and speculative reasons. Besides, IFRIC 3 proposes any guidance on the accounting treatment of carbon derivatives that are used for hedging (Haupt and Ismer, 2013). One year after its release, IFRIC 3 was withdrawn further to a negative notice of EFRAG (EFRAG, 2005) and complaints of numerous EU ETS firms, leaving a gap in international accounting standards to report carbon assets and derivatives (Lovell et al., 2013).

Interestingly, to better control the increasing financialisation of the EU ETS, the EC has included both EUA and CER derivatives in the revised MiFID Directive voted on 20 October 2011 (Rannou and Barneto, 2016), so that they are now classified as financial instruments. In the absence of a commonly accepted accounting standard, a survey of the International Energy Trading Association (IETA) (2007) indicated that 53% of respondents deem the EUA and CER derivatives to be within the scope of IAS 39 *Financial Instruments* and 47% either fair value the contracts through the income statement or fair value them through reserves.

Since the 'own use' exemption (under IAS 39) was rarely applied in the case of EUA and CER derivatives, Haupt and Ismer (2013) argue that the hedge accounting regime of IFRS 9 should be adequate to report carbon hedges involving those derivatives. Accordingly, changes in the fair value of EUA and CER derivatives used for compliance purposes will be recorded as adjustments to a cash flow hedging reserve on the balance sheet and do not affect profits until the hedged transactions are recorded in the P&L through OCI. In contrast, EUA and CER derivatives that companies held for trading purposes should be accounted for in the P&L.

3 Methodology

3.1 Assessment of hedging needs of EU ETS power firms

Given the newness of the EU ETS, it is not surprising to see that research on carbon futures market has started to focus on its relationship with energy related markets. Based on a CAPM framework, Chevallier (2012) shows that introducing EUA and CER futures leads to a reduction in the idiosyncratic risk of a portfolio including energy (natural gas and coal), bonds but not its systematic risk due to the dependency of all these assets on macroeconomic shocks since the advent of the financial crisis in 2008. Unlike other energy markets that are affected by macroeconomic conditions, volatility risk factors on the carbon market are also closely related to the fuel-switching behaviour of power firms (Bangzhu and Chevallier, 2017).

Among the nine industrial sectors covered by the EU ETS, the sector 'combustion', which includes power firms (i.e., firms that hold individual factories and cogeneration plants), provides the largest source of carbon emissions.[9] Table 2 gives an overview of the annual EUA shortages of the 'combustion' sector according to EU Member States. Overall, EUA shortages to be covered by 6 591 installations belonging to the sector 'combustion' have increased sevenfold (*resp.* fourfold) in volume (*resp.* in value) from Phase II to Phase III (2013-2015).[10]

[Table 2 is inserted about here]

[9] Sectors are combustion, cement, ceramics, coke ovens, glass, iron & steel, metal ore, paper & board, refineries.
[10] The economic crisis, which reduced carbon emissions more than anticipated and high imports of CERs, has generated a 2 billion surplus of EUAs at the end of 2014. This has led to a significant fall in carbon prices. In July 2015, the EC has decided to postpone the auctioning of 500 million EUAs in 2016 and 2017. Given that this decision reduces drastically the volume of EUAs auctioned, the spot (auction) EUA market becomes much less liquid than previously and EUA spot prices become artificially much more volatile. Therefore, the variance of spot (unhedged) and futures (hedged) EUA portfolio that we estimate would have been necessarily affected after 2015. In this respect, we have considered the period 2013-2015 in order to study the carbon hedging strategies in Phase III given a EUA spot market offering comparable conditions of liquidity and price volatility.

An exhaustive research from the 6 591 installations to estimate their own hedging needs is a very difficult challenge, if not impossible (Lovell et al., 2013). For this reason, we constitute a panel of the 19 most representative European power companies which mimics this of Lovell et al. (2013). We then proceed in two steps to estimate their respective carbon hedging needs. First, we use the database of the European Union International Transaction Log (EU ITL) to identify installations and their corresponding amounts of emissions and EUAs granted. Second, since the EU ITL provides only details of installations and not EU ETS company data, we undertake a matching of installations by Internet searches to the 19 power companies. As a result of our searches, we find that these 19 companies collectively own 378 installations in the period 2008-2015. Third, we follow the methodology of Berta et al. (2017)[11] to estimate their theoretical hedging needs. For each installation, we compute the difference between allocation of EUAs and verified emissions recorded in April of the following year. These positions, when installations are 'short' i.e., have negative difference (*resp.* 'long' i.e., have positive difference), are aggregated to calculate the overall shortage (surplus) for all of the power companies.

Table 3 presents a snapshot of theoretical hedging needs estimated for the 19 representative power companies. We calculate these hedging needs by subtracting the number of EUAs and CERs that have been surrendered by companies to the amount of verified emissions emitted by companies. We observe a noticeable change from Phase II, where two firms (CEZ and PPC) were long of quotas (number of EUAs and CERs held by annual year exceed the amount of yearly verified emissions), while in Phase III, there is only one (PPC). In fact, power firms need to purchase EUAs by auctions in Phase III (2013-2020) rather than being granted freely as in Phase II (2008-2012).

Based on an average carbon price of 14 Euros per $tC0_2eq$. in Phase II, our calculation gives an annual average amount of 81.207 million euros per company to be hedged. Given an average carbon price of 7 euros per $tC0_2eq$. along the period 2013-2015, an annual average amount of 146.367 million euros per company has to be hedged. These two amounts underscore the importance for these 19 representative power companies to carry out effective hedging strategies through the use of EUA and CER derivatives, which calls into question whether or not they can apply the IFRS 9 hedge accounting framework to report them.

[Table 3 is inserted about here]

3.2 Hedge Ratio estimation

Our empirical work consists of first estimating optimal hedge ratios using daily returns and then assessing hedging effectiveness based on these hedge ratios. We consider that the optimal hedge ratio is the number of futures per unit of the spot minimizing the variance of the hedged portfolio returns (see e.g., Ederington, 1979; Fan et al., 2013; 2014). In order to estimate optimal hedge ratios, we use EUA and CER daily futures prices traded on ICE-ECX, Bluenext spot prices for the period: 2008 - 2012 and EEX auction spot prices for the period: 2013-2015.[12]

Panels A and B of Table 4 display the basic properties of the EUA and CER spot or futures continuously compounded rate of returns (*first difference*) averaged for Phase II and Phase III (2013-2015). The variance of the EUA futures returns is lower than that of the CER futures returns, resulting in lower volatility of price risks. The skewness of the EUA (*resp.* CER) futures returns is -0.282 (*resp.* -0.216) reflecting a clear left-side feature. The kurtosis of the EUA (*resp.* CER) futures returns is on average 5.181 (*resp.* 5.611) higher than 3, indicating a clear departure from the normal distribution that is confirmed by the Jarque Bera tests.

[Table 4 is inserted about here]

[11] We follow the rules applied by Berta et al. (2017) to correct missing data related to verified emissions and new entrants when it impacts the short positions of installations. See Berta et al. (2017) for more details.

[12] Since Bluenext closed their activities in December 2012, we use EEX spot prices between 2013 and 2015.

We then examine the possibility of cointegration between spot and futures price series.[13] As shown in Panels A and B of Table 5, the assumption of no cointegration for both EUA and CER markets is rejected according to the Johansen trace test statistics. Looking at the cointegrating vectors, we observe a long run relationship between spot and futures series i.e., futures prices contains information that can help predict the spot prices. The β estimates inform whether spot and futures price series are nearly equal over time and the basis adjustments of substitutes. When cointegration exists, the vector of adjustment coefficients α informs how quickly the EUA or CER markets adjust. Overall, we confirm the findings of Fan et al. (2014) and Bangzhu and Chevallier (2017). Bangzhu and Chevallier (2017) detect cointegration among Bluenext spot and ECX futures over the period January 2008-April 2009. Fan et al. (2013) also find cointegration between Bluenext spot and ECX futures in Phase II for CER markets.

