Pre-adoption of IFRS 9 to account for carbon derivatives: methodology and impact assessment

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ABSTRACT

This paper aims at contributing to the latest discussions on the financial reporting of carbon derivatives linked to the European Union Emission Trading Scheme (EU ETS). From the withdrawal of IFRIC 3, the absence of a commonly accepted accounting standard has led to the use of various methods by EU ETS companies to account for carbon derivatives. If it raises concerns about the comparability of their financial statements, the ability to inform on their cost of complying with EU ETS obligations is also hindered.

To address these two issues, it is shown that IFRS 9 should be applied to report carbon derivatives used for cash flow hedging. To this respect, two measures of hedging effectiveness: the minimum variance and the VaR measures based on static and time-varying ratios are proposed. If the first measure can be used to inform on the usefulness of carbon derivatives for cash flow hedging, the second one enables EU-ETS companies to assess the relevance of hedged portfolio rebalancing allowed by IFRS 9. Building on these new insights, the authors show how a EU ETS company may adopt IFRS 7 disclosure requirements to better inform about the nature and extent of carbon derivatives positions in their financial statements.

KEYWORDS: International Financial Reporting Standard (IFRS), Carbon derivatives, Hedge effectiveness

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I. Introduction

The 21st Conference of the Parties (COP 21) organized in Paris one year ago witnessed an historic global step forward in taking action to keep the global temperature increase below 2°C. Looking ahead, the implementation of the Paris Agreement would enable jurisdictions to expand regional carbon pricing initiatives and facilitate cooperation. A major step forward for carbon pricing took place in 2005 with the European Union Emission Trading Scheme (EU ETS). The EU ETS helps polluting companies to reduce their carbon emissions at minimized costs by the issuance of European Allowances (EUA) and Certified Emissions Reductions (CERs). The study of Lovell et *al*. (2014) highlights that the materiality of EUAs and CERs is between 14% and 85% of profit/loss before tax of companies covered by the EU ETS. However, the authors describe a diversity in accounting practices among them: non-disclosure, cost method, fair value method with no particular method emerging as dominant in this arena.

As the Task Force on Climate-related Financial Disclosures of the Financial Stability Board has recently underlined, the impacts of climate change may be not correctly priced without accountability of carbon emissions and related price risks. Until now on, there is a limited evidence of disclosed carbon price risks on corporate financial statements whether voluntary (Clarkson et *al*., 2013)[4] or compulsory (Tuck-Riggs, 2015). Besides, the results of Tuck-Riggs (2015) indicate that both the EU ETS mandate and IFRS accounting guidelines have greatly influenced the reporting of carbon emissions undertaken by airline companies.

As the annual amount of EUA and CER transactions is about 140 billion euros in 2012 (Linacre et *al*., 2012), the need to communicate clearly to stakeholders about how EU ETS companies' performance is affected is of paramount importance. To this respect, 26 EU ETS companies questioned by PwC and IETA (2007) regretted the absence of specific reporting guidance is since the IASB decision to withdraw IFRIC 3 'Emission Rights' in 2005.

With the evolution of the EU ETS, not only the carbon spot market but also carbon derivative markets have gradually emerged. EUAs and CERs are traded through futures and OTC forwards representing more than 76% of trades in Phase II (Linacre et *al*., 2012). Price risk arise when future prices fluctuate, encouraging EU ETS companies to undertake long or short positions in the derivative and spot markets to hedge their exposure to price risk. As carbon prices are highly volatile, EU ETS companies have a huge interest in hedging price risks to fix their future compliance costs (Schopp and Neuhoff, 2012). Interviewing 13 hedging experts from power EU ETS companies, Schopp and Neuhoff (2012) report that annual rollover

[4] Clarkson et *al.* (2013) assess relative environmental performance of U.S high polluting firms using the Toxics Release Inventory (TRI) emissions. They obtain that voluntary environmental disclosures have incremental explanatory power for these U.S. polluting firms' future profitability.

strategies are largely employed to hedge long-term commitment through the purchase of EUA (*resp.* CER) December futures on annual basis. Meanwhile, the handling of EUA and CER derivatives poses additional accounting questions. The Directive and Regulation on Markets in Financial Instruments (MiFID) has classified EUA and CER derivatives as financial instruments since November 2011. Under IFRS, within the scope of IAS 39, financial instruments are subject to treatment at fair value through profit or loss which could result in a significant degree of volatility in the income statement. However, IAS 39 contains two provisions which exempt EU ETS companies to account for derivatives at fair value: (1) **Own use contracts exemption** or (2) **Hedge accounting**. In practice, EUA and CER derivatives rarely meet the criteria of the own use exemption, because they are traded on a liquid market (Haupt and Ismer, 2013). If EU ETS companies need to adjust the amount of hedging according to actual production, EUA and CER derivatives fall within scope of IAS 39 and are treated as a financial instrument. Alternatively, EU ETS companies may apply cash flow hedge accounting and report fair value changes in other comprehensive income (OCI). Revaluing EUA or CER derivatives through OCI has the advantage of increased transparency on the costs of carbon emissions (Haupt and Ismer, 2013). Additionally, management focus is drawn to the potential freeing of liquidity when carbon emissions are diminished.

From January, 1, 2018, IFRS 9 *Financial instruments* will replace IAS 39. The IFRS 9 requirements are aligned more closely with risk management activities than IAS 39[5]. A first improvement is that IFRS 9 requires an economic relationship between the hedging instrument and the hedged item that endures over the life of the hedge relationship whereas under IAS 39 the hedge relationship must be highly effective within a range of 80-125 per cent[6]. A second improvement is that IFRS 9 enables companies to maintain their hedges by means of rebalancing whereas IAS 39 imposes companies to de-designate an old hedge and designate a new one with a new hedge ratio. The third improvement is that companies are only required to perform a prospective assessment of hedge ineffectiveness under IFRS 9. In the view of these improvements, the Climate Disclosure Board (CDSB hereafter) and the International Energy Trading Association (IETA hereafter) (2013) both suggest to apply the IFRS 9 business model.

As a matter of importance, two questions arise with respect to derivatives hedging under IFRS 9. The first is how to estimate the optimal number of futures contracts, and the second is how to measure the efficiency of the hedging strategy. These two questions are integrally related and are tackled together by some empirical studies on European carbon markets. Fan et

[5] Onali and Ginesti (2014) find that investors react positively to events related to the implementation of IFRS 9 Main expectations are a cost reduction of testing hedge effectiveness and a decrease of information asymmetry.
[6] The method of assessing hedge effectiveness can be changed due to subsequent changes provided that the hedge documentation has been updated to reflect the change in hedge effectiveness.

al. (2013) estimate hedge ratios using OLS static models and time-varying models based on GARCH structure. Interestingly, their estimations are consistent with those found for more mature financial derivatives markets. Indeed, they find that hedge ratios ranging from 0.5 to 1.0 and conclude that the OLS models provide the greatest reduction of variance in most cases. Conversely, Philip and Shi (2016) provide evidence of the superiority of a time-varying Markov regime switching (MRS-LR-DCC) hedge ratio[7].

