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Full length article

Stock markets' bubbles burst and volatility spillovers in agricultural commodity markets

Lucia Baldi,[a,]* Massimo Peri,[b] Daniela Vandone [c]

[a] *Associate Professor of Statistics -Department of Food, Environmental and Nutritional Sciences (DEFENS), University of Milan, Via Celoria 2, Milan, Italy*
[b] *Assistant Professor of Environmental Economics and Appraisal -Department of Economics, Management and Quantitative Methods (DEMM),University of Milan, Via Celoria 2, Milan, Italy*
[c] *Associate Professor of Economics of Financial Markets and Intermediaries- Department of Economics, Management and Quantitative Methods (DEMM), University of Milan, Via Conservatorio 7, Milan, Italy*

ARTICLE INFO

Article history:
Received 15 April 2016
Received in revised form 28 April 2016
Accepted 29 April 2016
Available online xxx

Keywords:
Stock markets' bubbles
Financialization
Volatility spillover
Agricultural commodity market
VIRF

JEL code:
G11
C32
Q11

ABSTRACT

Our paper focuses on commodity financialization and the gradual integration between commodity and financial markets, investigating to what extent shocks in stock markets impact commodity price volatility, and the persistency of the phenomenon. To this end, we estimate Volatility Impulse Response Function from stock markets to agricultural commodity markets over a symmetric window before and after two of the most important bubble bursts since the new millennium, the 2000 dot.com bubble and the 2008 financial crises. Results highlight that volatility spillover increased significantly after the 2008 financial crises, signalling a rising interconnection between financial and agricultural commodity markets.

1. Introduction

Over the last decades, there has been a rapid and steady growth of financial investments in commodities. The appeal of investing in commodities is generally attributed to low correlation and interdependence with traditional asset classes, stocks and bonds, which allows for portfolio diversification benefits. The underlying rationale is that the price of commodities is driven by different fundamentals -such as weather conditions, supply constraints in the physical production, geopolitical events- which determine different price patterns and dynamics in respect to traditional assets.

Until recently, a large body of empirical literature, using different dataset and different econometric specifications, has provided consensus on the diversification benefits of including commodities into investors' portfolio (Erb and Harvey 2006; Gorton and Rouwenhorst 2006; Sanning et al., 2007; German and Kharoubi, 2008; Buyuksahin et al., 2010; Chong and Miffre 2010; Masset and Weisskopf, 2010).

* Corresponding author.
Email addresses: lucia.baldi@unimi.it (L. Baldi); massimo.peri@unimi.it (M. Peri); daniela.vandone@unimi.it (D. Vandone)

http://dx.doi.org/10.1016/j.ribaf.2016.04.020
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In the last few years, however, empirical evidences seem more blurred than in the past, and some results are coming to light that deny the diversification properties of commodities. Delatte and Lopez (2013) using a copula approach find that co-movements between commodities and stock index returns exist, and have increased over years becoming stronger for all commodities after the 2008 financial crisis. Tang and Xiong (2012) report that increase in correlation is more pronounced for commodities in the S&PGSCI, confirming the growing relevance of index trading. Daskalaki and Skiadopoulos (2011) using an out-of-sample static non-MV framework find that the incorporation of commodities in investment portfolios does not make the investor better off and that the increased financialization of commodities is impairing diversification benefits.

Such recent evidences are attributed to the growing relevance of commodity index traders. Indeed, increase in flow of funds by institutional investors for diversifying assets in traditional portfolios has been much stronger, compared to the past (Irwin and Sanders, 2011; Cheng et al., 2014; Peri et al., 2013; Baldi et al., 2014; Huchet and Fam, 2016), and commodity index traders have been the main vehicle for investing in commodities (Stoll and Whaley, 2010). According to the Commodity Futures Trading Commission (CFTC), while at the beginning of the new millennium physical hedgers represented almost 80% of positions in commodity futures and options, in 2012 they accounted for less than 30%. In March 2011, the total amount of commodity assets under management was already 412bn dollars (Carpenter 2011).

This process of massive increase in investments in commodities through financial instruments, known as “commodity financialization”, has generated a gradual integration between commodity markets and financial markets which, in turn, has risen levels of correlation, convergence of risk-adjusted returns, and spillover volatility between markets (Karyotis and Alijani, 2016; Adams and Glück, 2015; Olson et al., 2014).