[Table 5 is inserted about here]

There are two categories of hedge ratios that we have considered in this chapter: static (or time-invariant) and time-varying. A static hedging ratio implies that once the optimal hedging ratio is defined, the position in the futures market is constant until the end of the hedging period. A time-varying ratio may be used for the purpose of rebalancing allowed by IFRS 9, which consists of adjusting the quantities of either the hedged item or the hedging instrument.[14]

Few attempts to estimate hedge ratio have been made in the European carbon market with the noticeable exception of Fan et al. (2013) that have calculated hedge ratios and their respective performance for CER markets from 2008 to 2010. Before estimating hedge ratios, we have taken some of the EU ETS specificities into account. First, in Phase II of EU ETS, we have considered the spot contract traded on Bluenext as a proxy of the hedged instruments for the Phase II (2008-2012) during which EUAs were almost freely allocated. In Phase III, where an increasing proportion of EUAs (from 30% in 2013 to 100% in 2020) are purchased by auctions, we have studied the most liquid auction spot contract traded at EEX as a proxy of the hedged instrument since Bluenext has closed its activities in December 2012. Second, we have assumed that power companies may use either the front or the second nearest EUA (*resp.* CER) December futures traded on ECX to hedge their spot market positions. Indeed, the results of Lucia et al. (2015) suggest that the hedging demand dominates the activity of the second nearest December futures more than this of the front December futures due to the fact that speculative activity occurs mainly in the front contract. Third, we have considered that power firms trade EUA (*resp.* CER) December futures expiring at the end of the year to hedge against the price risk of buying EUA (*resp.* CER) on the spot market. This framework is consistent with the rollover hedging strategies of power firms (Schopp and Neuhoff, 2013)[15] and convenient from a reporting perspective as emissions are counted on the calendar year basis. Finally, we have supposed no daily marking-to-market, so the different estimated hedge ratios via two time-invariant (Naïve, OLS and VECM) methods and two time-varying methods (VECM GARCH and VECM GJR-GARCH) are not tailed (see Fan et al., 2013).[16]

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[13] Before using the Johansen trace test for detecting cointegration, we apply the Augmented Dickey-Fuller and Phillips-Perron unit root tests to all series. The results show that the series have a stochastic trend in their univariate time-series presentations (non-stationary), while first differences are stationary.

[14] If the position taken in the EUA or CER futures changes over time, the hedging strategy is dynamic, implying that the optimal hedge ratio is time-varying and the position in the futures market continuously rebalanced.

[15] After interviewing 13 experts and managers of power companies, Schopp and Neuhoff (2013) conclude that annual rollover strategies are largely employed to hedge long-term commitment through the purchase of EUA December futures on an annual basis.

[16] Since EUA and CER futures are affected by daily marking-to-market cash requirements, adjustments might be made as “tailing” the hedge. These adjustments reduce the size of hedge ratios especially for longer hedges.

3.2.1 Static hedging and estimation of time invariant hedge ratios

A naïve hedging model is used for comparison purposes due to its inability to be optimal. It relies on the application of a constant hedge ratio that is always equal to one because each spot contract is offset by exactly one futures contract.

Next, we run ordinary least squares (OLS) regression of the spot return on the futures return to obtain the slope coefficient that gives the value of a static optimal hedge ratio (Ederington, 1979). Based on the continuously compounded rates of return of spot and futures price series respectively, we write the following OLS model:

$$\Delta \boldsymbol{S_t} = \alpha + \beta \cdot \Delta \boldsymbol{F_t} + \mu_t \quad (1)$$

Where: ΔS_t and ΔF_t is the continuously compounded rate of return of spot and futures respectively, μ_t is the error term, $\beta = \frac{COV(\Delta S_t, \Delta F_t)}{VAR(\Delta F_t)}$ is the minimum variance (optimal) hedge ratio.

In the above OLS regression model, the arbitrage condition ties the spot and futures prices, so that they cannot drift far apart in the long run. Consequently, the OLS model is inappropriate because it ignores the existence of cointegration relationship between the spot and futures prices. Lien (2009) argues that the estimated hedge ratio will be smaller if the cointegration relationship is not taken into consideration. If spot and futures are cointegrated, an error correction term should be added to the OLS model. Thus, we consider an error correction model. First, the long-run cointegrating equation is specified as follows: $\boldsymbol{S_t} = \beta_0 + \beta_1 \cdot \boldsymbol{F_t} + \varepsilon_t$ where β_1 is the cointegrating vector and β_0 is the constant term. Inserting the lagged regression residual from the cointegration equation into the VECM, we obtain:

$$\Delta \boldsymbol{S_t} = \delta_{10} + \beta_{11} \cdot \hat{\varepsilon}_{t-1} + \sum_{j=1}^{n} \gamma_{s1i} \cdot \Delta \boldsymbol{S_{t-j}} + \sum_{i=1}^{m} \gamma_{s2i} \cdot \Delta \boldsymbol{F_{t-i}} + \mu_t^s \quad (2a)$$

$$\Delta \boldsymbol{F_t} = \delta_{20} + \beta_{21} \cdot \hat{\varepsilon}_{t-1} + \sum_{j=1}^{n} \gamma_{f1i} \cdot \Delta \boldsymbol{S_{t-j}} + \sum_{i=1}^{m} \gamma_{f1i} \cdot \Delta \boldsymbol{F_{t-i}} + \mu_t^f \quad (2b)$$

Where: δ_{10} and δ_{20} are intercepts, β_{11} and β_{21} are parameters, μ_t^s and μ_t^f are white-noise disturbance terms. $\beta_{\bullet 1} \cdot \hat{\varepsilon}_{t-1}$, is the error correction term which measures how the dependent variable (in the vector) adjusts to previous long-term disequilibrium. The coefficients δ_{11} and δ_{21} is the speed of adjustment parameters. The more negative the δ_{11} or δ_{21}, the greater the response of ΔS and ΔF to $\beta_{\bullet 1} \cdot \hat{\varepsilon}_{t-1}$, the previous periods disequilibrium.

3.2.2 Dynamic hedging and estimation of time varying hedge ratios

OLS and VECM static hedge ratios assume the error term with a mean of zero and a time-invariant variance. For a sample of limited observations, Lien (2009) demonstrates that a sufficiently large variation in the conditional variance of the futures return, favors the time-varying hedge ratio performance against this of static hedge ratio (OLS and VECM).

Furthermore, Bangzhu and Chevallier (2017) emphasise the importance of asymmetric volatility when they find negative leverage effects on the conditional volatility of EUA spot and futures between 2008 and 2009. Therefore, we consider two models which allow the second moment to be time-varying with symmetric effects (VECM GARCH model) and with asymmetric effects (VECM GJR GARCH model) on volatility. These two bivariate models require allowing the conditional variance-covariance matrix of the m-dimensional zero mean random variables ε_t, to depend on elements of the information set Ω_{t-1}.

Letting H_t, be measurable with respect to Ω_{t-1}, we allow GARCH effects in the estimation of optimal hedge ratio through the following VECM GARCH (1,1) model as specified below:

$$\boldsymbol{S}_t = \alpha_0 + \beta_0(\boldsymbol{S}_{t-1} - \lambda \boldsymbol{F}_{t-1}) + \varepsilon_{s,t} \quad (3a)$$

$$\boldsymbol{F}_t = \alpha_1 + \beta_1(\boldsymbol{S}_{t-1} - \lambda \boldsymbol{F}_{t-1}) + \varepsilon_{f,t} \quad (3b)$$

<u>Where:</u>

$$\begin{bmatrix} \varepsilon_{s,t} \\ \varepsilon_{f,t} \end{bmatrix} \| \Omega_{t-1} \sim \boldsymbol{N}(0, \boldsymbol{H}_t) \text{ and } \boldsymbol{H}_t = \begin{bmatrix} \boldsymbol{h}_{ss,t} & \boldsymbol{h}_{sf,t} \\ \boldsymbol{h}_{sf,t} & \boldsymbol{h}_{ff,t} \end{bmatrix}$$

H_t is the 2x2 variance-covariance matrix, ε_{ft} *and* ε_{st} are the vector of residuals of Eq. (3a) and Eq. (3b) and represent the residuals obtained from the spot and futures mean equations with conditional mean 0. The term $(\boldsymbol{S}_{t-1} - \lambda \boldsymbol{F}_{t-1})$ is the error correction term that represents the cointegration between the spot (S) and futures (F) series with λ as the cointegration parameter.