Building on these insights, our empirical work focus on proven methods to estimate optimal hedge ratios and their hedging effectiveness in order to demonstrate the relevance of IFRS 9. We also contribute to the carbon finance literature in respect to the following ways. First, we estimate hedge ratios using two static models (OLS, VECM) and two time-varying ratios (VECM-GARCH and VECM-GJR GARCH) based on the idea that the large EU ETS companies use rollover strategies to cover their long-term hedging needs. Second, our empirical results indicate that hedge ratios sometimes fall outside the range of 80%-125% whereas VECM-GJR GARCH ratios provides superior hedging effectiveness and reduce the Value at Risk measure to a larger extent. Interestingly, the time varying ratios may be used for rebalancing purposes in the case of changes in the hedge relationships provided that prior to rebalancing, hedge ineffectiveness has been measured and recognized in profit or loss. Consequently, the fair value approach may be applied to provide a more relevant balance sheet and income statement information by EU ETS companies. Third, we illustrate with a case study the economic implications of reporting EUA and CER derivatives under IFRS 9, which are reflected into the income statement and the OCI according to IFRS 7 principles.

The remainder of the paper is organized as follows. The EU ETS system and the accounting frameworks including IFRS 9 that are applicable to EUA and CER derivatives are described in Section 2. Next, proven methodologies to estimate both static and time-varying hedge ratio and their corresponding hedge effectiveness are outlined in Section 3. Section 4 presents empirical tests to discuss the relevance of such methodologies when they are applied to EUA and CER derivatives and a case study to assess the IFRS 9 implications on the financial statements based on the IFRS 7 disclosure requirements. Section V concludes.

[7] The MRS-LR-DCC allows to estimate 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.

II. The EU ETS system and carbon assets accountability

2.1. Presentation of the EU ETS

To achieve the CO_2 pollution targets set in the Kyoto protocol, the EU established an Emission Trading Scheme (EU ETS hereafter) in 2005. In this scheme, each Member State proposes, per period, the maximum limits of European Allowances (EUAs) in their National Allocation Plan (NAP). The European Commission (EC hereafter) evaluate and decide whether such NAP is or is not in line with what each Member State is expected to comply with. Then, Member States are in charge of allocating the number of European Allowances (EUAs) or quotas among the different sectors and 13,000 installations involved (emitting facilities).

By the end of April, the physical emission of installations is verified, and the respective number of EUAs or CERs have to be surrendered back. Failing to surrender the necessary emission credits result in an excess emission penalty of (currently) 100 euros per tCO_2eq. in Phase II. An installation emitting below its own cap can sell the excess of CERs otherwise they are immediately cancelled. In the Phase I (2005-2007) and Phase II (2008-2012) of EU ETS, EUAs were granted free of charge for 98% of the total volume. In contrast, 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.

Whilst the EU ETS represents the most important tool to meet Kyoto obligations, other measures built around the 'Clean Development Mechanism (CDM) [8] have emerged. The CDM allows industrialised countries (*i.e.* Annex I countries of the Kyoto protocol) to earn 'Certified Emissions Reductions' (CERs) through investment in low-carbon intensive projects in the host countries of the project. With a limit of 13.4% of annual volume on average, CERs can be converted in EUAs by companies for compliance purposes (Trotignon and Leguet, 2009).

Any EU ETS firms can access to five regulated carbon exchanges to trade EUA and CER derivatives including OTC forwards (EFS, EFP, block (500 contracts)), listed futures, and options. 90% of totalled carbon exchange trades are executed through the European Climate Exchange (ECX) that concentrates 95% of EUA derivatives traded in Phase II of EU ETS (2008-2012). The rapid development experienced by the European carbon market is reflected into a sharp increase in the volume of EUA and CER derivatives contracts representing respectively 81% and 75% of EUA and CER trading activity in Phase II (Linacre et *al*., 2012).

[8] The Clean Development Mechanism (CDM) is a mechanism governed by the United Nations that has been put in place by the Kyoto Protocol to benefit firms that implement projects to reduce carbon emissions in developing countries. To qualify for CERs, projects must meet a number of additionality criteria', namely: (i) Reducing emissions below the level that would have occurred in the absence of the project, (ii) Demonstrating that a project would not have occurred without the additional incentive provided by the emission reduction credit, (iii) Obtaining certification of actual emission reduction from an independent authority.

As a matter of fact, Fezzi and Bunn (2009)[9] report that a part of hedging carbon emission costs is passed on to consumers by electricity producers. By bringing the amount of this hedging carbon costs on to the balance sheet of the EU ETS companies, a clear connection between their own carbon price risks and their corporate value has emerged (Lovell et *al*., 2014).

2.2. Review of current accounting frameworks to report carbon assets

On 20 October 2011, the EC includes European carbon assets in the revised MiFID Directive so that EUA and CER derivatives has been reclassified as financial instruments. Accounting for financial instruments has been subject to much controversy, particularly accounting practices related to derivatives held for hedging purposes. For cash flow hedges, poor matching may result when fair-value accounting is prescribed for the hedging instrument and historical cost is prescribed for the assets that generate the ‘‘highly probable forecast transaction’’ to be hedged. Fair-value accounting may therefore induce excess variations in earnings, which could make a firm appear to be more risky than it actually is.

2.2.1. The IFRIC 3 framework

IFRIC 3 ‘**Emission Rights**’ as an IFRS interpretation states that EUA and CER derivatives are intangible assets. IAS 38 *Intangible Assets* implies that EU ETS companies can opt for either the cost method or for the revaluation method. A cost method implies that intangible carbon assets are valued at historical cost less amortisation and impairment while a revaluation method implies that they are fair valued, with gains recognised under ‘Equity’ in the balance sheet as a revaluation surplus. In contrast, carbon assets held for sale and not for compliance purposes fall within the scope of IAS 2 *Inventories*. If EUAs or CERs were issued at less than fair value (in Phase II the bulk of EUAs are allocated free of charge), they are initially measured at their fair value, the difference between the fair value and the amount paid is considered as a government grant. On the liability side, the obligation to deliver EUAs equivalent to the actual volume of emissions is a liability treated as a ‘provision’ within the scope of IAS 37 *Provisions, Contingent Liabilities and Contingent Assets*. Overall, IFRIC 3 proposes a gross basis approach that creates a maturity mismatch since changes due to any revaluation of EUA and CERs were recognised under equity in the balance sheet, while gains or losses that arise from the valuation of emissions liabilities were reported in the income statement. Additionally, a measurement mismatch emerges when some EU ETS companies recognize intangible assets at historical cost while others measure them at fair value (Bebbington and Larrinage-Gonzalez, 2008). A third mismatch is related to the timing of

[9] Fezzi and Bunn (2009) estimate that a 1% increase in the price of carbon has been translated into an increase of 0.32% in UK electricity prices on average along the period 2005 and 2008.

recognition. Carbon assets are recognised as intangibles when they are acquired while the emissions liabilities are recognised as emissions occur throughout the calendar year.

Since these three mismatches would result in an artificial profit volatility for EU ETS companies, the European Financial Reporting Advisory Group (EFRAG) issued a negative endorsement advice on IFRIC 3 (Bebbington and Larrinaga-Gonzalez, 2008). In June 2005, the IASB withdrew IFRIC 3, meaning that EU ETS companies must follow accounting practices that are consistent with IFRSs under the hierarchy for selecting accounting policies in IAS 8 *Accounting Policies, Changes in Accounting Estimates and Errors*.

