Worldwide Evidences in the Relationships between Agriculture, Energy and Water Sectors

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1 Introduction

Water, food and energy (WFE) are strongly interconnected: each depends on the other for a lot of concerns, spanning from guaranteeing access to services, to environmental, social and ethical impact issues, to price relations.
The development, use, and waste generated by demand for these resources drive global changes and fears of resource scarcity. To date, a new approach to the concept of sustainable development is emerging and a joint analysis of these three areas is needed. "Demand for water, food and energy is expected to rise by 30-50% in the next two decades, while economic disparities incentivize short-term responses in production and consumption that undermine long-term sustainability. Shortages could cause social and political instability, geopolitical conflict and irreparable environmental damages. Any strategy that focuses on one part of the WFE relationships without considering its interconnections risks serious unintended consequences" (World Economic Forum, 2011).
In the last years international organizations have organized several conferences to raise awareness of the WFE nexus (IISD 2011, footnote p.6) and some studies have addressed this issue trying to provide a theoretical integrated view aimed at understanding how to tackle these complex relationships when identifying policies and actions (Brazilian et al. 2011, Elobeid et al. 2013, Howells et al. 2013). These studies have analyzed the technical connection that exists between the three elements in order to highlight the need for joint policy designed to ensure a sustainable development. From an economic point of view, there are still very few analysis that utilize empirical approaches to support recent theoretical literature (Peterson et al. 2014, Curmi et al. 2013).
This area is clearly massive and an economic analysis of the link aimed at understanding the interactions and correlations on a global scale is still needed. Such an analysis can be conducted using price relationships.
We know that there are technical links between WFE, so we expect that there are linkages also in the dynamics of prices. We also know from financial theory that the more the variables are correlated the greater is the possibility that shocks propagate between sectors. Therefore, the economic analysis is important because it allows to highlight the strength of these relations and their dynamics to understand how shocks are transmitted from one price to the other prices.
Within this framework, the first step of our paper is to empirically analyze the volatility spillovers and the dynamic conditional correlation between the WFE prices using a multivariate GARCH method.
This is relevant since it helps policy makers seeking to mitigate the potential correlations across these resources, which may create future undesirable shocks to the economy. We use daily data spanning from November 2001 to May 2013
We then focus on a specific component of the nexus – water - which is particularly relevant and scarcely analyzed within the context of the nexus. The reason of its relevance is that water has no substitute and it is essential to life. To date, one-fifth of the world's population lives under conditions of water scarcity. Among others, there is a strong need to increase access to water supply and sanitation in developing countries, water storage, and to rehabilitate water supply and sanitation infrastructure. This implies the need for massive investment in infrastructure, given the lumpy nature of the investments. Economic literature analyses several economic instruments supporting water sector (OECD, 2009), but one of most relevant regards transfer, taxes and tariff (3Ts). However, to support the strong development required to face all the above mentioned needs, additional finance is needed. Indeed, according to the OECD,

while revenues from the 3Ts are spread over a much longer period of time, repayable finance can bridge the financing gap since it provides financing up-front so as to pre-finance investments that are repaid over time.
This finance may come from capital markets, through the issue of bonds or equities. An analysis of the characteristics of the industry is needed in order to help water policymakers and water managers to strengthen the financial dimension of water resources management and to understand challenges and opportunities for investors.
Using the same dataset we apply a multifactor market model based on the theory of Capital Asset Pricing Model (CAPM) with the aim to analyze the impact of agriculture and energy price trends on the share price value of exchange-listed companies that derive a substantial portion of their revenues from the potable and wastewater industry.
Understanding price dynamics is relevant both to water, agriculture and energy policy makers and to investors, since it influences information dissemination, price discovery, efficient allocation of resources, hedging and portfolio optimization.
The novelty in this work is threefold. Firstly, the paper focuses on a topic of great relevance from an economic, environmental and ethical perspective, as recently outlined by many international organizations. The complex interactions and policy implications that consider all three sectors together need more work in order to effectively support decision-making. Secondly, it performs the first econometric analysis of the relationship among the three sectors using a Dynamic Conditional Correlation model and the first application of the multifactor market model to the water industry. Finally, the paper presents the first use of the S&P Global Water Index in an academic context, presenting this databank to the wider research community through one of the uses that can be made of this resource.
The paper is organized as follows: Section 2 focuses on issues related to the relation between the three sectors, Section 3 focuses on the water issues, Section 4 presents the empirical framework, Section 5 presents data, Section 6 reports the results, Section 7 discuss main conclusions.