Then, we model the conditional covariance matrix H_t by using a BEKK parameterization to ensure a positive semi-definite conditional variance-covariance matrix in the optimisation process: a necessary condition for the estimated variance to be zero or positive. The BEKK parameterization for the VECM GARCH (1,1) model is the following:

$$\boldsymbol{H}_t = \boldsymbol{C}'\boldsymbol{C} + \boldsymbol{A}'\boldsymbol{H}_{t-1}\boldsymbol{A} + \boldsymbol{B}'\varepsilon_t \varepsilon_t' \boldsymbol{B} \quad (4)$$

We thus expand Eq. (4) in the following manner:

$$\boldsymbol{H}_t = \begin{vmatrix} \boldsymbol{h}_{ss,t} \\ \boldsymbol{h}_{sf,t} \\ \boldsymbol{h}_{ff,t} \end{vmatrix} = \begin{vmatrix} \boldsymbol{C}_{ss,t} \\ \boldsymbol{C}_{sf,t} \\ \boldsymbol{C}_{ff,t} \end{vmatrix} + \begin{vmatrix} \boldsymbol{a}_{11} & \boldsymbol{a}_{12} & \boldsymbol{a}_{13} \\ \boldsymbol{a}_{21} & \boldsymbol{a}_{22} & \boldsymbol{a}_{23} \\ \boldsymbol{a}_{31} & \boldsymbol{a}_{32} & \boldsymbol{a}_{33} \end{vmatrix} \cdot \begin{vmatrix} \varepsilon^2_{s,t-1} \\ \varepsilon_{s,t-1}\varepsilon_{f,t-1} \\ \varepsilon^2_{f,t-1} \end{vmatrix} + \begin{vmatrix} \boldsymbol{b}_{11} & \boldsymbol{b}_{12} & \boldsymbol{b}_{13} \\ \boldsymbol{b}_{21} & \boldsymbol{b}_{22} & \boldsymbol{b}_{23} \\ \boldsymbol{b}_{31} & \boldsymbol{b}_{32} & \boldsymbol{b}_{33} \end{vmatrix} \cdot \begin{vmatrix} \boldsymbol{h}_{ss,t-1} \\ \boldsymbol{h}_{sf,t-1} \\ \boldsymbol{h}_{ff,t-1} \end{vmatrix} \quad (5)$$

Here, conditional variance and covariance only depend on their own lagged squared residuals and lagged values. We use the BHHH (Berndt, Hall, Hall, Hausman) algorithm to produce the maximum likelihood parameter estimates and their corresponding asymptotic standard errors.

The symmetric VECM GARCH model incorporates a time-varying conditional covariance and variance between spot and futures prices generating more realistic time-varying hedge ratios. The time varying hedge ratio which is optimal at time t is then equal to $\boldsymbol{h}_t = \frac{\boldsymbol{h}_{sf,t}}{\boldsymbol{h}_{ff,t}}$.

To allow for asymmetric effects of negative ($\varepsilon_{i,t} < 0$) and positive ($\varepsilon_{i,t} \geq 0$) shocks on conditional variance, Glosten et al. (1993) introduced the asymmetric GJR GARCH presented below:

$$\boldsymbol{h}_t = \omega + \alpha_1 \varepsilon^2_{t-1} + \beta_1 \boldsymbol{h}_{t-1} + \gamma_1 \varepsilon^2_{t-1} \boldsymbol{I}_{t-1} \quad (6)$$

<u>Where:</u> $\boldsymbol{I}_{t-1} = \begin{Bmatrix} 1, \varepsilon_{i,t} \geq 0 \\ 1, \varepsilon_{i,t} < 0 \end{Bmatrix}$ (7)

The short-run persistence of positive shocks is given by α_1 and short-run persistence of negative shocks is given by $\alpha_1(\alpha_1 + \gamma_1)$.

Further, the VECM GJR GARCH model differs from the VECM GARCH model since the H_t variance-covariance matrix (see Eq. 5) is replaced by:

$$\boldsymbol{H}_t = \boldsymbol{C}'\boldsymbol{C} + \boldsymbol{A}'\boldsymbol{H}_{t-1}\boldsymbol{A} + \boldsymbol{B}'\varepsilon_t \varepsilon_t' \boldsymbol{B} + \boldsymbol{G}' \eta_{t-1}' \eta_{t-1} \quad (8)$$

<u>Where:</u> H_t is a linear function of its own past values and values of squared shocks while η_t accounts for asymmetry in the conditional variances. A, B, and G are matrices of coefficients, η_t is the additional quadratic form of the vector of negative return shock.

Parameter estimates of Eq. (8) are obtained by maximizing the below log-likelihood function:

$$L_t(\Theta) = -\log(2\Pi) - \frac{1}{2}\log|H_t| - \frac{1}{2}e_t'(\Theta)H_{t-1}(\Theta)e_t(\Theta) \tag{9}$$

Where: θ is the vector of all parameters, β_{ij} for i = EUA (*resp.* CER) spot and futures series, j = 1 or 2 whether it is variance or covariance respectively.

In order to maximize this log-likelihood function, we use the simplex method and the BHHH algorithm. Then, we compute the optimal time-varying hedge ratio h* as the conditional covariance between spot and futures return divided by the conditional futures return variance. Finally, we calculate the time-varying ratio at time t: $h^* = \frac{h_{sf}}{h_{ff}}$ as made previously for the symmetric VECM GARCH (1,1) model.

3.3 Assessment of hedging effectiveness

We use two risk measures to compare the effectiveness of the four above-mentioned hedge strategies. Since the basic motivation for hedging is to form a portfolio that reduces fluctuations in its value, the hedge is considered as effective as soon as a significant reduction in the portfolio variance is reported. In this respect, the first measure of hedging effectiveness used is based on the reduction in the variance of a hedged portfolio as compared with the variance of an unhedged portfolio (i.e., the unhedged spot return) (Ederington, 1979).

We begin by calculating the returns of hedged portfolios constructed from the four above mentioned models of hedge ratio estimation. The hedged portfolios are constructed every trading day and their respective returns ($R_{H,t}$) are given by :

$$R_{H,t} = (\Delta S_t) - h_t \times (\Delta F_t) \tag{10}$$

Where: h_t denotes the hedge ratio estimated at the (trading) day t according to the four models (OLS, VECM, VECM GARCH, VECM GJR GARCH), ΔF_t and ΔS_t are the changes of futures and spot series at the day t respectively.

We also construct unhedged portfolios every trading day and their respective returns ($R_{U,t}$) are therefore based on the daily spot changes.
Then, we calculate the variance of the unhedged ($R_{U,t}$) and hedged ($R_{H,t}$) portfolios as below:

$$VAR(R_{U,t}) = \sigma^2_{S,t} \tag{11}$$

$$VAR(R_{H,t}) = \sigma^2_{S,t} + h_t^2 \cdot \sigma^2_{F,t} - 2h_t \cdot \sigma_{SF,t} \tag{12}$$

Where: σ_S and σ_F are the standard deviations of spot and futures changes at day t respectively, $\sigma_{S,F,t}$ is the covariance of spot and futures changes at day t, h_t is the hedge ratio estimated from the four models (OLS, VECM, VECM GARCH, VECM GJR GARCH) at day t.

Intuitively, a smaller variance of the hedged portfolio $\mathbf{VAR(R_{H,t})}$ indicates that the hedging strategy used is better.

Next, we calculate the degree of hedging effectiveness (HE) as the percentage reduction in variance of the hedged and the unhedged portfolios as Ederington (1979) recommended:

$$\mathbf{HE_{VAR}} = \frac{\mathbf{VAR(R_{U,t}) - VAR(R_{H,t})}}{\mathbf{VAR(R_{U,t})}} = 1 - \frac{\mathbf{VAR(R_{H,t})}}{\mathbf{VAR(R_{U,t})}} \tag{13}$$

$\mathbf{HE_{VAR}}$ measures the relative reduction in variance gained by taking the optimal combined futures position (h_t) in this case. Put differently, HE_{VAR} estimates the greatest degree of risk reduction attainable if h_t is selected. However, it does not reveal the extent to which the user actually reduces risk toward the minimum achievable.

The second hedging effectiveness measure that we have used is the Value at Risk (VaR) measure previously applied to the EUA Phase II futures by Philip and Shi (2016). In fact, Harris and Shen (2006) demonstrate that the minimum-variance hedging reduces the standard deviation of portfolio returns but also increases simultaneously the portfolio kurtosis and the effectiveness of hedging compared to VaR. Based on the demonstration made by Harris and Shen (2006), we employ the minimum-VaR measure that minimizes the historical VaR of the hedged portfolio as an alternative to the minimum-variance measure seen before.