PwC and IETA (2007) reported in 2007, that 53% of respondents deem the EUA and CER forward purchase/sale contracts to be within scope of IAS 39 and either fair value the contracts through the income statement, (46%) or fair value through reserves. Fair-value accounting of derivatives can boost earnings volatility due to mismatches in the timing of the recognition of gains and losses on derivative instruments used for hedging purposes and those of the hedged items themselves. Alternative to fair value accounting was the application of hedge accounting, by means of cash flow hedge accounting under which changes in the fair value of the contract are reported in OCI. Since the own use exemption related to IAS 39 is rarely applied, Haupt and Ismer (2013) consider that cash flow hedge accounting should be made the general rule in the event that EUA and CER derivatives are used to hedge price risks for future carbon compliance purposes. Hence, changes in the fair value of derivatives used for compliance are recorded as adjustments to a hedging reserve on the balance sheet and do not affect profits until the hedged transactions are recorded in the income statement. Conversely, EUA and CER derivatives held for trading should be accounted for in profit or loss. However, Berta et *al.* (2016) show that the distinction between hedging and speculation is irrelevant in the case of EUA and CER derivatives markets. 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. Then, the price risk imposed by the compliance feature of the market is exacerbated by its financial feature. Therefore, we consider in the next paragraphs that both hedging and speculative derivatives trades as financial transactions, whose aim is primarily to transfer price risk or to benefit from price variations[10].

2.2.2. The new IFRS 9 framework

From January 1, 2018, IFRS 9 will replace IAS 39 to account for financial instruments. At present, adoption of IFRS 9 is optional, but EU ETS companies should consider any benefits

[10] Under IAS 39, if hedge effectiveness is below the 80-120% threshold, the hedging strategy is believed to have a speculative component and no exception from fair-value accounting is granted (Beisland and Frestad, 2013).

of adopting the new IFRS 9 hedge accounting requirements which are likely to be aligned more closely with risk management activities than IAS 39 (Beisland and Frestad, 2013).

Table 1 provides a summary of the main changes introduced by the new IFRS 9 principles based approach compared to the existing IAS 39 rule-based approach. We note that IAS 39 is very restrictive on hedge accounting for groups of items and does not allow entities to hedge net positions, while fair value hedges of net positions are permitted under IFRS 9 (any recycling of the hedging instrument gains or losses into profit or loss is presented in a separate line item, and is not adjusted to the related individual line items). Under IAS 39, companies are not allowed to isolate the risk associated with a component of the risk being hedged. However, companies may voluntarily **discontinue** hedge accounting at any time *i.e.* deliberately fail hedge accounting while continuing to economically hedge. This brings the potential for an entity to discontinue hedge accounting to achieve a desired accounting result, which the IFRS 9 model eliminates. If a derivative contract to buy or sell was entered into and continues to be for the entity's expected purchase, sale or usage requirements, it is referred to as the '**own use**' exemption that fall outside the scope of IAS 39. In contrast, IFRS 9 extends the fair value option to '**own use**' contracts if this would eliminate or significantly reduce an accounting mismatch[11]. Besides, the fixed price of '**own use**'[12] contracts can be measured at fair value through profit or loss (Other Comprehensive Income, OCI), with the related changes in the hedged asset value offsetting the fair value changes from the hedging instrument.

[Table 1 is inserted about here]

More importantly, IAS 39 requires that the hedge relationship must meet the 80-125% quantitative threshold both retrospectively and prospectively. This requirement is operationally onerous and prevented many economic hedging relationships from qualifying for hedge accounting. In contrast, IFRS 9 requires only to perform prospective hedge effectiveness tests and removes the 80-125% threshold. Moreover, IFRS 9 introduces partial discontinuation of hedge accounting, so that the hedge accounting continues for the remaining part of the hedging relationship. Therefore, companies report 30% of ineffectiveness in profit or loss without discontinuing hedge accounting as in IAS 39 if the hedge was 70% effective at the end of a reporting period. To avoid discontinuation, IFRS 9 allows rebalancing for companies to refine their hedge ratio so that they can reduce this source of recorded ineffectiveness. The concept of

[11] An accounting mismatch arises when assets and related liabilities are accounted for differently (one at fair value and the other at amortized cost) or where one is recognized on balance sheet and the other is not.

[12] An example of own use is a forward contract to purchase EUAs that the entity holds to meet a shortfall in the entity's emissions obligation, i.e. where granted EUAs and/or purchased EUAs held by the entity are less than the expected number of allowances required to meet the entity's obligation for a specific period.

rebalancing comprises changes to the hedge ratio to reflect expected changes in the relationship between the hedged item and the hedging instrument. Rebalancing can be achieved by:

- Increasing (or decreasing) the volume of the hedged item;
- Increasing (or decreasing) the volume of the hedging instrument.

Finally, for more complex hedging relationships, where the hedged item is of a different grade to the hedging instrument, a qualitative test is also required under IFRS 9.

Table 2 summarizes the advantages and drawbacks of IFRS 9 principles against IAS 39 rules in terms of hedging accounting policies.

[Table 2 is inserted about here]

III. Methodology

3.1. Assessment of hedging needs of EU ETS firms

An exhaustive research from 13,000 installations (individual factories/power stations) held by EU ETS companies to estimate their own hedging needs is a very difficult challenge, if not impossible (Lovell et *al.*, 2014). For this reason, we constitute a panel of 26 representative companies which mimics this of Lovell et *al.* (2014) constituted by 26 companies that represent 26% of the total verified emissions in 2008 and have different carbon assets reporting practices. We then proceed in two steps to estimate the hedging needs of these 26 EU ETS companies. First, we use the database of the European Union Transaction Log (EUTL) to identify installations and their corresponding amounts of emissions and EUAs granted. Second, since the EUTL provides only details of installations, and not EU ETS company data, we undertake a matching of installations by Internet searches to the 26 EU ETS companies. As a result of our searches, we find that these 26 companies collectively own 510 installations in the period 2008-2015. Third, we follow the methodology of Berta et *al.* (2016)[13] to estimate their theoretical hedging needs. For each installation, we compute the difference between allocation of EUAs and verified emissions recorded in April 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 26 EU ETS companies.

Table 3 presents a snapshot of theoretical hedging needs estimated for the 26 companies. We calculate these hedging needs by subtracting the number of EUAs and CERs that have been surrendered back by companies to the amount of verified emissions emitted by companies. We observe a noticeable change from Phase II, where up to 23.1% of companies (6 companies)

[13] We also follow the rules applied by Berta et *al.* (2016) to correct missing data related to verified emissions and new entrants when it impacts the short positions of installations. See Berta et *al.* (2016) for more details.

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 are 15.4% (4 companies). The main reason is that EUAs are more increasingly auctioned rather being granted freely in Phase III.

Based on an average carbon price of 10 Euros per $tC0_2eq$. in Phase II, our calculation leads to an annual figure of 52.09 million Euros per company that needs to be hedged. Given an average carbon price of 8 euros per $tC0_2eq$. along the period 2013-2015, we obtain an annual amount of 139.67 million Euros per company that is required to be hedged. These two observations give clear evidence on the necessity for these 26 representative companies to carry out hedging strategies through the use of EUA and CER derivatives, which calls into question whether or not the IFRS 9 framework may be applied 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 traded prices and then assessing hedging effectiveness based on these hedge ratios. An optimal hedge ratio is the number of futures per unit of the spot minimizing the variance of the hedged portfolio returns. 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[14]. We convert these prices into continuously compounded rates of return using logged spot prices *i.e.* $\Delta St = \ln (S_t/S_{t-1})$ and logged futures prices *i.e.* $\Delta F_t = \ln (F_t/F_{t-1})$.

Panels A and B of Table 4 displays the basic properties on the log return of EUA and CER spot and futures averaged for the period 2008-2015. The variance of the EUA futures is lower than that of the CER futures, resulting in lower volatility of price risks. The skewness of the EUA (*resp.* CER) futures is -0.282 (*resp.* -0.216) reflecting a clear left-side feature. The kurtosis for EUA (*resp.* CER) futures is on average 5.181 (*resp.* 5.611) higher than 3, which signals a clear departure from the normal distribution, which is confirmed by the Jarque Bera tests.