Financialization is relevant under two distinct issues: the first is related to financial investors, while the second concerns policy makers. As far as financial investors, as underlined above commodity financialization is significant for portfolio diversification strategies. Regarding policy makers, financialization is crucial for its impact on real economy and, in particular, in the agricultural commodity sector. The two perspectives – finance and real economy – are strictly linked: as recently highlighted by Lagoarde-Segot (2015, 2016) and Karyotis and Alijani (2016) commodity financialization is part of a wider issue related to the ongoing expansion of the financial sector and the subsequent effects on the relationship between finance, the economy and the society. Indeed, the combination of several key factors, as the development of information technologies, the deregulation of economies and the rise of shareholders value paradigm, produces a number of interrelated changes in the financial and the real sector, suggesting a new research agenda for the international research community (Lagoarde-Segot, 2016; Lagoarde-Segot and Paranque, 2016).

In this framework, our paper provides an empirical contribution to highlight the relationships between stock markets and commodity markets. We focus on volatility spillover that can be interpreted in the light of rising interconnection between financial and commodity markets. Indeed, shocks in one market may induce institutional investors to rebalance their portfolio’s asset classes moving funds to other asset classes, such as commodities, or quickly selling all assets to restore their balance sheet, thus transferring price volatility from one market to another. Therefore, a deep understanding of the dynamics in such a changing environment may be helpful for getting insights into recent trends affecting financial markets and contribute to the ongoing debate on commodities financialization.

To this end, we specifically investigate to what extent shocks in stock markets impact commodity price volatility, and the persistency of the phenomenon. In particular, we adopt the Hafner and Herwartz (2006) methodology to estimate Volatility Impulse Response Function (VIRF) focusing on the financial market shocks related to the most important bubble bursts since the new millennium – the 2000 dot.com bubble and the 2008 financial crises.

We focus on bubble bursts, since they correspond to periods of extreme market conditions, that facilitate the identification of market dynamics. Moreover, they occur in periods characterized by different levels of financialization that may underline changes in interconnection between stock and commodity markets. In particular, the dot.com bubble bursts happened in a period when institutional investors’ interest in commodities as a diversification asset was not present yet. Vice-versa, during the 2008 bubble burst investment in commodities was already considerable, as the financialization phenomenon began to take shape during the second half of the 2000s. We also compare volatility impulse response function from stock markets to commodity markets over a symmetric window before and after both the bubbles, given that financial markets are more subject to volatility pattern after the burst of a bubble (Forbes and Rigobon, 2002).

To our knowledge the impact of financial bubbles on agricultural commodity, specifically grain and corn markets, has not been investigated yet using VIRF. The issue of volatility spillover between financial and agricultural commodity markets has relevant implications both for market practitioners and for policy makers. For the first, volatility spillover is a tool for portfolio strategies and risk management, given its relevance in computing hedge ratios and portfolio weights, as well as assessing investment and leverage decisions (Singleton 2014). For agricultural policy makers, it has relevant implications as highlighted by the still open debate on the increasing role of non-commercial investors in commodity markets and the likely impact on agricultural price volatility (Aboura and Chevallier, 2015; Peri et al., 2014).

The paper is organized as follows: Section 2 focuses stock market bubbles and volatility, Section 3 describes the empirical model, Section 4 presents data results, Section 5 concludes.

2. Stock market bubbles and volatility

From the perspective of our analysis, bubble bursts are relevant since they determine high levels of volatility. From a theoretical point of view, a typical element of bubbles is the attitude of individuals to implement herding behaviour of practices most widespread among other investors (Galariotis et al., 2015; Bernales et al., 2016). Both before and during the bubble burst, investors decision making are driven by euphoria – first – and panic – later – rather than an objective assessments about the prospects of firm's future returns. In fact, while the value of a stock should simply reflect the company's fundamental value (e.g. net income, leverage, solvency, growth forecasts), irrational behaviour may induce a significant departure from those fundamental values, driven by few informed traders that speculate and many noise traders that simply do the same thing without knowing exactly the reason (Black 1986; Peri et al., 2014).

Previous studies have analysed volatility spillovers from stock markets to commodity markets (Haase et al., 2016 for a review); however, only few of them use VIRF and they mainly focus on energy sector (Olson et al., 2014; Le Pen and Sévi 2010; Jin et al., 2012). Conceptually, this approach is relevant since it allows to visually examine VIRF for multivariate GARCH models, highlighting how an independent shock in the economic system impacts volatility. Besides, compared to traditional impulse response function, it explores the conditional variance rather than the conditional mean (Allen et al., 2015).