Assuming the hedged portfolio return is normally distributed, we write the VaR of the hedged portfolio at a confidence level α similar to Philip and Shi (2016) as below :

$$\boldsymbol{VaR} = \boldsymbol{V}_0 \times \left[\boldsymbol{E}\left(\boldsymbol{R}_{H,t}\right) + z_\alpha \sqrt{\boldsymbol{VAR}(\boldsymbol{R}_{H,t})} \right] \tag{14}$$

Where: $\mathbf{V_0}$ is the initial wealth of the portfolio (in Euros), $\mathbf{E(R_{H,t})}$ is the expected return (or loss) of the hedged portfolio given a (variance) risk : $\mathbf{VAR(R_{H,t})}$ and z_α denotes the quantile of the normal distribution at α.

Intuitively, a smaller VaR exposure of the hedged portfolio signals a better hedging strategy. We consider here a portfolio with an initial value of 100 million euros and a 95% confidence level under which a power firm using carbon hedge strategies would expect losses in excess of the VaR to occur. Then, we estimate the VaR is the value-at-risk figure with z_α equals to the normal distribution 5% quantile value (consistent with a 95% confidence level).

After proceeding similarly to calculate the VaR of the unhedged portfolio, we compute the percentage reduction in VaR that serves as a second measure of hedge effectiveness such that:

$$\mathbf{HE_{VaR}} = \frac{\mathbf{VaR(R_{U,t}) - VaR(R_{H,t})}}{\mathbf{VaR(R_{U,t})}} = \mathbf{1} - \frac{\mathbf{VaR(R_{H,t})}}{\mathbf{VaR(R_{U,t})}} \tag{15}$$

4 Empirical results and impact assessment

4.1 Values of hedging ratios

Table 6 presents the optimal hedge ratios that are estimated with the methods discussed above: naïve, OLS, VECM, VECM GARCH and VECM GJR GARCH using the front and the second nearest EUA or CER December futures contracts.

As can be seen from Panels A and B of Table 6, the estimated hedge ratios differ from year to year and from model to model both for the EUA and the CER markets. First, the value of hedge ratios for the VECM and VECM GARCH are very similar in most cases. This result is not surprising since these models share the same error correction fundamentals. Besides, the difference of values is greater once asymmetries in return distribution are taken into account with the GJR GARCH model. This difference may induce significant impact on hedge ratio performance assessment, as hedge ratios are important inputs for the hedging effectiveness estimation. Second, both time-invariant and time-varying hedge ratios diminish over the period 2013-2015 compared to Phase II (2008-2012). We can explain this result by the higher variance of EUA and CER futures price variations observed in Phase III.[17]

Interestingly, the significant variance of EUA and CER futures has led to lower the values of hedge ratios, which fall outside the range 80-125% required by IAS 39 from 2012. However, this authorised range does not exist in IFRS 9 and the hedge relationship could be verified provided that the economic justification is provided.

[Table 6 is inserted about here]

[17] Since the optimal hedge ratio is obtained by dividing the covariance between spot and futures returns by the variance of the futures return, any impact on the variance of the futures returns will affect the value of hedge ratios.

4.2 *Results of hedging effectiveness assessment*

In view of a wide range of static and dynamic hedge ratios that power companies can apply, it is now important to assess their performance in terms of hedging effectiveness.

Table 7 reports how effective Naïve, OLS, VECM, VECM-GARCH and VECM GJR GARCH models are in terms of variance or VaR reduction for EUA and CER front December futures.[18] If all models achieve an important level of variance reduction, the VECM GJR GARCH outperforms the other models. Given the reaction of financial markets to news and the corresponding need to adjust off-setting hedges, this result appears to be obvious, consistent with Brooks et al. (2002) who find that GARCH hedge models that consider asymmetries in returns (e.g., GJR GARCH) better perform when applied to commodity derivatives.

Quite importantly, the measures of hedging effectiveness based on the reduction of variance (**HE$_{VAR}$**) exhibit a significantly declining trend from 2013 to 2015. For example, applying the VECM GJR GARCH model generates a risk reduction for the EUA portfolio of 94.28% in 2013 compared to 86.44% in 2015. It is noteworthy that a similar declining trend is observed in CER markets in line with Fan et al. (2013) results. Notwithstanding this evolution, this first set of results confirms that the potential of hedging effectiveness remains strong for both EUA and CER hedged portfolios.

For a portfolio of carbon assets with an initial value of 100 million euros and assuming a 1-year hedging horizon, the VaR exposure averaged over the period 2008-2015 is 447 972 euros (*resp.* 698 619 euros) for EUA (*resp.* CER) markets when the VECM GJR GARCH hedge model is applied, which is a decrease of 73 890 (*resp.* 36 903) euros as compared to the VaR exposure related to the OLS hedge model. Overall, our results confirm that rebalancing EUA and CER portfolios according to time varying hedge ratios (VECM GARCH and VECM GJR GARCH) offer more significant risk reductions in terms of VaR exposure. In addition, we note that the measures of hedging effectiveness based on the reduction of the value at risk (**HE$_{VaR}$**) are lower in Phase III for both EUA and CER futures. For instance, applying the VECM GJR GARCH model leads to a risk reduction for the EUA hedged portfolio of 92.02% in 2012 while it offers a risk reduction of 79.33% in 2015.

[Table 7 is inserted about here]

4.3 *Effects of IFRS 9 hedge accounting on financial statements according to IFRS 7*

The disclosure requirements for firms applying hedge accounting under IFRS 9 are detailed in IFRS 7. These requirements imply that firms shall disclose information about:

- The risk management strategy and how it is applied to manage risks;
- How the risk management activities may affect the amount, timing and uncertainty of future cash flows;
- The effect that hedge accounting has had on the statement of financial position, the statement of comprehensive income and the statement of changes in equity.

The firm's hedges qualified under IFRS 9 should be presented either in a note or in a separate section in the financial statements. As shown in Table 8, those disclosures are extensive and consistent with the aim that hedge accounting reflects the firm's risk management activities. Firms are intended to describe every qualified hedge under IFRS 9 by type of managed risks (e.g., commodity risk), this description must include how each risk arises and how and to what extent the risk is managed. To this end, firms should assess the appropriate level of detail, the balance between different disclosure requirements, and the need to bring further explanations.

[Table 8 is inserted about here]

[18] The hedge effectiveness percentages estimated from the second nearest EUA and CER December futures are very similar to those estimated from the front EUA and CER December futures both in Phase II and III.

For the sake of illustration, we present in the following paragraphs, a case study describing all reporting implications for a non-financial firm: Alpha that reports carbon hedges in its financial statements according to IFRS 7 disclosures. Alpha is a power firm that holds a coal-fired and a gas-fired installation to produce electricity. Alpha sells its electricity production through a variety of supply contracts which are priced using two specific formulas: (1) **the clean spark spread** expressed in €/MWh, that represents the net revenue a gas-fired installation makes from selling power, having bought gas and the required number of EUAs; (2) **the clean dark spread** expressed in €/MWh, that represents the net revenue a coal-fired installation makes from selling power, having bought coal and the required number of EUAs.

The market risk for Alpha mainly arises from the fluctuations of commodity prices. Alpha has established guidelines for entering into contractual arrangements (i.e., derivatives that are priced according to pricing benchmarks) in order to manage its commodity price risks on a mid-term basis. Notably, Alpha forecasts its volume of expected carbon emissions for a period of 18 months and manages carbon price risk exposure on a 12-month rolling basis. Alpha's risk management strategy includes 100% hedging of its exposure to EUA carbon price risks related to its electricity production. Hence, Alpha determines a carbon price exposure that is separately identifiable and reliably measurable. This exposure is an eligible risk component for designation as a hedged item. Put differently, the underlying risk of the EUA futures contracts is here identical to the hedged risk component (i.e., the EUA benchmark price).

In January 2013, the treasurer of Alpha anticipates a higher carbon price risk exposure because of the gradual abandonment of free EUAs in Phase III. Therefore, he buys a large amount of 100,000 December 2013 futures contracts valued at 10 euros each to purchase EUA assuming that Alpha hedges a forecasted EUA consumption with an EUA futures contract. The amount of this hedging instrument is reported in Fig. 2 according to the format of Paragraph 24A of IFRS 7 in the Statement of Financial Position of Alpha as of 31 December 2013**.**

Alpha has previously established a hedge ratio of 0.75:1 for its hedging relationship. Alpha's exposure to the variability in the purchase price of EUA is integrated into its general risk management strategy and its decision to switch from coal hired installations to gas hired installations (*resp.* or vice versa) on the basis of clean spark (*resp.* dark) spread.