2 The relationships between water, agriculture and energy sectors

Population growth, changes in lifestyles, increasing prosperity are putting rising pressures on resources. According to international organizations - such as the FAO, the International Food Policy Research Institute IFRI and the International Energy Agency IEA – by 2030 the demand for food, energy and water is expected to rise by 30-50%.
Resources are scarce and shortages could impact on communities and cause social and political instability, geopolitical conflict, environmental degradation.
Consequently, in order to satisfy such an increased demand many efficiency improvements for both development and implementation need to be exploited: new sources for food, changes in water use, more efficient mix of energy production systems.
Improvements require not only research and developments investments and funds, but also an integrated approach since WEF are strongly interrelated. Indeed, agriculture and food production require large amount of water and energy in all the production stages; energy production needs water as well as bio-resources; water extraction and distribution requires energy. Bazilian et al (2011) clearly and exhaustively identify the descriptive elements of the WEF nexus. Among them:

- all three areas have many billions of people without access (quantity or quality or both. Lack of access to modern fuels or technologies for cooking/heating; lack of access to safe water; no improved sanitation; people chronically hungry due to extreme poverty; lack of food security);
- all have rapidly growing global demand;
- all have resources constraints;
- all have different regional availability and variations in supply and demand;
- all have strong interdependencies with climate change and the environment;

Figure 1 is a diagram that shows the WFE interrelations (World Economic Forum 2011).

Given those interrelations, any improvement strategy that focuses on water, food and energy without considering the nexus risks unintended negative consequences. For example, shale gas extraction can reduce the use of fossil fuels and is cleaner-burning than oil and coal; however, hydraulic fracturing requires large amount of water and this reduces the availability of water for other uses. Moreover, the fluid injected into the subsurface contains chemical additives that can contaminate surrounding areas. Likewise, the use of biofuel reduces vehicle emissions, but may impact worldwide availability of food and lead to higher agricultural prices.
Those are clearly trade-offs that policy makers have to think about when assessing planning for investments, actions and policies. Water, food and energy relation needs global governance and integrated response strategies.