Several approaches can be used to select the date of the shocks for the VIRF analysis. Some authors detect historical shocks (Le Pen and Sévi, 2010; Jin et al., 2012) whereas others compare two relevant periods (Panopoulou and Pantedlidis, 2009; Olson et al., 2014), while Hafner and Herwartz (2006) tests both the approaches. For the purpose of our analysis, we date external shocks over periods of extreme market conditions that are in correspondence of two recent strong market bubbles burst: the dot.com and 2008 financial crisis.

2.1. The dot.com bubble

The dot.com bubble is linked to the discovery of new information technologies and the development of companies operating in the internet, hence the name dot-com (Basco, 2014). It originated in the mid-90s when a widespread process of euphoria began due to the extreme confidence by investors in the growth potential of companies operating in the New Economy. This euphoria fuelled expectations of future and continuous rise in the value of securities issued by companies in this sector, regardless of the fundamental values of the enterprises, and therefore evolving in a growing and marked overestimation of securities' prices.

In March 2000, the bubble bursts because of bad news related to dot.com balance sheet providing evidence that the investment in companies in this sector could prove unprofitable. As a consequence, prices began to fall; the Nasdaq lost almost 9% in few days, many dot.com companies closed or were the target of M&A deals, and in 2004 only 50% of listed companies in 2000 were still active, although with share prices definitively lower compared to their highs (Goldfarb et al., 2007).

2.2. The 2008 financial crises

The framework that gave rise to the financial crisis of 2008 began to take shape in the US in 2003, with the significant increase in the supply of subprime mortgages due, among other things, to the accommodative monetary policy of the Federal Reserve – which kept interest rates at historically low until 2004, in response to the crisis of the dot.com bubble – the dynamics of the US housing market and the development of securitization. In particular, securitization allowed banks to get fresh cash from the sale of long-term assets that would otherwise been paid back at the end of the loans contracts; in turn, cash could be reused to supply new mortgages to new borrowers, mainly subprime, given that apparently banks could get rid of the risk of default by borrowers of funds. The result was a weakened in the incentive to properly assess the reliability of customers (Bianco 2008; Buchanan 2016).

The bubble bursts in 2008, as a consequence of the joint actions of many drivers: increase in interest rates; growing number of families defaulting on unexpected costly loans repayment; reduction in the demand for real estate resulting in bursting of the housing bubble and decline in the value of the mortgages securitized by these houses; widespread fraud by many financial-industry actors (FCIC 2011).

The situation triggered a crisis of confidence and liquidity that soon became systemic; on 15 September 2008 Lehman Brothers started bankruptcy proceedings and this triggered a new phase of intense instability with unprecedented turbulence that extended from the market for structured products to stock markets, and gradually the entire financial system showing a very strong degree of interconnection (Hieronymi, 2016).

3. Empirical model

The Hafner and Herwartz (2006) methodology was used to analyze how bubble shocks impact the volatility transmission from S&P500 to commodity markets.

A bivariate GARCH model is defined with the mean equation modelled with residuals obtained by a preliminary AR(n) process in return series:

$$z_t = \phi + \Gamma z_{t-1} + \theta \epsilon_{t-1} + \epsilon_t \tag{1}$$

With,

$$\epsilon_t | \Omega_{(t-1)} \sim \left(0, H_t\right) \tag{2}$$

where vector z_t includes two variables, Γ represents coefficients of the matrices AR(n), and Ω_{t-1} is the whole information set at time $t-1$ and earlier. A BEKK specification was used to model the conditional variance H_t (Engle and Kroner, 1995):

$$H_t = C'C + A'\epsilon_{t-1}\epsilon'_{t-1}A + B'H_{t-1}B \tag{3}$$

where in the bivariate specification $A'A$, $B'B$ is a 2×2 matrices and C is a lower triangular matrix to ensure positive definiteness of H. The diagonal elements of matrix A (a_{11} and a_{22}) represent the ARCH effect, that is, the effect of lagged shocks, while the off-diagonal elements (a_{12}, a_{21}) represent the crossover-spillover effects. The diagonal elements of matrix B (b_{11} and b_{22}) measure the GARCH effect, that is, the lagged volatility effect, and the off-diagonal (b_{12} and b_{21}) represent the crossover-volatility spillover effects. Therefore, the off-diagonal elements of matrices A and B respectively refer to shock spillover effects and volatility spillover effects.