[Fig. 2 is inserted about here]

Next, we look in Fig. 3 at what happens when the correlation between the hedged item (i.e., EUA) and the hedging instrument (i.e., EUA futures) changes from 100% to 95% under IAS 39 vs IFRS 9. Under IAS 39, a hedge relationship has to be discontinued if the hedge ratio falls outside the 80-125% boundaries. Given that 75% is outside these boundaries, the full amount of line 1 *IAS 39*'s hedging instrument is reported in the P&L account. By contrast, IFRS 9 does not impose such boundaries but allows rebalancing to avoid hedge discontinuation.

If Alpha opts for maintaining its hedge ratio constant (see line 2 *IFRS 9 without rebalance*), 1,000,000 euros are recorded in the OCI and 250,000 euros of hedge ineffectiveness are recognized in the P&L account.

If Alpha decides to rebalance the hedge relationship by increasing the volume of the hedged item by 5%, the hedge ratio changes from 75% to 75%/ (100 +5%×100) =71.4%. Hence, the over hedge between the hedged item and the hedging instrument is 300,000 reported in the P&L account while the augmented amount, 1,050,000 = 1,000,000 × (100 +5%×100) is recognized in the OCI as shown in line 3 *IFRS 9 with rebalance*.

[Fig. 3 is inserted about here]

As a result, the modified hedging relationship involves reclassification of 50,000 euros from the cash flow hedge reserve of the OCI to the P&L account. As shown in Fig. 4, this change must be reported according to the indications given by Paragraph 24B of IFRS 7.

[Fig. 4 is inserted about here]

5 Conclusion

The increasing importance of commodity derivatives and related hedges presents a number of challenges not only for corporate treasurers but also for accountants (Gumb et al., 2018). These challenges have incited accounting bodies to produce a regulatory framework defined in FAS 133 for the US-GAAP and in IFRS 9 for the IASB. If for instance IFRS 9 requires derivatives to be reported at fair value on the balance sheet, it also allows for derivatives to be reported as part of a hedge by firms in order to avoid an increase in their earnings' volatility due to changes in derivatives' market values. This hedge accounting treatment is generally preferred by investors and shareholders since it better reflects the economic objectives of the hedge. Furthermore, failure to qualify for hedge accounting can have tax consequences (DeMarzo and Duffie, 1995).

This chapter examines the pertinence of the IFRS 9 hedge accounting requirements from the relatively unexplored perspective of commodity derivatives. We notably consider the particularly interesting case of the European carbon derivatives. In fact, European power firms use them to hedge their exposure to risks associated with carbon emission compliance costs (Schopp and Neuhoff, 2013). As the Task Force on Climate-related Financial Disclosures of the Financial Stability Board (FSB) has underlined, the impacts of climate change may not be correctly priced without accountability of carbon emissions and related price risks (FSB, 2017). Nonetheless, the absence of a commonly accepted accounting standard has led to the use of various methods to report carbon derivatives. If it raises doubts about the comparability of their financial statements, the ability to inform on their risk management strategies and their cost of complying with EU ETS obligations is also hindered. To overcome these two issues, two professional organisations, CDSB and IETA, have recommended that the IFRS 9 requirements should be applied to account for EUA or CER derivatives (CDSB and IETA, 2013).

Following this recommendation, our prospective study complements the study of Haupt and Ismer (2013) by showing the relevance of the IFRS 9 requirements for European power firms to report carbon derivatives for three main reasons. A first reason is the removal of the arbitrary 80-125% boundaries for hedge ratios. A second reason is the abandonment of retrospective tests to assess hedging effectiveness required by IAS 39.[19] Instead, the hedge effectiveness tests are only prospective. A third reason is that IFRS 9 allows corporates to maintain their hedges by means of rebalancing without discontinuing the hedging relationship.

By adopting IFRS 9, European power firms should provide more relevant balance sheet and P&L information through the OCI when reporting EUA and CER futures hedging positions. Furthermore, applying the hedge accounting requirements of IFRS 9 allows these firms to reduce the volatility in their earnings if they had applied the fair value approach.

We also contribute to the empirical literature on carbon markets in four directions. First, we compare relevant methods to assess static and time-varying hedge ratios and associated hedging effectiveness. We find that the estimated hedge ratios sometimes fall outside the range of 80%-125% boundaries in Phase III especially for the case of less liquid CER markets, confirming the relevance of IFRS 9 abandoning these boundaries. Second, we provide evidence of the superiority of time-varying carbon hedges that may be used in the context of rebalancing. Third, we show that the associated hedging effectiveness measured by variance reduction and VaR are noteworthy and may help companies to monitor continuously their carbon hedging strategies. Taken together, our findings confirm the relevance of the IFRS 9 requirements to account for carbon hedges using EUA and CER derivatives, which are increasingly important for power firms since they have received less and less free EUAs since 2013.

[19] The prospective (*resp.* retrospective) hedge effectiveness test is a forward-looking (*resp.* backward-looking) evaluation of whether or not the changes in the fair value or cash flows of the hedging item are expected to be highly effective in offsetting the changes in the fair value or cash flows of the hedged item over the term of the relationship (*resp.* since the date of designation).

Finally, we provide a case study with a given power firm to illustrate how it can use IFRS 7 disclosure requirements to report carbon hedges using EUA derivatives in its financial statements provided that the IFRS 9 requirements have been met.

Two avenues for further research may be considered. On the one hand, other energy derivatives could be incorporated into global commodity portfolios including carbon futures (Kleindorfer and Li, 2011) to test the appropriateness of the macro hedging accounting that could be proposed under IFRS 9.[20] On the other hand, the European Market Infrastructure Regulation (REMIT), a chapter of Mifid that has been recently adopted, imposes the centralised settlement and reporting of all traded energy derivatives including carbon derivatives. The analysis of potential synergies between the provision of REMIT and IFRS 9 information, which can reduce the costs of the implementation of IFRS 9 for power firms, is left for future work.

[20] The IASB issued a discussion paper on 'Accounting for dynamic risk management: a portfolio revaluation approach to macro hedging' in April 2014 (IASB, 2014). After having received comments of experts, the IASB expects to release the core IFRS 9 model of macro hedging by the second half of the year 2019.

6 References

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Table 1. Advantages and disadvantages of IFRS 9 hedge accounting requirements

ADVANTAGES	DISADVANTAGES
• More opportunities to use hedge accounting: - Ability to designate non-financial risk components to be hedged; - More flexibility to hedge group of items; - Increased ability to hedge items; • Reduction of costs and effort to assess hedge effectiveness through the abandonment of the 80-125% retrospective tests; • Introduction of fair value option for credit risk (removes accounting mismatch); • New accounting treatments of time value of options and futures/forward contracts reduce the income statement volatility.	• Impossible to discontinue hedge accounting on a voluntary basis; • Need to rebalance continuously the hedge ratio when hedge effectiveness is too low; • Cost and effort of measuring hedge effectiveness can remain important for small and mid-sized companies (albeit reduced).