[Table 4 is inserted about here]

We then examine the possibility of cointegration between spot and futures prices[15]. Panels A and B of Table 5 present trace test statistics that reject the assumption of no cointegration for both EUA and CER markets. Looking at the cointegrating vectors estimated from the Johansen's (1991) maximum likelihood method, we observe a long run relationship between spot and futures prices showing that futures price series contains information that can help

[14] Since Bluenext closed their activities in December 2012, we use EEX spot prices between 2013 and 2015.
[15] Before using the trace test of Johansen (1988) 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.

predict the spot price series. The β estimates inform whether exchange prices are nearly equal over time and the basis adjustments of substitutes. When cointegration exists, the vector of adjustment coefficients α is able to inform how quickly the EUA or CER markets adjust.

Overall, we confirm the findings of Chevallier (2010) and Fan et *al.* (2013). Chevallier (2010) detects cointegration among BlueNext spot and ECX December futures over a sample from February 2008 to April 2009. Fan et *al.* (2013) also find cointegration between BlueNext spot and ECX futures in Phase II for both EUA and CER markets.

[Table 5 is inserted about here]

There are two broad categories of hedge ratios that we consider: 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 involves a continuous rebalancing of the futures position that is allowed by IFRS 9[16].

Few attempts to estimate hedge ratio have been made in the European carbon market to the noticeable exception of Fan et *al.* (2013) that computed 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 studied the daily EUA and CER futures traded on ECX for Phase II (2008-2012) where EUAs were almost freely allocated as a proxy of the hedged instruments. 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 for the case of EUAs. Second, we have assumed that EU ETS companies are mainly concerned with breaching their emissions cap and price risks of purchasing EUA (*resp.* CER) at the end of a year at the spot market. Therefore, they 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. From a liquidity perspective, this framework is consistent with the rollout strategies applied by firms (Schopp and Neuhoff, 2012). This is also convenient from a reporting perspective as emissions are counted on the calendar year basis. Finally, we assume no daily marking-to market, so the different estimated hedge ratios via three 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)[17].

[16] 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.
[17] 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

The naïve model is used for comparison purposes due to its inability to be optimal. The naïve hedge ratio is always equal to one because each spot contract is offset by exactly one futures contract. Traditionally, ordinary least squares (OLS) regression of the spot return on the futures return is run, with the slope coefficient being the hedge ratio (e.g. Ederington, 1979). Based on daily logged changes in spot and futures prices, the OLS model is written as follows:

$$\Delta \boldsymbol{S}_t = \alpha + \beta \cdot \Delta \boldsymbol{F}_t + \mu_t \tag{1}$$

Where: ΔSt and ΔFt are logged changes in spot and futures prices (*i.e.* prices return) respectively, μ_t is the error term and $\beta = \frac{\boldsymbol{COV}(\Delta \boldsymbol{S}_t, \Delta \boldsymbol{F}_t)}{\boldsymbol{VAR}(\Delta \boldsymbol{F}_t)}$ is the estimated 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 co-integrated, an error correction term should be added to the OLS model. Thus, we consider an error correction model. First, the long-run co-integrating equation is specified as $\boldsymbol{S}_t = \beta_0 + \beta_1 \cdot \boldsymbol{F}_t + \varepsilon_t$ where β_1 is the co-integration vector, β_0 is the constant term. Inserting the lagged regression residual from the cointegration equation into the VECM, we obtain:

$$\Delta \boldsymbol{S}_t = \delta_{10} + \beta_{11} \cdot \hat{\varepsilon}_{t-1} + \sum_{j=1}^{n} \gamma_{s1i} \cdot \Delta \boldsymbol{S}_{t-j} + \sum_{i=1}^{m} \gamma_{s2i} \cdot \Delta \boldsymbol{F}_{t-i} + \mu_t^s \tag{2a}$$

$$\Delta \boldsymbol{F}_t = \delta_{20} + \beta_{21} \cdot \hat{\varepsilon}_{t-1} + \sum_{j=1}^{n} \gamma_{f1i} \cdot \Delta \boldsymbol{S}_{t-j} + \sum_{i=1}^{m} \gamma_{f1i} \cdot \Delta \boldsymbol{F}_{t-i} + \mu_t^f \tag{2b}$$

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, Chevallier (2010) emphasizes on the importance of asymmetric volatility when he finds negative leverage effects on the conditional volatility of EUA spot and futures between 2008 and 2009. Therefore, we consider two models which allows 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:

$$\boldsymbol{S_t} = \alpha_0 + \beta_0(\boldsymbol{S_{t-1}} - \lambda \boldsymbol{F_{t-1}}) + \varepsilon_{s,t} \quad (4a)$$

$$\boldsymbol{F_t} = \alpha_1 + \beta_1(\boldsymbol{S_{t-1}} - \lambda \boldsymbol{F_{t-1}}) + \varepsilon_{f,t} \quad (4b)$$

<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. (4a) and Eq. (4b) 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 and the futures series with λ as the cointegration parameter.

Then, we model the conditional covariance matrix H_t by using a BEKK parameterization, which ensures a positive semi-definite conditional variance-covariance matrix in the optimization process which is a necessary condition for the estimated variance to be zero or positive[18]. The BEKK parameterization for the VECM GARCH (1,1) model is written as:

$$\boldsymbol{H_t} = \boldsymbol{C'C} + \boldsymbol{A'H_{t-1}A} + \boldsymbol{B'}\varepsilon_t\varepsilon_t^{'}\boldsymbol{B} \quad (5)$$

We expand Eq. (5) in the following manner:

$$H_t = \begin{vmatrix} h_{ss,t} \\ h_{sf,t} \\ h_{ff,t} \end{vmatrix} = \begin{vmatrix} C_{ss,t} \\ C_{sf,t} \\ C_{ff,t} \end{vmatrix} + \begin{vmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{vmatrix} \begin{vmatrix} \varepsilon^2_{s,t-1} \\ \varepsilon_{s,t-1}\varepsilon_{f,t-1} \\ \varepsilon^2_{f,t-1} \end{vmatrix} + \begin{vmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \end{vmatrix} \begin{vmatrix} h_{ss,t-1} \\ h_{sf,t-1} \\ h_{ff,t-1} \end{vmatrix} \quad (6)$$

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.

[18] A and B are matrices of coefficients, and C is an upper triangular matrix of intercept coefficients.

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 $h_t = \frac{h_{sf,t}}{h_{ff,t}}$.

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:

$$\boldsymbol{h_t} = \omega + \alpha_1 \varepsilon_{t\text{-}1}^2 + \beta_1 \boldsymbol{h}_{t\text{-}1} + \gamma_1 \varepsilon_{t\text{-}1}^2 \boldsymbol{I}_{t\text{-}1} \quad (7)$$

Where: $\boldsymbol{I}_{t-1} = \begin{Bmatrix} 1, \varepsilon_{i,t} \geq 0 \\ 1, \varepsilon_{i,t} < 0 \end{Bmatrix}$ (8)

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. 6) is replaced by:

$$\boldsymbol{H_t} = \boldsymbol{C'C} + \boldsymbol{A'H}_{t\text{-}1}\boldsymbol{A} + \boldsymbol{B'}\varepsilon_t \varepsilon_t^{'} \boldsymbol{B} + \boldsymbol{G'}\eta_{t\text{-}1}^{'} \eta_{t\text{-}1} \quad (9)$$

Where: 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. (9) are obtained by maximizing the following log-likelihood function:

$$\boldsymbol{L_t}(\Theta) = \text{-}\log(2\Pi) \text{-} \frac{1}{2}\log|\boldsymbol{H}_t| \text{-} \frac{1}{2}\boldsymbol{e}_t^{'}(\Theta)\boldsymbol{H}_{t\text{-}1}(\Theta)\boldsymbol{e}_t(\Theta) \quad (10)$$

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 : $\boldsymbol{h}^* = \frac{\boldsymbol{h_{sf}}}{\boldsymbol{h_{ff}}}$ as made previously for the symmetric VECM GARCH (1,1) model.