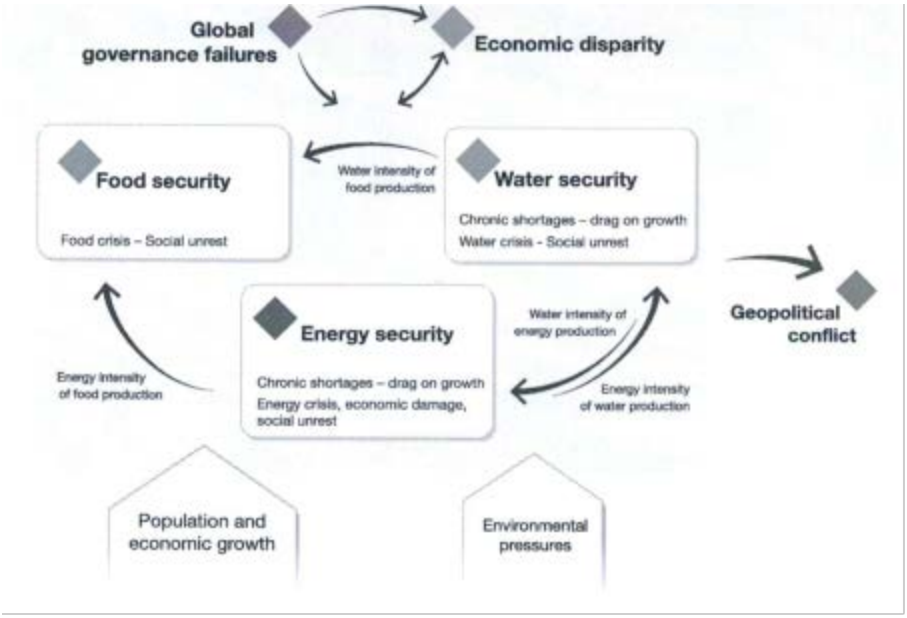

Figure 1. *Diagram of WFE interrelations*
Source: World Economic Forum, 2011

3 Exploring the water sector

Water is a key component of the nexus, and will be the lens we use to investigate it. Indeed, water has no substitute and it is essential to life. This makes its demand independent from the main traditional economic drivers (such as inflation, economic cycle, income, etc.) and increasing over time, as population grows, while supply remains fixed. Although water covers most of the globe, with a total volume of 1.4 billion km3, the volume of freshwater is only 2.5% of the total (around 35 million km3) and the latter is not evenly distributed on earth. Around 70% of water is in form of ice and snow, 30% is groundwater and only the 0.3% is represented by lakes and rivers. These water basins in most cases are shared between nations and this creates further tensions and difficulties in accessing the resource (Unesco, 2012). According to the FAO estimates (2012), around 45% of the world freshwater is in the Americas, 28% in Asia, 15.5% in Europe and the remaining is located in Africa (9.3%) and Oceania (2.1%). Data highlight the imbalances between demand and supply of freshwater around the globe, with Asia accounting for more than 60% of population with only 28% of resources. Africa also lives a shortage in water, representing the 15% of world inhabitants and having access to less than the 10% of freshwater; the situation is made more severe by its arid climate, which characterizes especially the north of the continent.
The already limited availability of freshwater is likely to further diminish in the next years because of climate changes, increasing needs for a growing population and an ageing infrastructure that will have

to be repaired or substituted. It is estimated that in 2050 more than half of the population will be short of water (Summit Global Management, 2012).
Together with natural scarcity, also economic scarcity exists in areas where water is abundant relative to demand, but still malnutrition exists, depending on socio-economic conditions, lack of water management and of proper infrastructures (Unesco, 2012).
Water is used in a plentiful range of human activities and is a key component in the water-energy-food relation. Its demand is mainly driven by agricultural (70%) and industrial activities (around 20%), while domestic use accounts only for 10% of the freshwater withdrawals (Unesco, 2012). To consider the impact of agriculture and manufacturing on the water resources, researchers have created a water footprint measure (beside the well-known carbon footprint) that evaluates how much water has been used to produce a given product or service.
Water has also a tight two way relationship with energy. The latter is employed in the withdrawal and distribution of water and water is used in the generation of energy. An example is provided by shale gas extraction, where hydraulic fracturing or fracking using huge amounts of water enables to release gas from the shale (Maxwell, 2013). It is really difficult to forecast what will be the demand of water for energy production in the future. Understanding and balancing the trade-off between energy production and water consumption will be crucial and new technologies might find ways to optimize the use of water for energy and food production.
The growing demand, the sustainability issues and the relation between water, energy and food create the prerequisites for an increase in the demand of water–related products and services and for an expansion of the sector.
The water sector represents an enormous set of different firms and operators that deal with water supply, water use and wastewater handling; to refer more properly to the water business the term hydrocommerce is sometimes used. Because of the magnitude of the business, its boundaries are not easy to define and its actual size is difficult to determine both in terms of number of firms and in terms of counter value. According to recent estimates, there are at least 400 public companies operating in the water business in the world with a $900 billion market capitalization and these figures are destined to grow in the future (Summit Global Management, 2012).
All the firms in the hydrocommerce will be called to optimize the collection and distribution of water. Infrastructures need to be replaced and this will increase the request for pipes, pumps, valves and other related goods. Collection and storage will involve the creation of new tanks and groundwater banks, while existing dams will need intervention. New technologies will help in the re-use and recycle of water, in order to optimize the use of the resources; in this sense, it is believed that incremental innovation will play a major role in the sector (Maxwell, 2012). Additionally, management tools, including the activity of data collection, data analysis, regulation and governance, needs to be developed (Unesco, 2012). These are essential to accurately estimate the quantity and quality of water and to manage the resource effectively, taking into account increasing uncertainty and risks.

2.1 Financial issues

In order to pursue all the above-mentioned challenges, the industry needs additional capital and funds. For instance, in Africa, one of the most water stressed area of the globe, water and sanitation spending needs for the period 2006-2015 are estimated to be $22.6 billion per year (around 3.3% of Africa's GDP), of which more than $15 billion for investments and the remaining for water maintenance ($5.7 billion) and sanitation maintenance ($1.4 billion) (Foster and Briceño-Garmendia, 2010 in Unesco, 2012). Additional $18 billion are required for small-scale irrigation and $2.7 billior for large-scale irrigation systems for the next fifty years (Unesco, 2012).
Tariffs, taxations and transfers from institutions are not sufficient to guarantee future investments in the industry. Indeed, public contribution in the future might be limited. Funds are scarce and their use needs to be optimized. In fact, although water is commonly perceived as a public good and public intervention in the past has been heavy, forecasts show that the huge amount of capital needed by the industry cannot be exclusively provided by the public sector and more private intervention is expected.
This financing gap can be bridged with the aid of repayable finance. Bonds have been used by municipalities in the US and were successfully subscribed by private investors (OECD, 2010), but the funding gap remains wide (Tracy Mehan III, 2011; Summit Global Management, 2012).