In agreement with Hafner and Herwartz (2006), the BEKK model is then transformed in its *Vech* representation so as to generate volatility impulse response functions defined as the expectation of volatility conditional on initial shock and history minus the expectation conditional only upon history:

$$vech(V_{t+1}) = A\ vech(u_t u_t' - H_t)$$

(4)

$$vech(V_{t+k}) = (A + B)\ vech(V_{t+k-1})$$

where H_t is the covariance matrix, previously estimated by Eq. (3), at time t. The shock to the conditional variance is the amount by which $u_t u_t'$ differs from its expected value.

Distinguishing properties in comparison to the traditional impulse response functions are that VIRF is a symmetric function of the shock and is determined by the history through the volatility conditions when the initial shock occurs.

The Hafner and Herwartz (2006) methodology in a bivariate framework can be used to analyze the impulse response of the conditional variance for the two variables of interest separately as well as the response of the conditional covariance. A bivariate GARCH-BEKK and VIRF methodology was then implemented between: S&P500 and S&P Agriculture; S&P500 and S&P Grain and S&P500 and S&P Corn.

4. Data and results

We use weekly data from 1970 to 2015 for S&P Agriculture Index, Grain Index and Corn Index, and for S&P500 Index. S&P Agriculture is a benchmark for investments performance in the global agriculture commodity market and includes wheat, corn, soybeans, coffee, sugar, cocoa, and cotton. S&P Grain is a composite index of grain commodity prices, including soy, corn and wheat, while S&P Corn reflects the risk/return characteristics of only one grain commodity – corn – which is the most traded commodity in the financial markets. The overall stock market is proxy by the S&P 500.

Fig. 1 shows the indexes' price trends. Visual inspection of data clearly indicates that the three commodity indexes have a similar pattern, reaching very high peaks in mid-2008 and dramatically falling after September 2008. The S&P500 line clearly highlights the two bubbles under analysis. After the burst of the dot.com bubble, commodity indexes remain quite stable, suggesting that they were not strongly linked with stock markets patterns. Conversely, after the 2008 crisis, all the series appear much more interrelated, suggesting a closer relation between commodity and financial markets.

Table 1 reports descriptive statistics for each series, with a total of 2388 valid observations. All the three commodity indexes display excess kurtosis and are positively skewed. Conversely S&P 500 shows negative kurtosis and very weak skewness. For each variable Jarque-Bera test rejects the normality hypothesis so the Student-t distribution is used in the subsequent analysis.

Residuals of an AR(2)-GARCH(1,1) process of the individual return series are used in the mean equation of the bivariate GARCH-BEKK specification. Table 2 reports the diagnostics for the residuals after the filtering process. Ljung-Box Q statistics suggest that generally serial correlation is no longer present in the series.

Tables 3 shows the results of the BEKK model's estimates for the three pairs of series and their eigenvalues. The BEKK model captures the volatility dynamics among series, given that the majority of coefficients are significant. In particular off-diagonal estimated coefficients are statistically significant and this confirms the presence of volatility spillover between S&P500 and each of the other three indexes. All the eigenvalues are only slightly smaller than one indicating that the duration of volatility