3.2. Assessment of hedging effectiveness

The basic motivation for hedging is to form a portfolio that will reduce fluctuations in its value. The effectiveness performance of a hedge is relevant as soon as a reduction a portfolio variance is reported. A popular measure of hedging effectiveness is provided by Ederington (1979) that relies upon the unconditional variance of the hedged portfolio.

We begin by assessing the hedging effectiveness performance of the five above mentioned models by the portfolio variance using a one-year hedging horizon.

First, we compute the return of un-hedged and hedged portfolios as follows:

$$R_U = S_{t+1} - S_t \tag{11}$$

$$R_H = \left(S_{t+1} - S_t\right) - h^*\left(F_{t+1} - F_t\right) \tag{12}$$

Where: R_U and R_H are the return on un-hedged and hedged portfolio respectively. F_t and S_t are the respective logged futures and spot prices *with* h*, the hedge ratio calculated at time *t*.

Second, we compute the variance of the unhedged (R_U) and of hedged (R_H) portfolios:

$$Var(R_U) = \sigma_U^2 \tag{13}$$

$$Var(R_H) = \sigma_S^2 + h^{*2} \cdot \sigma_F^2 - 2h^* \cdot \sigma_{S,F} \tag{14}$$

Where: $Var(R_U)$ and $Var(R_H)$ are variance of unhedged and hedged portfolios with σ_S, σ_F and σsf are standard deviations of spot and futures prices, $\sigma_{S,F}$ the covariance of spot and futures series. h* is the hedge ratio obtained from the different static and dynamic models used.

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

$$HE = \frac{VAR(R_U) - VAR(R_H)}{VAR(R_U)} = 1 - \frac{VAR(R_H)}{VAR(R_U)} \tag{15}$$

HE measures the relative reduction in variance gained by taking the optimal combined position (h^*) for a given hedging instrument like futures (Ederington 1979). HE measures the greatest degree of risk reduction attainable if h^* is selected. However, it does not reveal the extent to which the user actually reduces risk toward the minimum achievable. Harris and Shen (2006) find that the minimum-variance hedging reduces the standard deviation of portfolio returns but increase portfolio kurtosis and the effectiveness of hedging compared to VaR. Thus, they employ the minimum-VaR hedging strategy that minimizes the historical simulation VaR of the hedge portfolio as an alternative to minimum-variance.

Therefore, we propose to estimate the hedging effectiveness with the Value at Risk (VaR). Assuming the hedged portfolio return (R_S) is normally distributed as Harris and Shen (2006) do, we compute the VaR of the hedged portfolio at 5% confidence level as below:

$$\mathbf{VaR} = \mathbf{V_0} \times [\mathbf{E(R_S)} + \mathbf{0.05} \times \sqrt{\mathbf{Var(R_S)}}] \tag{15}$$

Where: V_0 is the initial wealth of the portfolio of EUA (*resp.* CER) spot and futures portfolio.

IV. Empirical results and impact assessment

4.1. Values of hedging ratios

We begin by presenting the estimated hedge ratios that are calculated from the use of methods discussed above: naïve, OLS, VECM, VECM GARCH and VECM GJR GARCH. Since the latest method allows for conditional variance ad covariance matrix, the two latest hedge ratios are dynamically adjusted on a daily basis. As shown in Panels A and B of Table 6, the time-varying asymmetric VECM GJR GARCH hedge ratios outperform the OLS and naïve counterparts. 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 asymmetries in time-varying hedge ratios perform well for financial instruments.

Since the optimal hedge ratio is calculated by dividing the covariance between spot and futures return by the variance of the futures return, any impact on the covariance and variance will affect the hedge ratios. Therefore, the significant variance of EUA and CER spot and futures has led to lower hedge ratios, which fall outside the range 80-125% required by IAS 39 from 2012. However, this authorized range does not exist in IFRS 9 and the hedge relationship could be verified in the case that the economic justification is provided (see §2.2.2).

[Table 6 is inserted about here]

4.2. Results of hedging effectiveness assessment

In the view of a wide range of static and dynamic hedge ratios that EU ETS companies can apply, it is now important to assess their performance in terms of hedging effectiveness achieved. Table 7 reports how effective Naïve, OLS, VECM, VECM-GARCH and VECM GJR GARCH models are in terms of variance reduction for EUA and CER portfolios.

All above mentioned models achieve an important level of variance reduction, but the VECM GJR GARCH outperforms the other models. However, the variance of hedging portfolio returns exhibits a significantly declining trend from 2013 to 2015. For example, applying the VECM GJR GARCH model gives a risk reduction for EUA which varies from a 90.8% reduction in 2013 to a reduction of 82.4% 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 portfolio.

Assuming a 10 million euros of initial wealth invested in a portfolio, the daily average estimated VaR exposure is 180 131 euros (*resp.* 196 676 euros) for EUA (*resp.* CER) markets at 95% confidence level when applying the VECM GJR GARCH hedge, which is a decrease of 4 586 (*resp.* 4543) euros as compared to the daily average VaR exposure for the OLS hedge.

This second set of results confirm that rebalancing EUA and CER portfolio according to a time varying hedge ratio allowed by the IFRS 9 hedging accounting model may generate substantial reductions of VaR exposure for EU ETS companies.

[Table 7 is inserted about here]

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

Along the development of IFRIC 3 '**Emission Rights**', accounting hedging positions at fair value had been largely discussed since the fair value approach could improve market transparency in giving an estimate of the cost of carbon emissions incurred by EU ETS companies (Lovell et *al*., 2014). Such disclosures are an important cornerstone of the hedge accounting model, as they provide the link between a company's risk management activities and how they affect its financial statements. In particular, IFRS 9 requires an adjustment of the hedge ratio *i.e.* a portfolio rebalancing when there is a change in the economic relationship between the hedged item and the hedging instrument[19]. Prior to rebalancing (before adjusting the updated quantities of futures), ineffectiveness have to be measured and recognized in profit or loss given the previous quantities of the hedged item and hedging instrument. Further, IFRS 7 disclosure rules implies that hedging strategies must be described separately by type of risk; this description include how each risk arises, and how and to what extent, the risk is managed. In the following paragraphs, we provide an illustration of associated reporting implications for a company Alpha on financial statements in the frame of IFRS 7[20].

Alpha is an electricity producer and has long-term supply contracts to buy natural gas. Their supply contracts are priced using a specified formula that references gas, coal and carbon prices. This formula calculates the clean dark spread, expressed in €/MWh, which is the difference between the natural gas price and the price of coal used to generate that electricity, corrected for the energy output of the gas fired plant[21]. Alpha's risk management strategy is to hedge 100% of its 1 million exposure to carbon price risk due to its natural gas production. Alpha forecasts its volume of expected emissions along the following period of 18 months and manages carbon price risk exposure on a 12-month rolling basis. In January 2013, Alpha enters

[19] In contrast, IAS 39 force companies to end up with the existing relationship and establish a new one.