Table 2. Theoretical carbon hedging needs of the power sector per country (in volume and in value)

		PHASE II (2008-12)		**PHASE III (2013-15)**	
Country	Number of installations	Annual volume (*in million tC02eq*)	Annual value (*in € million)*	Annual volume (*in million tC02eq*)	Annual value (*in € million)*
Austria	99	0.064	0.908	4.071	28.497
Belgium	217	4.444	62.21	12.211	85.474
Bulgaria	70	(0.209)	Long Position	16.299	114.095
Croatia	25	N/A	N/A	2.793	19.551
Czech Republic	166	(6.033)	Long Position	21.829	152.807
Denmark	335	0.308	4.314	7.822	54.751
Estonia	42	0.508	7.122	6.734	47.136
Finland	121	(0.545)	Long Position	2.761	19.325
France	816	9.869	138.165	25.004	175.025
Germany	1117	90.557	1 267.795	309.213	2 164.489
Greece	63	3.952	55.34	38.001	266.009
Hungary	140	0.275	3.845	8.839	61.87
Ireland	93	(1.046)	Long Position	11.839	82.875
Italy	270	1.897	26.564	18.751	131.257
Latvia	8	(0.053)	Long Position	(0.028)	Long Position
Lithuania	83	(1.163)	Long Position	(0.671)	Long Position
Luxembourg	12	(0.155)	Long Position	0.293	2.049
Netherlands	287	5.255	73.57	44.039	308.277
Poland	487	(1.234)	Long Position	93.827	656.788
Portugal	97	(2.170)	Long Position	14.153	99.073
Romania	138	(7.191)	Long Position	11.163	78.143
Slovakia	119	(7.242)	Long Position	6.276	43.933
Slovenia	47	0.162	2.262	4.432	31.024
Spain	497	10.898	152.573	66.51	465.546
Sweden	690	3.554	49.763	(1.923)	Long Position
United Kingdom	551	16.249	227.484	78.64	550.467
Total	**6 591**	**120.951**	**1 416.981**	**802.878**	**5 638.461**

Note: 'Long Position' indicates that the company has a theoretical surplus of EUAs to cover their emissions. If not, the country has a 'short position' and figures express a negative difference between the amount of EUAs/CERs held and this of verified emissions observed. 'N/A' means that data is not available**.**

Table 3. Theoretical carbon hedging needs of the most representative power companies (in value)

COMPANY	Country	Number of installations	Hedging needs averaged over the period 2008-12[1] (*in € million*)	Hedging needs averaged over the period 2013-15[2] (*in € million*)	Δ
BEH	Bulgaria	11	23.472	117.707	+401%
BRITISH ENERGY	United Kingdom	11	100.270	128.869	+29%
CEZ	Czech Republic	19	Long Position	117.478	N/S
DRAX	United Kingdom	7	171.354	104.258	-39%
EAST ENERGIA	Italy	1	0.237	0.199	-16%
EDF	France	52	25.042	181.456	+625%
EDP	Spain	1	6.637	2.279	-66%
EDISON	Italy	14	17.880	31.390	+76%
ENDESA	Spain	16	83.511	162.585	+95%
ENEL	Italy	36	69.125	256.520	+271%
EON	Germany	85	34.976	0.904	-97%
ESSENT	Netherlands	11	3.100	48.074	+1451%
GROSSKRAFT WERK	Germany	1	8.112	44.127	+444%
IBERDROLA	Spain	18	13.419	15.329	+14%
NUON	Netherlands	16	62.443	72.997	+17%
PPC	Slovakia	2	Long Position	Long Position	N/S
PGE	Poland	11	69.690	397.002	+470%
RWE	Germany	51	684.947	852.473	+24%
TAURON	Poland	15	6.317	100.963	+1498%
Average annual value of hedging needs per company			81.208	146.367	+80.2%

[1] The amount of hedging needs has been estimated on the basis of a mean spot price of €14 per missing EUA (=1t$C0_{2eq}$)
[2] The amount of hedging needs has been estimated on the basis of a mean spot price of €7 per missing EUA (=1t$C0_{2eq}$)

Note: 'Long Position' indicates that the company has a theoretical surplus of EUAs to cover their emissions. If not, the company has a 'short position' and figures express a negative difference between the amount of EUAs/CERs held and this of verified emissions observed. 'N/S' means Non Significant, 'N/A' means that data is not available.

Table 4. Descriptive statistics of the EUA and the CER spot and futures series

Panel A: EUA (average continuously compounded rate of returns: spot and futures)

	Mean	**Median**	**Max.**	**Min.**	**St. Dev.**	**Skewness**	**Kurtosis**	**Jarque-Bera**	**Prob.**
Bluenext Spot *(2008-2012)*	-0.0042	-0.0041	0.7462	-0.4113	0.215	-0.402	4.736	11.89	0.000
EEX Auction Spot *(2013-2015)*	0.0012	0.0011	0.7506	-0.3303	0.266	-0.531	6.355	15.21	0.000
ECX December Futures	-0.0039	-0.0033	0.7784	-0.3424	0.194	-0.282	5.181	8.16	0.01

Panel B: CER (average continuously compounded rate of returns: spot and futures)

	Mean	**Median**	**Max.**	**Min.**	**St. Dev.**	**Skewness**	**Kurtosis**	**Jarque-Bera**	**Prob.**
Bluenext Spot *(2009-2013)*	-0.0041	-0.0043	0.8453	-0.4215	0.423	-0.424	5.339	13.04	0.000
EEX Auction Spot *(2013-2015)*	-0.0019	- 0.002	0.6871	-0.3875	0.398	-0.497	6.012	14.91	0.000
ECX December Futures	-0.044	-0.0034	0.86	-0.0117	0.233	-0.316	5.611	8.85	0.008

Table 5. Cointegration tests of spot and futures price series

Panel A: EUA (average Phase II: 2008-2012 and average Phase III: 2013-2015)

	H_0	H_1	VAR lag	Trace	Normalized Cointegrating Vectors (α ; β)
Spot/Futures Phase II	r = 0	r > 0	2	223.55*	Futures (**α** = - 0,239* ; **β** = 1,000)
(*2008-12*)	r ≤ 1	r > 1		3.855*	Spot (**α** = - 0,109 ; **β** = 1,003*)
Spot/Futures Phase III	r = 0	r > 0	2	181.22*	Futures (**α** = - 0,206* ; **β** = 1,000)
(2013-15)	r ≤ 1	r > 1		3.647*	Spot (**α** = - 0,092 ; **β** = 1,002*)

Panel B: CER (average Phase II: 2009-2012 and average Phase III: 2013-2015)

	H_0	H_1	VAR lag	Trace	Normalized Cointegrating Vectors (α ; β)
Spot/Futures Phase II	r = 0	r > 0	2	183.70*	Futures (**α** = -0,210* ; **β** = 1,000)
(*2009-12*)	r ≤ 1	r > 1		3.288*	Spot (**α** = -0,095 ; **β** = 1,002*)
Spot/Futures Phase III	r = 0	r > 0	2	141.19*	Futures (**α** = 0,160 ; **β** = 1,000)
(2013-15)	r ≤ 1	r > 1		1.747	Spot (**α** = 0,084 ; **β** = - 1,023*)

Note: We apply the Schwartz Information Criterion (SIC) to select optimal 'Lag' length of the unrestricted VAR model in levels. The null hypothesis (**H_0**) of trace statistics tests if the number of cointegrating vectors is less than or equal to r. **α, β** are the normalized cointegration vector of spot and futures price series.
* Indicates if they are significant at the 95% confidence level based on the calculated p-values.

Table 6. Estimation results of optimal (minimum variance) hedge ratios

Panel A: Hedge ratios when EUA (*resp.* EUA futures) is the hedged item (*resp.* hedging instrument)

Hedging Horizon	*Contract*	Naïve	OLS	VECM	VECM GARCH	VECM GJR GARCH
2008	*Dec-08*	100%	82.28%	82.27%	82.18%	82.11%
	Dec-09	100%	76.34%	77.87%	78.18%	78.09%
2009	*Dec-09*	100%	83.19%	83.12%	82.93%	83.03%
	Dec-10	100%	81.38%	78.02%	77.48%	77.97%
2010	*Dec-10*	100%	81.21%	81.57%	81.54%	81.51%
	Dec-11	100%	79.67%	79.18%	79.59%	79.03%
2011	*Dec-11*	100%	77.18%	76.19%	76.35%	78.61%
	Dec-12	100%	73.43%	72.46%	73.01%	75.02%
2012	*Dec-12*	100%	76.54%	75.34%	76.88%	78.97%
	Dec-13	100%	72.98%	72.35%	72.76%	74.55%
2013	*Dec-13*	100%	72.12%	71.24%	72.01%	71.91%
	Dec-14	100%	67.28%	66.67%	67.42%	67.57%
2014	*Dec-14*	100%	68.31%	66.92%	66.95%	67.06%
	Dec-15	100%	66.78%	66.11%	66.78%	66.89%
2015	*Dec-15*	100%	69.92%	68.45%	69.98%	70.11%
	Dec-16	100%	67.92%	67.19%	67.74%	68.87%

Panel B: Hedge ratios when CER (*resp.* CER futures) is the hedged item (*resp.* hedging instrument)