In the years, the industry has attracted (and still attracts) interest by numerous types of investors, such as private equity and venture capital funds, but also ETFs, Hedge Funds and wealthy individuals. These investors can provide funds for the different activities related to water withdrawal, storage, distribution and reuse and recycle.
In this regard, to date, markets have developed some indexes that follow exclusively the dynamics of the water sector. Most of the indexes include firms that operate in the water and waste water industry, according to the broad definition of hydrocommerce (box 1).
As the amount of money invested in the watersector continues to grow, understanding the financial mechanisms behind water companies, the dynamic of the stock prices, and the factors that affect their profitability can be relevant for capital investments and portfolio diversification strategies.

Box – 1.
Financial water sector indexes

Standard and Poor's has developed three main indexes on water. Two of them are equity indexes based respectively on 50 companies that operate globally in the water sector (S&P Global Water Index) and on 30 Asian water businesses (S&P Asia Water Index). The first was created in 2007 and the latter in 2008. The third index by S&P follows the municipal bonds' dynamics and it is constituted by around 3990 bonds in the S&P Municipal Bond Utility Index that operate in the water and sewer sector. Nasdaq OMX also developed two indexes. The NASDAQ OMX Global Water Index (GRNWATERL) tracks the performance of 36 companies around the globe; it was set in July 2011 with a base value of 1,000.00. On the same date and with an equal base value, NASDAQ OMX US Water Index was launched with a focus on 29 companies listed in the US. Another global index is provided by the International Securities Exchange, named ISE Water Index; the index start date was December 2000 with a base value of 25 and it comprises 36 firms that derive an important part of their revenue from the water industry. The World Water Indexes (WOWAX and WOWAXcw) owned by Société Générale have been calculated since 2006. They are constituted by 20 companies that pertain to hydrocommerce. WOWAX is computed using equal weighting, while the second has a market-weighted composition, although no single company can represent more than 10% of the index. The New York Stock Exchange market (NYSE, formerly AMEX) has created in 2003 the Palisades Water Index (ZWI), which is a modified equal-dollar weighted index that includes 30 U.S. listed companies operating in the global water industry.
A number of Exchange Traded Funds (ETFs) have been built on these indexes, in order to track their trends and benefit from the expected expansion of the industry. To date, most of the quoted water related ETF are based on S&P or NASDAQ OMX indexes on the water sector. BlackRock Asset Management manages two ETF with its Irish and Canadian subsidiaries, both launched in 2007, replicating the S&P Global Water Index. The same index is the benchmark for the Guggenheim ETF, whose trading has started in May 2007. Invesco Powershares follows the dynamics of NASDAQ OMX Indexes with its ETFs quoted on NYSE Arca, respectively the PowerShares Global Water Resources Portfolio (PIO) based on the NASDAQ OMX Global Water Index and launched in 2007, and the PowerShares Water Resources Portfolio (PHO) which has been tracking the US Water index since 2005. The London Stock Exchange trades the shares of the PowerShares Global Funds Ireland (PSHO), managed by Invesco Global Asset Management since 2007. The First Trust has set its own ETF following the ISE Water Index, listed on NYSE Arca, while Lyxor International Asset Management manages Lyxor ETF World Water on Euronext and a number of other trading platforms. The latter replicates the World Water Index Cap Weighted ntr.

4 The Empirical framework

4.1 The dynamic conditional correlation approach

T analyze the volatility spillovers among WFE prices, the econometric specification used is a multivariate GARCH system where the mean equation, the variance equation and the time relationships are modelled as follow.
We use a VAR system in the mean equation to allow for autocorrelation and cross correlation in the returns. To let a shock in one index to affect the variance of the others in the system we modeled the variance equation to be vector autoregressive moving average-GARCH (Ling and McAleer, 2003) and, finally, to increase model flexibility for studying over time evolution of the indexes relationships we use dynamic conditional correlation (DCC) model of Engle (2002).
In the multivariate GARCH we use the following mean equation specification:

$$R_{i,t} = \alpha_i + \sum_{j=1}^{n} b_{ij} R_{j,t-1} + \varepsilon_{i,t} \quad (1)$$