[20] IFRS 7 requires a reconciliation of the hedge components in equity (e.g. the hedging reserve) and an analysis of OCI. That information are to be disaggregated by risk category and should be disclosed in the notes.

[21] The following methodology to calculate the clean spark and dark spreads is extensively discussed in the report of CDC Climat Research Spark (*resp*. clean) spreads is divided by the natural gas (*resp.* coal) price per MWh by the gas-fired plant efficiency rate (carbon impact is not included). This result is deducted from the result from the electricity futures contract price. Then, clean spark (resp. dark) spreads are calculated by subtracting the carbon emission costs from the spark (resp. dark) spreads. It is advantageous for firms to switch from coal to natural gas (*resp.* natural gas to coal), when the EUA price is above (*resp.* below) this switching price which establish equality between the clean dark spread and the clean spark spread.

into 100,000 December 2013 futures contracts at 10€ per contract to purchase EUA considering an important price risk due to the abandonment of free EUA allocation in 2013 in the power sector. Thus, Alpha determines that the carbon price exposure is separately identifiable and reliably measurable so that this exposure is an eligible risk component for designation as a hedged item. Said differently, the underlying risk of the EUA futures contracts is identical to the hedged risk component (*i.e.*, the EUA benchmark price). Alpha has established a hedge ratio of 0.75:1 for all its hedging relationships. Alpha's exposure to the variability in the purchase price of EUA is integrated into its general risk management and its decision to switch from coal hired installations to gas hired installations on the basis of clean spark (dark) spread.

We consider that Alpha hedge a forecasted EUA consumption with a EUA futures. This hedging instrument is presented in Fig. 1 according the tabular format of Paragraph 24A of IFRS 7 on the statement of financial position of Alpha as of 31 December 2013**.**

[Fig. 1 is inserted about here]

Next, we look in Fig. 2 at what happens when the correlation between the hedged item and hedging instruments (EUA futures) changes from 100% to 95 under IAS 39 vs IFRS 9[22].

[Fig. 2 is inserted about here]

Under IAS 39, a hedge relationship has to be discontinued if the hedge ratio is outside the effectiveness boundaries. Given that 75% is outside the effectiveness boundaries, the full amount of line 1 (IAS 39)'s hedging instrument is accounted for in the profit and loss (P&L). In contrast, IFRS 9 does not impose an effectiveness boundary of 80-125%. In line 2 (IFRS 9 without rebalance), we therefore register 1 000 000 as OCI, and 250 000 of hedge ineffectiveness in the profit and loss account. In line 3 (IFRS 9 with rebalance), we observe that if Alpha 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%. In this case, the over hedge between the hedged item and the hedging instrument is 300 000, which has to be accounted for in the P&L, and the rest can be registered as OCI. The subsequent modified hedging relationship affects the profit and loss and other comprehensive income (OCI) of Alpha. The change is presented in Fig. 3 according the tabular format of Paragraph 24B of IFRS 7.

[Fig. 3 is inserted about here]

[22] Rebalancing the hedged portfolio on the basis of changes in the estimated time-varying hedge ratio is only possible when the hedging instrument and the hedged item are not the same but strongly correlated.

V. Conclusions

In November 2013, the Maystadt report asserted that the accounting standards must be conducive to the public good. In the same month, the IASB issued a new version of IFRS 9 Financial Instruments that introduces a more flexible hedging accounting model in comparison to IAS 39. However, expanding IFRS 9 principles to European carbon derivatives is only imaginable after an impact assessment. Indeed, the application of fair value hedges could refrain the plans of EU-ETS companies to invest in long-term low carbon projects due to a high volatility of EUA and CER prices that would be translated into their own financial statements.

Our prospective study extends the survey of Haupt and Ismer (2013) by proposing a methodology for EU ETS companies to report EUA and CER derivatives in their financial statements within the scope of IFRS 9. We notably develop complementary methods to assess hedging effectiveness assuming that EU ETS companies use rollover strategies to cover their hedging needs. Our main objective is that these techniques are simple to be implemented so that the potential cost advantage of IFRS 9 implementation compared to this of IAS 39 effectively occurs. We also contribute to the literature on carbon markets along three directions.

First, we find that the estimated hedge ratios sometimes fall outside the range of 80%-125% in Phase III especially for the case of less liquid CER markets. Second, we show, however, that the associated hedging effectiveness measured by variance reduction is noteworthy and help companies to cover significant variations in EUA and CER prices. Thus, the fair value approach may be applied to provide a more relevant balance sheet and income statement information. Third, we suggest that these companies use standard presentations in accordance with IFRS 7 to report their EUA and CER derivatives positions held.

Taken together, our findings confirm the relevance of IFRS 9 to account for EUA and CER derivatives especially in Phase III where the most actively underlying asset: the EUA have a price at inception due to the gradual abandonment of free allocation of EUA for auctions.

Avenues for further research may be stretched in two directions. Other energy related assets e.g. electricity and natural gas could be incorporated into global portfolios, which will include carbon assets. In the frame of IFRS 9, the time-varying hedge ratios and the VaR measures that we have presented should be applied to these portfolios in order to measure hedge effectiveness and to test the relevance of portfolio rebalancing for energy firms. Additionally, 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. The analysis of potential synergies between REMIT and IFRS 9, which can reduce the costs of their implementation for reporting energy derivatives, is left for future work.

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Table 1. Focus on the main differences between IAS 39 standards and IFRS 9 principles

Requirement	IAS 39 *Financial Instruments: Recognition and Measurement*.	IFRS 9 *Financial Instruments*
Hedge effectiveness testing	Must meet the quantitative retrospective and prospective hedge effectiveness assessment within the 80-125% threshold to qualify for hedge accounting.	Retrospective effectiveness testing is no longer required to qualify for hedge accounting. A qualitative effectiveness test for hedge accounting is also permitted.
Rebalancing *(new concept)*	If hedge ratio is adjusted (*i.e.* if the quantities of the hedged item or hedging instrument changes) for risk management purposes, must de-designate (terminate) the current hedge relationship and re-designate (start) a new hedge relationship.	If the quantity of the hedged item or hedging instrument vary, the hedge relationship continues. In contrast, the hedge ratio change prospectively if it is adjusted for risk management purposes.
Risk components for non-financial items	Not an eligible hedged item.	Eligible hedged item if the risk component is separately identifiable and reliably measurable.
Aggregated exposures	Derivatives cannot be designated as a hedged item. Therefore, any exposure that contains a derivative cannot be designated as a hedged item.	Combines a derivative and a non-derivative, provided that this aggregated exposure is managed as one exposure.
Discontinuation	Can discontinue hedge accounting at any time.	Voluntary discontinuation of the hedge is not permitted. Can only discontinue where the qualifying criteria are no longer met.
Own use contracts	EUA and CER futures contracts for the sale or purchase of a non-financial item that are for own use are outside the scope of IAS 39.	Option to account for 'own use' EUA and CER futures contracts at fair value through profit or loss if it eliminates an accounting mismatch.
Hedges of groups	Entities of the group are not allowed to hedge net positions, when risks within the group offset to some degree so that only the remaining net risk is hedged.	Permits fair value hedges of net positions and cash flow hedge accounting of a net position conditional on entities specifying at the start of the hedging relationship how and when each of the items related to the net position will affect profit or loss.
Forward points in forward contracts	When the EUA or CER spot contract (or auction) element is designated as the hedging instrument, the changes in forward points are recognized in profit or loss like a trading gain or loss.	When the EUA or CER spot (or auction) element is designated as the hedging instrument, entities may recognize the changes in forward points in OCI. The initial forward points are deferred in OCI and is amortized over the term of the hedging transaction.