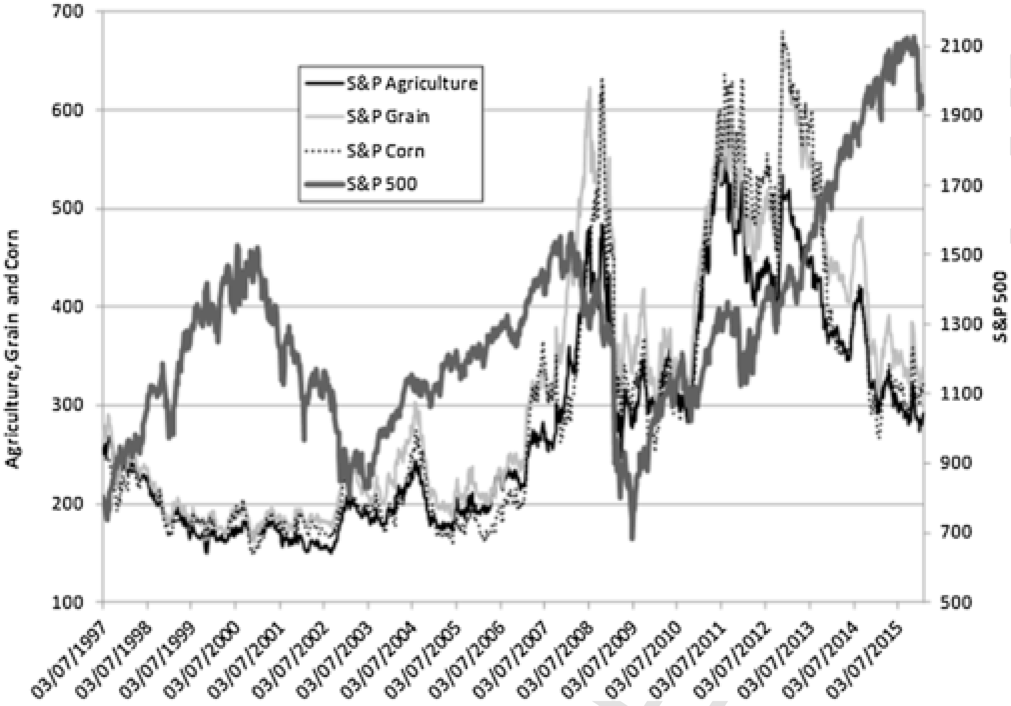

Fig. 1. S&P indexes.*Source: our elaboration on DATASTREAM data*

Table 1
Descriptive statistics (absolute values).
Source: our elaboration on DATASTREAM data

	S&P Agriculture	*S&P Grain*	*S&P Corn*	*S&P 500*
Mean	241.9	264.0	243.9	662.0
Standard deviation	87.5	105.5	105.5	568.6
Kurtosis	1.4	2.0	3.5	−0.8
Skewness	1.2	1.4	1.8	0.6
Min	98.3	98.3	93.4	62.3
Max	564.6	664.3	680.7	2126.6
Jarque-Bera	957.14	454.81	916.58	3770.33
sig.	*0.00*	*0.00*	*0.00*	*0.00*
Observations	2388	2388	2388	2388

Table 2
Residual diagnostics tests.

	ARCH-LM(1)	Q(10)	Q(16)
S&P500	8.162	11.232	17.570
	−0.004	*−0.260*	*−0.286*
S&P-AG	0.466	5.432	12.218
	−0.495	*−0.795*	*−0.662*
S&P-GRAIN	0.589	6.253	13.244
	−0.443	*−0.714*	*−0.583*
S&P-CORN	0.051	11.596	24.715
	−0.821	*−0.237*	*−0.054*

spillover is likely to increase. Table 4 reports diagnostic statistics, computed with multivariate Ljung-box, that confirms the adequacy of the model specification.

In order to visually examine volatility spillovers, we then generate volatility impulse response functions. Specifically, following Hafner and Herwartz (2006) the average value of estimated volatility impulse response functions was calculated for the three couples, for a window of 24 observations before and after the two bubble bursts set in March 2000 and September 2008.

Table 3
MV-GARCH, BEKK-t Estimation by BFGS algorithm.

Variable	S&P500 – S&P-AG		S&P500 – S&P-GRAIN		S&P500 – S&P-CORN	
	Coeff	*p-value*	Coeff	*p-value*	Coeff	*p-value*
mean equation						
Constant	0.228	*0.000*	0.221	*0.000*	0.226	*0.000*
AA{1}	−0.074	*0.002*	−0.073	*0.000*	−0.072	*0.002*
AA{2}	0.025	*0.206*	0.022	*0.283*	0.021	*0.287*
Constant	0.008	*0.848*	−0.002	*0.970*	0.048	*0.368*
RBB{1}	0.037	*0.066*	0.040	*0.049*	0.034	*0.107*
RBB{2}	0.062	*0.002*	0.048	*0.017*	0.044	*0.031*
variance equation						
C(1,1)	0.368	*0.000*	0.376	*0.000*	0.351	*0.000*
C(2,1)	−0.007	*0.784*	0.226	*0.000*	0.359	*0.000*
C(2,2)	0.478	*0.000*	0.677	*0.000*	0.773	*0.000*
A(1,1)	0.258	*0.000*	0.261	*0.000*	0.241	*0.000*
A(1,2)	−0.042	*0.000*	−0.040	*0.003*	−0.019	*0.101*
A(2,1)	0.032	*0.000*	0.033	*0.000*	0.028	*0.000*
A(2,2)	0.305	*0.000*	0.327	*0.000*	0.410	*0.000*
B(1,1)	0.951	*0.000*	0.950	*0.000*	0.958	*0.000*
B(1,2)	0.018	*0.000*	0.024	*0.000*	0.007	*0.002*
B(2,1)	−0.012	*0.000*	−0.026	*0.000*	−0.023	*0.000*
B(2,2)	0.934	*0.000*	0.915	*0.000*	0.882	*0.000*
Shape	8.551	*0.000*	8.682	*0.000*	7.700	*0.000*
Eigenvalues from BEKK-t						
	(0.96958, −0.00000)		(0.95791, −0.00000)		(0.97458, 0.00000)	
	(0.96686, 0.00628)		(0.95569, 0.02154)		(0.95098, 0.00000)	
	(0.96686, −0.00628)		(0.95569, −0.02154)		(0.94021, 0.00000)	