$$\varepsilon_{i,t} = h_{i,t}^{\frac{1}{2}} v_{i,t} \quad (2)$$

The returns are indexed by *i*, *n* is the total number of investigated sectors (for WFE n=3). $R_{i,t}$ is the first log difference of *i*th price index at time *t*, $\varepsilon_{i,t}$ is a random error term of the mean equation with conditional variance $h_{i,t}$ and $v_{i,t}$ is the innovation that is distributed as an *i.i.d* random vector.
Information criteria are used for the lag length selection for VAR in the mean equation. Based on AIC information criteria, in all the models tested the number of lag selected for the VAR systems is equal to one.
The variance term is specified as follow (Ling and McAleer, 2003):

$$h_{i,t} = c_j + \sum_{j=1}^{n} \alpha_{ij} \varepsilon_{j,t-1}^2 + \sum_{j=1}^{n} \beta_{ij} h_{j,t-1} \quad (3)$$

Equation (3) is a generalization of the Bollerslev (1990) specification which accommodate for interdependencies of volatility across indexes. $h_{i,t}$ is the conditional variance at time *t*, $h_{j,t-1}$ represent the own past variance when $j=i$ while, when $j \neq i$ it denotes past conditional variance of the indexes in the system.

$\sum_{j=1}^{n} \alpha_{ij} \varepsilon_{j,t-1}^2$ is the short run persistence (ARCH effects) while the long run persistence or GARCH effects is $\sum_{j=1}^{n} \beta_{ij} h_{j,t-1}$.
The dynamic conditional correlation model (DCC) of Engle (2002) is a generalized version of the constant conditional correlation (CCC) model of Bollerslev (1990). The specification of Engle's DCC model is as follows:

$H_t = D_t R_t D_t$ (4)

Where H_t is the conditional covariance matrix, D_t is a *n x n* diagonal matrix of conditional, time varying, standardized residual estimated in a first step by univariate GARCH models, R_t is the *n x n* time varying correlation matrix with the following form[1]:

[1] In Constant Conditional Correlation models $R_t=R$, with R time invariant

$$R_t = diag\left(q_{11t}^{-1/2},...,q_{nnt}^{-1/2} \right) Q_t diag\left(q_{11t}^{-1/2},...,q_{nnt}^{-1/2} \right) \quad (5)$$

Conditionally to the estimated D_t in a second step the correlation component Q_t, that is a weighted average of positive definite and a positive semidefinite matrix, is estimated with the following equation:

$$Q_t = \left(1-\theta_1-\theta_2\right)Q_0 + \theta_1 \varepsilon_{t-1}\varepsilon_{t-1}^{'} + \theta_2 Q_{t-1} \quad (6)$$

where Q_0 is the unconditional correlation matrix of the standardized residual epsilon, ϑ_1 and ϑ_2 are the parameters that respectively indicate the impact of past shocks on current conditional correlation and the impact of the past correlations. The model is mean reverting as long as $\vartheta_1 + \vartheta_2 <1$. The dynamic conditional correlation coefficient $\rho_{i,j,t}$, that are typical elements of Q_t, are calculated by:

$$\rho_{i,j,t} = \frac{q_{i,j,t}}{\sqrt{q_{i,i,t}q_{j,j,t}}} \quad (7)$$

In the empirical application the model is estimated using quasi maximum likelihood estimator (QMLE) by BFGS algorithm. *t* statistics are calculated using robust estimate of the covariance matrix.
For the specific purpose of this study we specify a MGARCH with n=3 considering water, agriculture and energy.

4.2 Multifactor market model

To analyze the impact of agricultural and energy price trends on the water industry we use a multifactor market model.
Multifactor models are an extension of single-factor CAPM models (for a deep analysis of the theory behind multifactor market models see Elton et al., 2010); in addition to the market factors, these financial models employ multiple factors to explain the performance of a security or a portfolio of securities (e.g. an index) (Fama and French, 1993; Fama and French, 1996; Muradoglu et al., 2001; Menike, 2006; Chen, 2009; Singh et al., 2011).
Since asset prices can be viewed as a stream of expected discounted cash flow and factors affecting price changes are related either to changes in expected cash flows or to changes in discount rates, different factors can affect stock prices and, thus, encourage or discourage investments in the water industry.
We argue that agriculture and energy prices may be relevant factors, and we believe that a better understanding of the relationships between water stock prices and agriculture and energy prices is critical to understand the economic interaction and the development of the water industry in the years to come.
The general form of a multi-factor model is:

$$R_t = a + b_1 F_{1t} + b_2 F_{2t} + ...b_i F_{it} + ... + b_n F_{nt} + e_t \quad with\ t = 1,...,T \quad (8)$$

Where:
i=1,.....n: number of factor
R_t : excess equity returns at *t* time
F_{it}: factor *i* at *t* time
b_i: sensitivity of the returns to changes in factor i
e_t : random component, with mean $E(e_t)=0$ and variance $var(e_t)=\sigma^2$.