Table 2. Advantages and disadvantages of applying the IFRS 9 principles

ADVANTAGES	DISADVANTAGES
• More opportunities to use hedge accounting: - Ability to designate non-financial risk components - More flexibility to hedge group of items - Increase ability to hedge items • New accounting treatments of time value of options and futures/forward contracts reduce profit and loss volatility • Introduction of fair value option for credit risk (removes accounting mismatch) • Reduction of costs and effort to assess hedge effectiveness through the abandonment of the 80-125% retrospective test.	• Impossible to discontinue hedge accounting on a voluntary basis • Need to rebalance the portfolio of futures/ OTC forward contacts due to fluctuations in the hedge ratio • Reduced ability to use rollover strategies • Cost and effort of measuring hedge effectiveness can remain important for small and mid-sized companies (albeit reduced) • Additional costs resulting from having to close out derivative positions to designate • Lack of convergence of IFRS 9 principles with US GAAP standards

Table 3. Evolution of theoretical hedging needs of most important EU-ETS emitting companies

COMPANY	Sector	Country	Number of installations	Average **Phase II of EU ETS** : **2008-12** (in thousands of tCO_{2eq})	Average **Phase III of EU ETS** : **2013-15** (in thousands of tCO_{2eq})	Δ Average **Phase III-Phase II**
ARCELOR MITTAL	Iron & Steel	France	77	Long Position	Long Position	N/S
BEH	Combustion	Bulgaria	11	1 676.586	16 815.240	+ 903%
BRITISH ENERGY	Combustion	United Kingdom	11	7 162.171	18 409.806	+ 157%
CEZ	Combustion	Czech Rep.	19	Long Position	16 782.510	N/S
DRAX	Combustion	United Kingdom	7	12 239.587	14 893.987	+ 22%
EAST ENERGIA	Combustion	Italy	1	16.919	28.483	+ 68%
EDF	Combustion	France	52	1 788.714	25 922.334	+1 349%
EDP	Combustion	Spain	1	474.050	325.510	- 31%
EDISON	Combustion	Italy	14	1 277.156	4 484.245	+ 251%
ENDESA	Combustion	Spain	16	5 965.058	23 226.358	+ 289%
ENEL	Combustion	Italy	36	4 937.499	36 645.714	+ 642%
EON	Combustion	Germany	85	2 498.259	129.166	- 95%
ESSENT	Combustion	Netherlands	11	221.412	6 867.666	+ 3 002%
GROSSKRAFT WERK	Combustion	Germany	1	579.440	6 303.923	+ 988%
IBERDROLA	Combustion	Spain	18	958.533	2 189.809	+ 128%
NUON	Combustion	Netherlands	16	4 460.237	10 428.172	+ 134%
PPC	Combustion	Slovakia	2	Long Position	Long Position	N/S
PGE	Combustion	Poland	11	4 977.873	56 714.513	+ 1 039%
RUUKKI	Iron & Steel, Metals	Norway	1	Long Position	Long Position	N/S
RWE	Combustion	Germany	51	48 924.765	121 781.841	+ 149%
SARAS	Refineries	Italy	1	166.047	185.098	+ 11%
SHELL	Refineries	United Kingdom	22	130.545	37.832	- 71%
TATA STEEL	Iron & Steel, Coke ovens	United Kingdom	14	Long Position	Long Position	N/S
TAURON	Combustion	Poland	15	451.230	14 423.235	+ 3 096%
THYSSENKRUPP	Iron & Steel, Metals	Germany	16	5 267.009	4 935.943	- 6%
U.S. STEEL KOSICE sro	Iron & Steel, Metals	Slovakia	1	Long Position	2 557.463	N/S

% of companies having hedging needs (short position)	*76.9%*	*84.6 %*	
Average annual volume of hedging needs per company (in thousands of tCO_{2eq})	5 208.655	17 458.584	+ 235%
Average annual value of hedging needs per company based on the average price calculated for the Phase considered	**52.09 M€**	**139.67 M€**	+ 168%

Note: **In Phase II of EU ETS** (2008-2012), 98% of EUAs are freely allocated while in **Phase III of EU ETS** (2013-2015), the part of auctioned EUAs will increase from 30% in 2013 to 70% in 2020 on average per company.
'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 are not available.

Table 4. Descriptive statistics of the EUA and CER log return times series

Panel A: EUA (average price return time series: 2008-2015)

	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 price return time series: 2008-2015)

	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 Phase II and Phase III of spot and futures 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 tests 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 prices.* 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	1.0000	0.8228	0.8227	0.8218	0.8211
2009	Dec-09	1.0000	0.8319	0.8312	0.8293	0.8303
2010	Dec-10	1.0000	0.8121	0.8157	0.8154	0.8151
2011	Dec-11	1.0000	0.7718	0.7619	0.7735	0.7961
2012	Dec-12	1.0000	0.7654	0.7534	0.7688	0.7897
2013	Dec-13	1.0000	0.7212	0.7124	0.7201	0.7191
2014	Dec-14	1.0000	0.6831	0.6692	0.6695	0.6706
2015	Dec-15	1.0000	0.6992	0.6845	0.6998	0.7011

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	1.0000	0.8234	0.8227	0.8225	0.8231
2010	Dec-10	1.0000	0.8511	0.8452	0.8454	0.8449
2011	Dec-11	1.0000	0.7918	0.7903	0.7901	0.7871
2012	Dec-12	1.0000	0.7276	0.7234	0.7220	0.7230
2013	Dec-13	1.0000	0.7117	0.7076	0.7073	0.7045
2014	Dec-14	1.0000	0.6835	0.6782	0.6788	0.6869
2015	Dec-15	1.0000	0.6789	0.6798	0.6769	0.6752

Table 7. Assessment of hedging effectiveness from the hedge ratios estimated in Table 6