Note: "1" corresponds to S&P500, "2" corresponds to commodities (agriculture, grain, corn).

Table 4
Multivariate Ljung-box test.

Multivariate Ljung-Box	S&P500 − S&P-AG		S&P500 − S&P-GRAIN		S&P500 − S&P-CORN	
	statistic	*P-Value*	statistic	*P-Value*	statistic	*P-Value*
(Q4)	23.181	*0.109*	22.738	*0.121*	17.743	*0.339*
(Q8)	40.703	*0.139*	40.703	*0.139*	36.777	*0.257*
(Q12)	58.351	*0.146*	57.054	*0.174*	53.129	*0.283*
(Q16)	68.608	*0.324*	76.069	*0.144*	78.451	*0.106*

Figs. 2–7 show the main results from the VIRF computed for each of the two bubbles. Specifically, Figs. 2–4 report the effect of the dot.com bubble on volatility transmission from S&P500 to commodity markets. For agriculture and grain markets the impact is negative before and after the bubble burst, suggesting that expected conditional variance tends to decrease rather than increase. Moreover the values of the variance are very low indicating that these markets are not so closely related. The solid lines (i.e. "before" the bubble) almost overlap the dashed lines reflecting that the dot.com bubble did not substantially alter the expected variance of agriculture and grain. As far as corn, the bubble had a little more significant impact. This evidence can be motivated considering that corn is one of the most treated commodity in financial markets; moreover Agriculture and Grain indexes in-

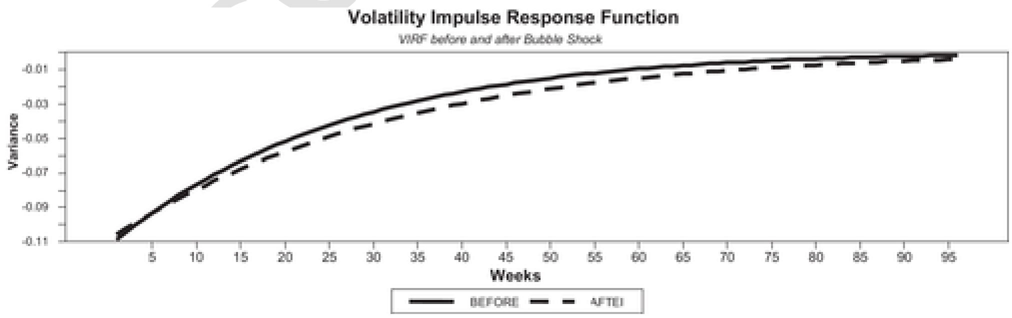

Fig. 2. VIRF of S&P- Agriculture index to S&P500 before and after Dot.com bubble.

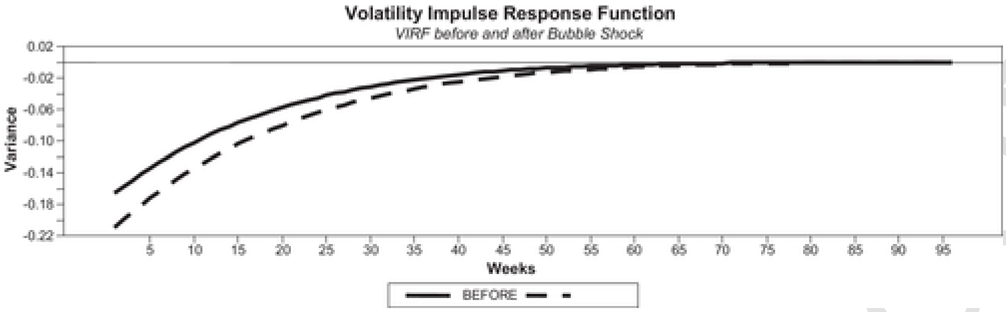

Fig. 3. Volatility impulse response function for Grain S&P index before and after Dot.com bubble.