Hedging Horizon	*Contract*	Naïve	OLS	VECM	VECM GARCH	VECM GJR GARCH
2009	*Dec-09*	100%	82.34%	82.27%	82.25%	82.31%
	Dec-10	100%	75.67%	75.94%	76.02%	76.67%
2010	*Dec-10*	100%	85.11%	84.52%	84.54%	84.49%
	Dec-11	100%	80.54%	79.97%	80.02%	80.13%
2011	*Dec-11*	100%	79.18%	79.03%	79.01%	78.71%
	Dec-12	100%	75.56%	75.90%	76.28%	76.12%
2012	*Dec-12*	100%	72.76%	72.34%	72.20%	72.30%
	Dec-13	100%	69.20%	69.06%	69.18%	69.40%
2013	*Dec-13*	100%	70.87%	70.76%	70.83%	71.25%
	Dec-14	100%	67.75%	67.45%	67.58%	68.16%
2014	*Dec-14*	100%	67.95%	67.82%	67.88%	68.69%
	Dec-15	100%	65.59%	65.22%	65.79%	66.78%
2015	*Dec-15*	100%	67.89%	67.98%	67.69%	68.02%
	Dec-16	100%	65.74%	66.11%	65.90%	66.57%

Table 7. Assessment of hedging effectiveness from the hedge ratios estimated in Table 6 with the front-end December futures contract

Panel A: Variance reduction and VaR measures when EUA (*resp.* EUA futures) is the hedged item (*resp.* hedging instrument)

Hedging horizon	Futures	Variance (VAR) Hedged	Naïve	OLS	VECM	VECM GARCH	VECM GJR GARCH	Value at Risk (VaR) hedged	Naïve	OLS	VECM	VECM GARCH	VECM GJR GARCH
2008	*Dec-08*	*VAR Unhedged = 0.1285*	**0.0171**	**0.0164**	**0.0163**	**0.0162**	**0.0158**	*VaR Unhedged = 2 679 760€*	**768 021€**	**767 220€**	**758 645€**	**747 650€**	**636 447€**
		HE_{VAR}	**85.91%**	**87.28%**	**87.12%**	**87.59%**	**87.71%**	**HE_{VaR}**	**71.34%**	**71.37%**	**71.69%**	**72.10%**	**76.25%**
2009	*Dec-09*	*VAR Unhedged = 0.0795*	**0.0104**	**0.0094**	**0.0094**	**0.0087**	**0.0091**	*VaR Unhedged = 2 359 711€*	**542 501€**	**541 792€**	**492 005€**	**494 600€**	**456 373€**
		HE_{VAR}	**87.48%**	**88.25%**	**88.19%**	**89.07%**	**88.68%**	**HE_{VaR}**	**77.01%**	**77.04%**	**79.15%**	**79.04%**	**80.66%**
2010	*Dec-10*	*VAR Unhedged = 0.0448*	**0.0066**	**0.0048**	**0.0045**	**0.0046**	**0.0042**	*VaR Unhedged = 2 228 223€*	**599 174€**	**596 943€**	**510 263€**	**424 924€**	**434 057€**
		HE_{VAR}	**85.34%**	**89.40%**	**89.96%**	**91.29%**	**92.19%**	**HE_{VaR}**	**73.11%**	**73.21%**	**77.10%**	**80.93%**	**80.52%**
2011	*Dec-11*	*VAR Unhedged = 0.0349*	**0.00515**	**0.00475**	**0.00465**	**0.00467**	**0.00425**	*VaR Unhedged = 2 054 353€*	**452 375€**	**401 214€**	**441 072€**	**380 678€**	**331 576€**
		HE_{VAR}	**79.54%**	**86.41%**	**86.78%**	**87.84%**	**91.85%**	**HE_{VaR}**	**77.98%**	**80.47%**	**78.53%**	**81.47%**	**83.86%**
2012	*Dec-12*	*VAR Unhedged = 0.0332*	**0.004**	**0.0041**	**0.003**	**0.0022**	**0.0021**	*VaR Unhedged = 2 070 372€*	**531 266€**	**467 905€**	**525 258€**	**380 331€**	**372 256€**
		HE_{VAR}	**75.90%**	**87.56%**	**90.99%**	**93.43%**	**94.28%**	**HE_{VaR}**	**74.34%**	**77.40%**	**74.63%**	**81.63%**	**82.02%**
2013	*Dec-13*	*VAR Unhedged = 0.0343*	**0.00505**	**0.0042**	**0.0041**	**0.0023**	**0.0025**	*VaR Unhedged = 2 046 231€*	**484 963€**	**475 340€**	**472 886€**	**467 566€**	**455 080€**
		HE_{VAR}	**77.26%**	**87.67%**	**88.08%**	**90.44%**	**92.71%**	**HE_{VaR}**	**76.30%**	**76.77%**	**76.89%**	**77.15%**	**77.76%**
2014	*Dec-14*	*VAR Unhedged = 0.0398*	**0.0065**	**0.0064**	**0.0063**	**0.0062**	**0.0059**	*VaR Unhedged = 2 222 230€*	**454 452€**	**411 113€**	**412 008€**	**441 119€**	**398 892€**
		HE_{VAR}	**76.13%**	**84.35%**	**84.37%**	**84.60%**	**86.68%**	**HE_{VaR}**	**79.55%**	**81.50%**	**81.46%**	**80.15%**	**82.05%**
2015	*Dec-15*	*VAR Unhedged = 0.0435*	**0.0078**	**0.0077**	**0.0076**	**0.0074**	**0.0079**	*VaR Unhedged = 2 414 685€*	**560 218€**	**513 368€**	**516 027€**	**522 789€**	**499 097€**
		HE_{VAR}	**74.18%**	**82.74%**	**82.76%**	**82.97%**	**86.44%**	**HE_{VaR}**	**76.80%**	**78.74%**	**78.63%**	**78.35%**	**79.33%**

Panel B: Variance reduction and VaR measures when CER (*resp.* CER futures) is the hedged item (*resp.* hedging instrument)

Hedging horizon	Futures	Variance (VAR) Hedged	Naïve	OLS	VECM	VECM GARCH	VECM GJR GARCH	Value at Risk (VaR) hedged	Naïve	OLS	VECM	VECM GARCH	VECM GJR GARCH
2009	*Dec-09*	*VAR Unhedged = 0.0811*	**0.0115**	**0.0109**	**0.011**	**0.0103**	**0.0112**	*VaR Unhedged= 2 656 190€*	**521 945€**	**513 974€**	**559 662€**	**526 193€**	**510 520€**
		HE_{VAR}	**85.76%**	**86.56%**	**86.44%**	**87.30%**	**86.07%**	**HE_{VaR}**	**80.35%**	**80.65%**	**78.93%**	**80.19%**	**80.78%**
2010	*Dec-10*	*VAR Unhedged =0.0458*	**0.0076**	**0.0051**	**0.0055**	**0.0056**	**0.0051**	*VaR Unhedged= 2 620 772€*	**682 972€**	**665 156€**	**653 623€**	**631 871€**	**579 190€**
		HE_{VAR}	**83.41%**	**88.86%**	**87.99%**	**87.77%**	**89.30%**	**HE_{VaR}**	**73.94%**	**74.62%**	**75.06%**	**75.89%**	**77.90%**
2011	*Dec-11*	*VAR Unhedged =0.0371*	**0.0063**	**0.0059**	**0.0038**	**0.0032**	**0.0029**	*VaR Unhedged= 2 365 625€*	**559 475€**	**538 423€**	**528 244€**	**511 455€**	**488 976€**
		HE_{VAR}	**83.02%**	**84.10%**	**89.76%**	**91.37%**	**93.80%**	**HE_{VaR}**	**76.35%**	**77.24%**	**77.67%**	**78.38%**	**79.33%**
2012	*Dec-12*	*VAR Unhedged =0.0382*	**0.0067**	**0.0065**	**0.006**	**0.0056**	**0.0058**	*VaR Unhedged= 2 477 611€*	**634 279€**	**609 995€**	**637 988€**	**631 057€**	**584 475€**
		HE_{VAR}	**77.22%**	**82.98%**	**84.29%**	**85.34%**	**84.55%**	**HE_{VaR}**	**74.40%**	**75.38%**	**74.25%**	**74.53%**	**76.41%**
2013	*Dec-13*	*VAR Unhedged = 0.0496*	**0.0081**	**0.0073**	**0.0071**	**0.0072**	**0.0062**	*VaR Unhedged= 2 861 010€*	**907 237€**	**867 746€**	**864 601€**	**861 169€**	**850 016€**
		HE_{VAR}	**81.65%**	**85.28%**	**85.69%**	**85.48%**	**88.91%**	**HE_{VaR}**	**68.29%**	**69.67%**	**69.78%**	**69.90%**	**70.29%**
2014	*Dec-14*	*VAR Unhedged = 0.0478*	**0.0081**	**0.0077**	**0.0066**	**0.0061**	**0.0057**	*VaR Unhedged= 2 828 496€*	**953 209€**	**897 202€**	**905 401€**	**912 753€**	**866 085€**
		HE_{VAR}	**74.69%**	**83.89%**	**86.19%**	**87.24%**	**88.49%**	**HE_{VaR}**	**66.30%**	**68.28%**	**67.99%**	**67.73%**	**69.38%**
2015	*Dec-15*	*VAR Unhedged = 0.0482*	**0.0104**	**0.0096**	**0.0088**	**0.0073**	**0.0069**	*VaR Unhedged= 3 088 185€*	**1 167 338€**	**1 056 160€**	**1 102 482€**	**1 110 827€**	**1 011 072€**
		HE_{VAR}	**70.12%**	**79.05%**	**81.33%**	**86.93%**	**88.38%**	**HE_{VaR}**	**62.20%**	**65.80%**	**64.30%**	**64.03%**	**67.26%**