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

Hedging horizon	Futures	Portfolio Variance	Naïve	OLS	VECM	VECM GARCH	VECM GJR GARCH	**Value at Risk (VaR)**
2008	Dec-08	Variance (R_U)=0.1285	0.0171	0.0164	0.0163	0.0162	0.0158	**OLS VaR** = -193 211
		***Reduced variance* (R_H)**	***0.1104***	***0.1121***	***0.1119***	***0.1125***	***0.1127***	**VECM GARCH VaR**=-191 256
		HE	**85.91%**	**87.28%**	**%**	**87.59%**	**87.71%**	**VECM GJR GARCH VaR**= -191 182
2009	Dec-09	Variance (R_U)=0.0795	0.0104	0.0094	0.0094	0.0087	0.0091	**OLS VaR** = -186 771
		***Reduced variance* (R_H)**	***0.0695***	***0.0701***	***0.0701***	***0.0708***	***0.0705***	**VECM GARCH VaR**=-181 715
		HE	**87.48%**	**88.25%**	**88.19%**	**89.07%**	**88.68%**	**VECM GJR GARCH VaR** = -181 790
2010	Dec-10	Variance (R_U)=0.0448	0.0066	0.0048	0.0045	0.0046	0.0042	**OLS VaR** = -179 416
		***Reduced variance* (R_H)**	***0.0382***	***0.04***	***0.0403***	***0.0409***	***0.0413***	**VECM GARCH VaR**=-173 124
		HE	**85.34%**	**89.40%**	**89.96%**	**91.29%**	**92.19%**	**VECM GJR GARCH VaR** = -172 897
2011	Dec-11	Variance (R_U)=0.03495	0.00515	0.00475	0.00465	0.00467	0.00425	**OLS VaR** = -167 368
		***Reduced variance* (R_H)**	***0.0278***	***0.0302***	***0.0303***	***0.0307***	***0.0321***	**VECM GARCH VaR**= -161 322
		HE	**79.54%**	**86.41%**	**86.78%**	**87.84%**	**91.85%**	**VECM GJR GARCH VaR** = -160 196
2012	Dec-12	Variance (R_U)=0.0332	0.004	0.0041	0.003	0.0022	0.0021	**OLS** = -169 812
		***Reduced variance* (R_H)**	***0.0252***	***0.0291***	***0.0302***	***0.031***	***0.0313***	**VECM GARCH VaR**= -164 511
		HE	**75.90%**	**87.56%**	**90.99%**	**93.43%**	**94.28%**	**VECM GJR GARCH VaR** = -163 902
2013	Dec-13	Variance (R_U)=0.0343	0.00505	0.0042	0.0041	0.0023	0.0025	**OLS VaR** = -173 228
		***Reduced variance* (R_H)**	***0.0265***	***0.0301***	***0.0302***	***0.032***	***0.0318***	**VECM GARCH VaR**= -167 877
		HE	**77.26%**	**87.67%**	**88.08%**	**90.44%**	**92.71%**	**VECM GJR GARCH VaR**= -168 171
2014	Dec-14	Variance (R_U)=0.0398	0.0065	0.0064	0.0063	0.0062	0.0059	**OLS VaR** = -181 112
		***Reduced variance* (R_H)**	***0.0303***	***0.0334***	***0.0335***	***0.0336***	***0.0345***	**VECM GARCH VaR**= -178 119
		HE	**76.13%**	**84.35%**	**84.37%**	**84.60%**	**86.68%**	**VECM GJR GARCH VaR**= -176 780
2015	Dec-15	Variance (R_U)=0.0435	0.0078	0.0077	0.0076	0.0074	0.0079	**OLS VaR** = -190 132
		***Reduced variance* (R_H)**	***0.0327***	***0.0358***	***0.0359***	***0.0361***	***0.0376***	**VECM GARCH VaR**= -189 202
		HE	**74.18%**	**82.74%**	**82.76%**	**82.97%**	**86.44%**	**VECM GJR GARCH VaR** = -189 456

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

Hedging horizon	Futures	Portfolio Variance	Naïve	OLS	VECM	VECM GARCH	VECM GJR GARCH	**Value at Risk Measure (VaR)**
2009	Dec-09	Variance (R_U) = 0.0811	0.0115	0.0109	0.011	0.0103	0.0112	**OLS VaR** = -213 432
		***Reduced variance* (R_H)**	***0.0695***	***0.0702***	***0.0701***	***0.0708***	***0.0698***	**VECM GARCH VaR**= -209 654
		HE	**85.76%**	**86.56%**	**86.44%**	**87.30%**	**86.07%**	**VECM GJR GARCH VaR**= -212 998
2010	Dec-10	Variance (R_U) = 0.0458	0.0076	0.0051	0.0055	0.0056	0.0051	**OLS VaR** = -193 791
		***Reduced variance* (R_H)**	***0.0382***	***0.0407***	***0.0403***	***0.0402***	***0.0409***	**VECM GARCH VaR**= -196 717
		HE	**83.41%**	**88.86%**	**87.99%**	**87.77%**	**89.30%**	**VECM GJR GARCH VaR**= -192 880
2011	Dec-11	Variance (R_U) = 0.0371	0.0063	0.0059	0.0038	0.0032	0.0029	**OLS VaR** = -187 653
		***Reduced variance* (R_H)**	***0.0308***	***0.0312***	***0.0333***	***0.0339***	***0.0348***	**VECM GARCH VaR**= -179 545
		HE	**83.02%**	**84.10%**	**89.76%**	**91.37%**	**93.80%**	**VECM GJR GARCH VaR**= -178 853
2012	Dec-12	Variance (R_U) = 0.0382	0.0067	0.0065	0.006	0.0056	0.0058	**OLS VaR** = -189 318
		***Reduced variance* (R_H)**	***0.0295***	***0.0317***	***0.0322***	***0.0326***	***0.0323***	**VECM GARCH VaR**= -183 974
		HE	**77.22%**	**82.98%**	**84.29%**	**85.34%**	**84.55%**	**VECM GJR GARCH VaR**= -184 652
2013	Dec-13	Variance (R_U) = 0.0496	0.0081	0.0073	0.0071	0.0072	0.0062	**OLS VaR** = -199 089
		***Reduced variance* (R_H)**	***0.0405***	***0.0423***	***0.0425***	***0.0424***	***0.0441***	**VECM GARCH VaR**=-196 652
		HE	**81.65%**	**85.28%**	**85.69%**	**85.48%**	**88.91%**	**VECM GJR GARCH VaR**= -194 267
2014	Dec-14	Variance (R_U) = 0.0478	0.0081	0.0077	0.0066	0.0061	0.0057	**OLS VaR** = -196 237
		***Reduced variance* (R_H)**	***0.0357***	***0.0401***	***0.0412***	***0.0417***	***0.0423***	**VECM GARCH VaR**= -193 125
		HE	**74.69%**	**83.89%**	**86.19%**	**87.24%**	**88.49%**	**VECM GJR GARCH VaR**= -191 560
2015	Dec-15	Variance (R_U) = 0.0482	0.0104	0.0096	0.0088	0.0073	0.0069	**OLS VaR** = -197 711
		***Reduced variance* (R_H)**	***0.0338***	***0.0381***	***0.0392***	***0.0419***	***0.0426***	**VECM GARCH VaR**=-192 564
		HE	**70.12%**	**79.05%**	**81.33%**	**86.93%**	**88.38%**	**VECM GJR GARCH VaR**= -189 722

Note: The variance on the EUA (*resp.* CER) hedged portfolio is calculated for each one year hedge horizon using the EUA (*resp.* CER) respective futures. The percentage of **variance reduction** is obtained by substituting the variance on the EUA (*resp.* CER) hedge portfolio denoted Variance (R_H) in Eq. (14) to the unhedged variance denoted Variance (R_U) in Eq. (13) for each of the four models used to estimate hedge ratios in Table 6. Assuming an initial amount of 10 million invested in the portfolio**,** we use Eq.(15) to calculate **OLS VaR** for the OLS hedge ratio VaR, and **VECM GARCH VaR** and **VECM GJR GARCH VaR** related to the VECM GARCH hedge and VECM GJR GARCH hedge respectively that are averaged throughout the one year hedging horizon.

	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. 1. 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 increase 20% hedged item

Fig. 2. Effects of hedge accounting on the Alpha's financial position and performance under IAS 39 vs. IFRS 9

	Hedging gain or loss recognised in OCI	Hedge ineffectiveness in profit and loss	Line item in the statement of comprehensive income that includes hedge ineffectiveness	Amount reclassified from OCI to P&L	Line item in the statement of profit and loss
EUA price risk (With rebalancing)					
Hedges of forecast purchases of EUA auctioned	(750,000)	(300,000)	(Other income)	50,000	Operating Expenses (Emission derivatives)

Fig.3. Alpha's disclosed amount of carbon hedged item according to Paragraph 24B of IFRS7