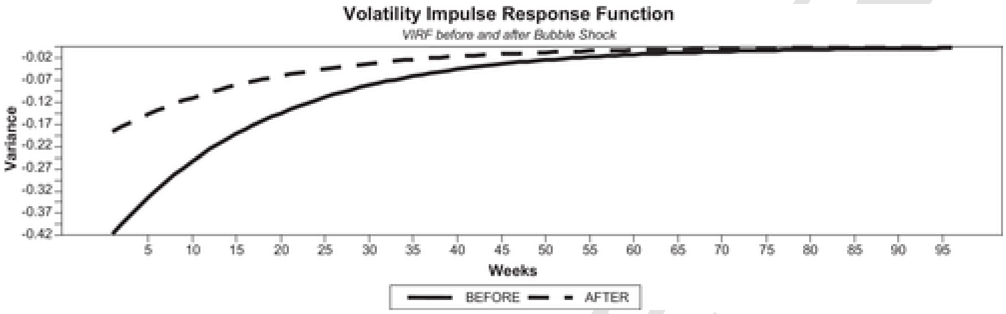

Fig. 4. Volatility impulse response function for Corn S&P index before and after Dot.com bubble.

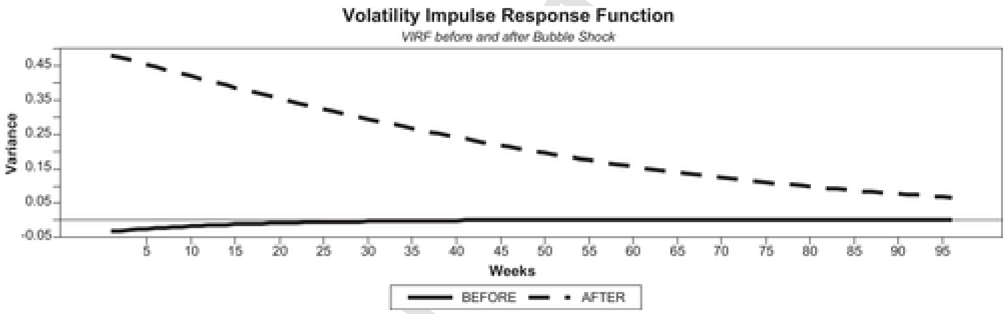

Fig. 5. Volatility impulse response function for Agriculture S&P index before and after 2008 bubble.

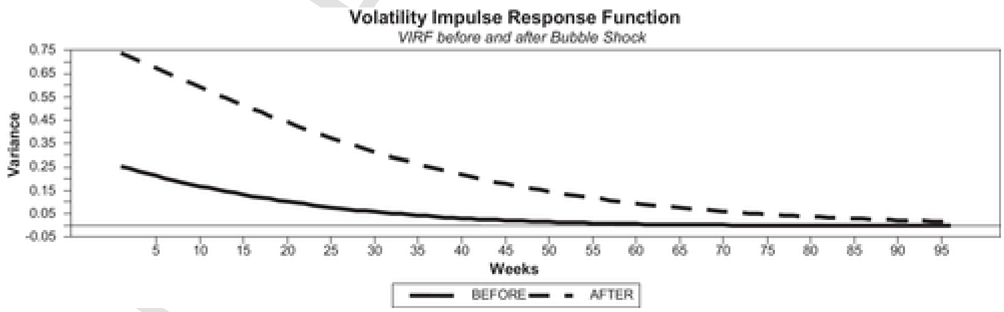

Fig. 6. Volatility impulse response function for Grain S&P index before and after 2008 bubble.

clude several agricultural commodities, therefore different trends are amortized. Finally, at the beginning of the new millennium, the financialization of commodities was still a not widespread phenomenon.