For the specific purpose of our study, we specify a multifactor market model where the dependent variables are excess stock returns for the water index. Independent variables are excess stock market

returns, agricultural price changes, energy price changes. Excess returns are measured by daily indexes returns minus the three-month US Treasury bill rate. The model is specified as follows:

$$WATER_t = \alpha + \beta_M S\&P_t + \beta_A AGR_t + \beta_E ENERGY_t + e_t$$

with t = 1,…,3008

WATER are the excess daily returns on the water stock index; S&P is the excess daily return to the market index; AGR is the daily return to S&P agricultural price; ENERGY is the daily return to S&P energy prices; and e_t is the idiosyncratic error. β_A is the agricultural beta that is the sensitivity of water stock index to agricultural price changes, β_E is the energy beta that is the sensitivity of water stock index to energy prices changes, β_M is the market beta.

5 Data

To investigate the relationship between water energy and agriculture we use daily data spanning from November 16, 2001 to May 28, 2013 obtained from DataStream. As a proxy for water price we use the S&P Global Water Index that provides liquid and tradable exposure to 50 companies from around the world that are involved in water related businesses. The 50 constituents of the index are distributed equally between two distinct clusters of water related businesses: Water Utilities & Infrastructure and Water Equipment & Materials.

For agriculture and energy sectors we used two sub-indexes of S&P GS-Commodity Index. Specifically we collect the spot index, a measure of the level of nearby commodity prices, for Agriculture-Livestock and Energy. Both the indexes are calculated primarily on a world production weighted basis, and comprise the principal physical commodities that are the subject of active, liquid futures markets[2]. The weight of each commodity in the index is determined by the average quantity of production as per the last five years of available data.

Figure 1 shows trend for Global Water index, Agricultural and Energy indexes. All series show common rising trend, with a strong break during the economic and financial crisis at the end of 2008. After this period prices decreased very fast and grew again at different rate but only agricultural prices have reached and exceeded the past levels. It is interesting to note that Water and Agriculture graphs show very similar trend only after prices crisis, suggesting the existence of a link between them.

We use the S&P price index to measure the equity market performance of developed and emerging markets. The variable interest rate is the yield on a 3-month US Treasury Bill.

Table 1 shows descriptive statistics of continuously compounded daily returns for each series. The t-statistics indicate that the mean is statistically significant only for Global Water index whereas the other indices' means are statistically insignificant from zero. Noticeably, Water indexes returns display a stronger amount of kurtosis than Agricultural and Energy indexes. Skewness is negative for all the indexes. The higher the kurtosis coefficient is above the normal level, the more likely future returns will be either extremely large or extremely small. This fact suggests to us to account for the presence of volatility in our models, using an Autoregressive Conditional Heteroskedasticity (ARCH) approach.

[2] The S&P GSCI Agriculture and Livestock Index comprise the following index components: Wheat, Corn, Soybeans, Cotton, Sugar, Coffee, Cocoa, Feeder Cattle, Live Cattle, and Lean Hogs. While the S&P GSCI Energy Index comprises WTI Crude Oil, Brent Crude Oil, RBOB Gas, Heating Oil, GasOil and Natural Gas.

Figure 1. Agriculture, Energy and Water indexes
Source: our elaboration on Datastream data

Table 1.
Descriptive statistics of daily returns.