Note: The variance and the VaR of the EUA (*resp.* CER) hedged or unhedged portfolios are calculated along a one year hedge horizon using the EUA (*resp.* CER) front-end December futures contract. The variance reduction denoted **HE_{VAR}** is computed according to the Eq. (13) and given the hedge ratios estimated in Table 6. The reduction of the Value at Risk denoted **HE_{VaR}** is calculated according to the Eq. (15) and given the hedge ratios estimated in Table 6.

Table 8. Disclosure requirements

Category	Comments/goals
• The firm's risk management strategy and how this strategy is applied to manage risk?	Information disclosed about a firm's risk management strategy should help users of financial instruments to assess: - How each risk appears; - How the firm manages each risk i.e., whether it fully hedges an item for all risks or hedges a risk component(s) of an item; - The extent of risk exposures that the firm manages.
• How the firm's hedging activities may affect the amount, timing and uncertainty of its future cash flows?	• Firms must provide a breakdown that discloses the following: - The monetary amount or quantity (e.g., tCO_{2eq} emitted for power firms) to which the firm is exposed for each risk; - The amount or quantity of the risk exposure being hedged; - How firm hedging modifies quantitatively the exposure; - For each category of risk, a description of the sources of hedge ineffectiveness needs to be disclosed.
• How does the hedge accounting influence the financial statements including the Statement of Financial Position, the Statement of Other Comprehensive Income (OCI) and the Statement of Changes in Equity of the firm?	• Both the carrying and notional amounts related to the hedging instruments, accumulated gains or losses on hedged items, must be disclosed, in a tabular format, by risk category for each type of hedge (i.e., fair value hedge, cash flow hedge, hedge of a net investment in a foreign operation).

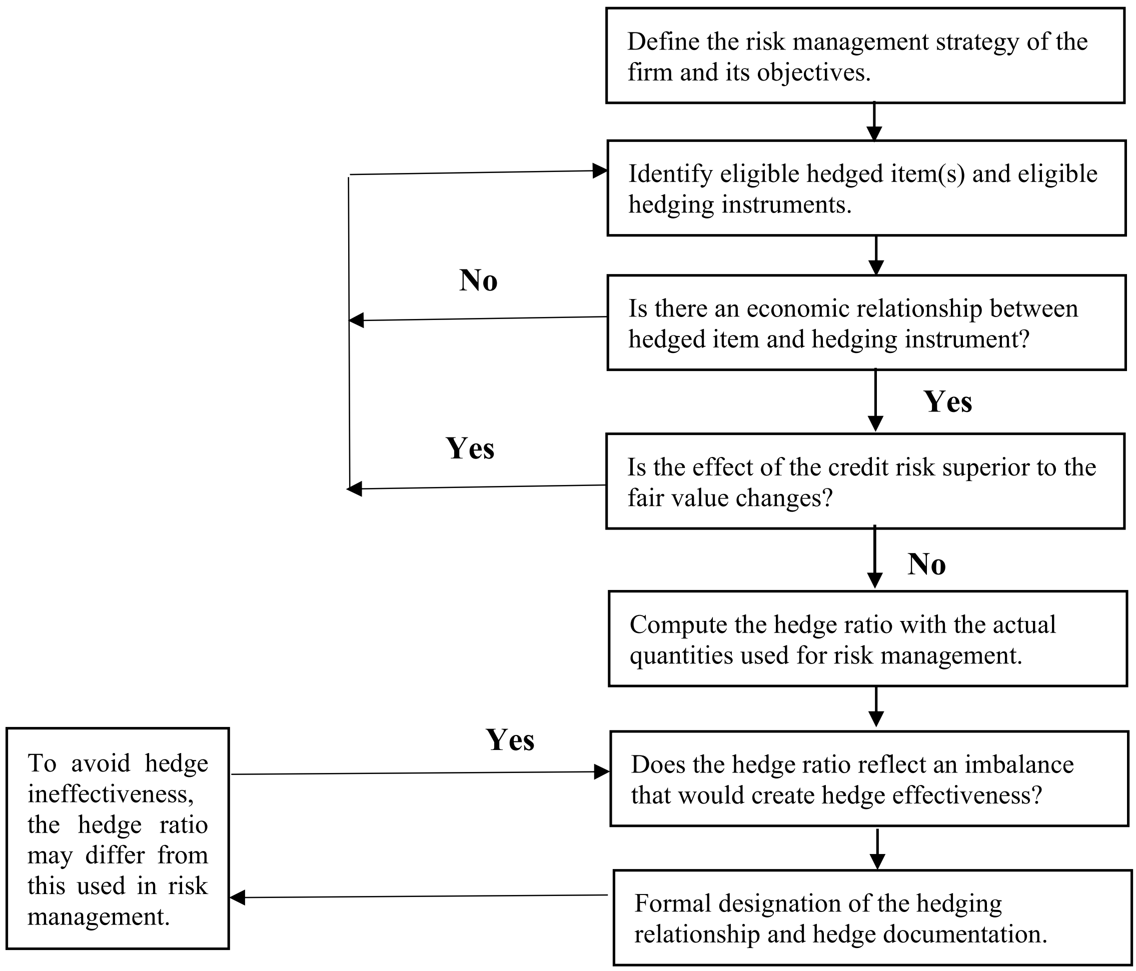

Fig. 1. Achieving hedge accounting under the scope of IFRS 9

	Notional amount	Carrying Amount of the hedging instrument	Line item in the Statement of Financial Position	Change in fair value used for calculating hedge ineffectiveness for the period
EUA December 2013 futures	100,000 contracts (@10€ per contract)	(1,000,000)	Short-term derivative financial liabilities	(250,000)

Fig. 2. Alpha's disclosed amount of carbon hedging instrument according to Paragraph 24A of IFRS7

	Hedging instrument	**Hedged item**	**Hedge Ratio**	**OCI**	**P&L**	**Comments**
IAS 39	-/- 750,000	1,000,000	75%	0	-/- 750,000	Hedge to be discontinued. Prospective test outside the boundaries.
IFRS 9 without rebalance	-/- 750,000	1,000,000	75%	-/- 1,000,000	-/- 250,000	Hedge can continue. No boundaries under IFRS 9.
IFRS 9 with rebalance	-/- 750,000	1,050,000	71.4%	-/- 1,050,000	-/- 300,000	Rebalance with increased 20% hedged item.

Fig. 3. Effects of hedge accounting on Alpha's financial position and performance under the scope of IAS 39 or IFRS 9

Cash flow hedge [(1)]	Hedging gain or loss recognised in OCI	Hedge ineffectiveness in profit and loss	Line item in the Statement of Other Comprehensive Income (OCI) that includes hedge ineffectiveness	Amount reclassified from the cash flow reserve (OCI) to P&L	Line item affected in profit or loss because of the reclassification
COMMODITY PRICE RISK					
EUA price risk (With rebalancing)					
Hedges of forecasted purchases of EUA auctioned	(750,000)	(300,000)	Other income	50,000	Operating Expenses (Emission derivatives)

[(1)] The information presented in the Statement of Changes in Equity (through the cash flow hedge reserve) should have the same level of detail as the proposed disclosure requirements.

Fig. 4. Alpha's disclosed amount of carbon hedged item according to Paragraph 24B of IFRS7