Conversely, volatility spillovers from financial markets to agricultural markets clearly appear after the 2008 bubble burst (Figs. 5–7), likely due a greater exposures of commodity to uncertainty about the economy, and turmoil in stock markets and

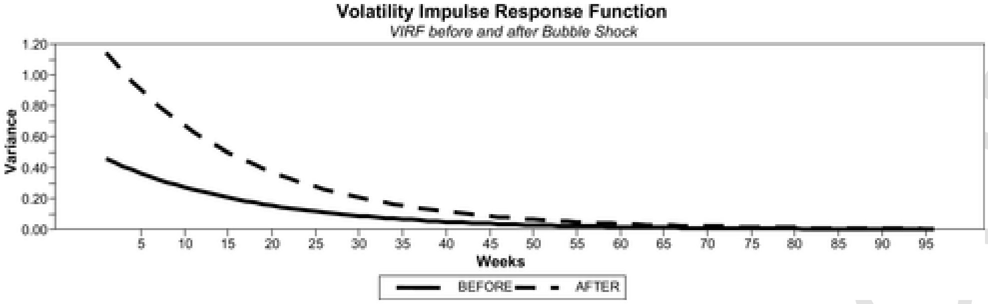

Fig. 7. Volatility impulse response function for Corn S&P index before and after 2008 bubble.

bond markets. Specifically, for agriculture the volatility transmission highlights a 50% increases; the effect is even stronger for grain, with a 85% increase.

A relevant consequence of the effects of the shocks is the persistency. Following Panopoulou and Pantelidis (2009) in order to measure the decrease in volatility persistency we calculate the half-life of the volatility shock, computed as the time needed by the impact of the shock to reach the half of its maximum value. Table 5 shows several interesting trends. For both shocks the length of the persistence after the shock is always greater than the persistence before the shock. However, the persistence after the 2008 financial crisis is on average higher that for the dot.com bubble. Besides, the length of the persistence of the S&P Agriculture is the highest; this is reasonably due to the fact that it includes the effects of different commodities that add up and interact with each other, therefore using more time to reach the new equilibrium. Vice versa, for corn, although the impact of the shock is significantly higher, the persistency is shorter due to a deeper market where trading activity boosts a quicker absorption of volatility.

5. Conclusions

Our paper fits in a recent stream of literature on commodity financialization investigating the interconnection between agricultural commodity and stock markets.

Given that spillover volatility can be interpreted in the light of rising relationship between markets, we estimate volatility impulse response function between stock and commodity markets comparing a symmetric window before and after the two most important and recent bubble bursts in financial markets – dot.com and 2008 financial crisis.

Results show that volatility spillovers from stock markets to commodity markets were negative before and after the dot.com bubble. Conversely, volatility spillovers increased significantly after the 2008 financial crisis, in particular for those commodities – like corn – that are largely traded on stock markets as alternative asset classes and, thus, are more “financialized”.

Our results confirm recent empirical findings that underline a rising interrelationship between these markets (Delatte and Lopez, 2013; Tang and Xiong, 2012; Daskalaki and Skiadopoulos, 2011), although with a different and more innovative methodology that focuses on volatility rather than correlation.

The implications of our results are relevant. An increasing awareness of institutional investors of these rising correlation dynamics – signalling a likely reduction in the diversification role of commodities in financial portfolios − may slow down investments in commodity indexes, with a reduction in spillover effects. This might benefits commodity markets, given that agricultural commodity’s prices are now determined by financial investors’ strategies, and not only by supply and demand levels (Tadesse et al., 2014; Peri et al., 2013). However, commodities have fully become part of financial markets strategies and it is unlikely that institutional investors completely leave these alternative asset classes.

Therefore, only a new vision of the financial system can address the problem of financialization. In this sense the statement of Padoa-Schioppa (2010) appears relevant, althought difficult to realize: he supports as a possible route for the achievement of stability in the financial markets the identification of the market itself as a public good, non-excludable and non-rivalrous. In a

Table 5
Persistence and maximum values in volatility spillover.

	Dot.com bubble		2008 bubble	
	Before	After	Before	After
	Persistence (weeks)			
Agriculture	19	23	11	40
Grain	14	15	16	25
Corn	14	13	13	13
	Maximum values			
Agriculture	−0.11	−0.11	−0.03	0.48
Grain	−0.17	−0.21	0.25	0.74
Corn	0.42	−0.19	0.46	1.15

more pragmatic vision and in agreement with Lagoarde-Segot, (2016), Aboura and Chevallier (2015), and Karyotis and Alijani (2016), the scientific research agenda should consider the adoption of new approaches for financial issues in order to embed also social and environmental welfare and to build a model of sustainable business.

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