	Global Water indexes	*Agriculture price index*	*Energy price index*	*Interest rate*	S&P
Obs.	3007	3007	3007	3007	3007
Mean	0.034	0.028	0.052	-0.121	0.013
Median	0.070	0	0.025	0	0.035
Std. Dev.	1.119	1.096	1.982	17.718	1.301
Kurtosis	8.17	2.66	2.13	76.39	9.15
Skewness	-0.306	-0.218	-0.123	-1.165	-0.202
Minimum	-8.07	-5.81	-9.35	-333.22	-9.47
Maximum	10.90	5.72	9.81	203.69	10.96
t-statistic	1.648	1.416	1.434	-0.375	0.528

Source: our elaboration on Datastream data
*Note: Descriptive statistics are presented for continuously compounded daily returns calculated as 100*ln(pt/pt-1) where pt is daily price.*

6 Empirical results and comments

Tab. 2 reports results of multivariate GARCH estimate. The estimates of these elements can provide measures of the significance of the short-run persistence (ARCH effects of past shocks) and the long-run persistence (GARCH effects of past volatilities).
The first part of the table shows the mean equations estimates and the second one the variance equation estimates. In the mean equation the estimated coefficients of Agriculture in the Water equation (0.033) is positive and significant as well as Agriculture and Energy between them.
In the variance equation ARCH effects are mostly significant. Own conditional effects (a_{ii}) are always bigger than cross effects as expected, with water coefficient (0.083) that shows the strongest shocks dependence. Inter sector shock spillovers are present in both Agriculture and Energy equations.

Long term persistence expressed by GARCH coefficients (bii) is still always present with all the coefficients significant. For each i, the estimated bii values are bigger than their respective estimated aii values, indicating that own conditional volatility is larger than short-run persistence. There is also evidence of cross volatility effects between all the three sectors with many bij coefficients significant at the 1% or 10% level.
θ1 and θ2 that indicate the impact of past shocks on current conditional correlation and the impact of the past correlations respectively are positive and significant at 1% level and their sum is less than one indicating the model is mean reverting that is prices will tend to move to the average price over time.
Table 2 also reports the diagnostic tests Q(12) and Q(20) for the presence of autocorrelation in squared residuals. Overall result is that models perform statistically well.
ARCH and GARCH coefficients highlight that volatility spillover exist between water, agricultural and energy sector; this result is itself relevant since it confirms the existence of a relation in the short and long term.

Table 2.
Multivariate GARCH estimates and diagnostic tests

		Water	Agriculture	Energy
Mean eq.	Water	0.109	0.001	0.060
		0.000	*0.969*	*0.018*
	Agriculture	0.033	0.022	0.038
		0.010	*0.142*	*0.062*
	Energy	0.005	-0.020	-0.038
		0.465	*0.015*	*0.011*
	costant	0.075	0.025	0.073
		0.000	*0.108*	*0.003*
Variance eq.	*ARCH effects*			
	Water	0.083	-0.017	0.015
		0.000	*0.018*	*0.000*
	Agriculture	-0.004	0.039	-0.012
		0.642	*0.000*	*0.127*
	Energy	0.003	0.010	0.035
		0.424	*0.042*	*0.000*
	GARCH effects			
	Water	0.890	0.021	-0.047
		0.000	*0.074*	*0.000*
	Agriculture	0.006	0.956	0.041
		0.394	*0.000*	*0.001*
	Energy	0.010	-0.012	0.956
		0.065	*0.125*	*0.000*
	θ_1	0.018		
		0.000		
	θ_2	0.979		
		0.000		
	Log L	-13,904.82		
	AIC	9.29		
	SBC	9.36		
	HQ	9.32		
	nobs	3006		
	Q(12)	91.631		
		0.871		
	Q(20)	157.787		
		0.882		

Note: Model is estimated using quasi maximum likelihood estimator (QMLE) by BFGS algorithm. P-value in italic.

To better fit with the purpose of this analysis we also report the graphs of the time varying dynamic conditional correlations (fig. 2) that plot the time series for each pair of series: water/agriculture, water/energy, and agriculture/energy. This figure informs us about how effects evolve over time, that is the relationship between price indexes in function of both the history of variance (volatility) that each series as undergone and correlation between them.
On the overall, the dynamic conditional correlation is positive. A very strong break is evident at the end of 2008, when the economic and financial crises occurred. After this moment, a strong upwards pattern is evident for each pair of correlation. Specifically, in few weeks the conditional correlation between water and energy jumps from -0.06 up to 0.60; similarly, the conditional correlation between water and agriculture increases from -0.03 to 0.59.
Interestingly, before financial crises, correlation between agriculture and energy is always stronger than correlation of the two variables with water. Moreover, the water and energy relationship in few small windows shows negative values. Conversely, after the global economic downturn this evidence becomes not so clear since in many periods the dynamic conditional correlation between water and energy and water and agriculture is higher than the correlations between agriculture and energy. This highlights the rising relevance of water issues within the nexus.

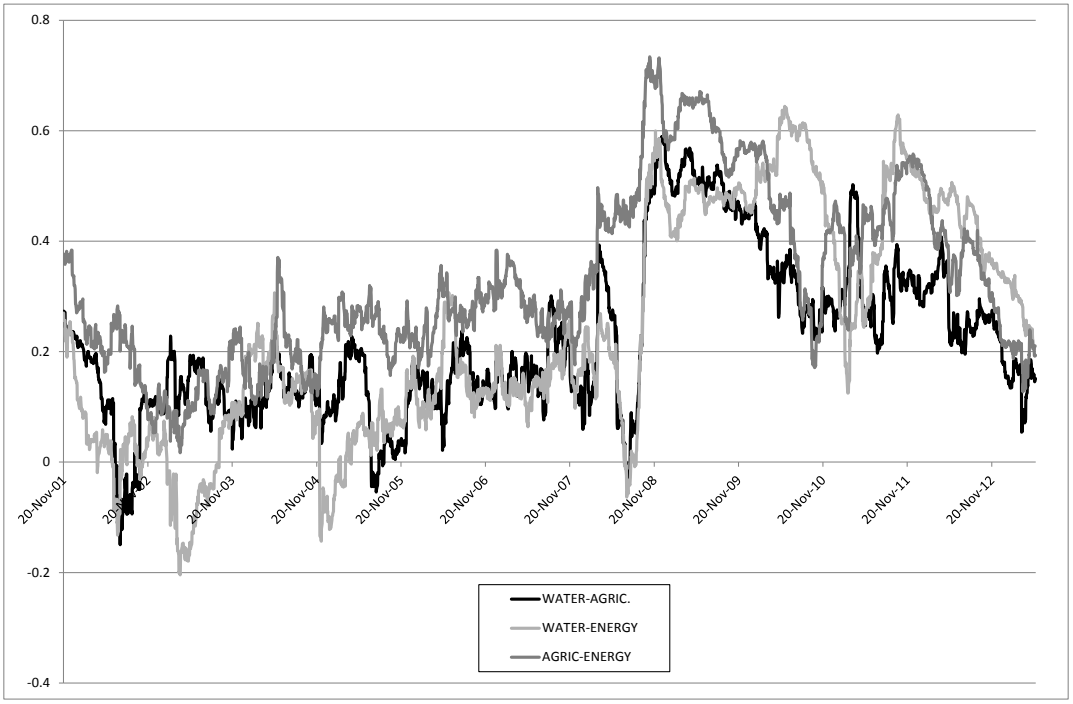

Figure 2. Time-varying conditional correlations

The effects of energy and agriculture on water is supported by the results of the multifactor market model. The previous analyses in Figg. 1 and 2 suggest that one breaks should have occurred during prices crisis at the end of 2008. Chow test reject the null hypothesis of no breaks at specified breakpoints (30/07/2008) at the 1% level so we decide to carry out two different models: one for the whole period and one for the sub-period August 2008 until Maj 28, 2013. This comparison allows us to verify if during this sub-period agriculture and energy prices influenced differently the returns on Water Global Index.
Provided that we are using series showing excess of kurtosis (as Table1 specifies), we also account for the presence of volatility, and in particular, we first test the autoregressive conditional heteroskedasticity in the OLS residuals (Engle, 1982) utilizing ARCH test[3]. Results suggest to carry out a generalized ARCH model (GARCH) (Bollerslev,1986) to address the presence of heteroskedasticity. Table 3 shows the estimates.

[3] Result are available on request

We use GARCH(1,1) for both the entire period and the sub-period, and we obtain evidence of no ARCH effects in the residuals.
The estimated coefficient of MSCWI is positive and statistically significant, in line with the literature on the capital asset pricing model (CAPM). Thus the water index is positively affected by stock market returns. What is interesting is that the energy betas is also positive and significant, supporting the hypothesis of an economic nexus. Indeed, energy is primarily derived from oil; a raise in oil prices may drive an increase in demand for alternative energy sources.
Among others, those alternative energy sources come from the hydroelectric sector and from shale gas, that makes intensive use of water during the extraction process. In this perspective the water industry performance is positively affected by the energy price changes.
Another interesting result is that after 2008 global crises agriculture betas is also positive and significant. This is not surprising provided that during the crisis, prices grew a lot also for the scarcity of agricultural supply due to the biofuel competition and above all the drought problems. This situation drives demand for water sanification, recycle, collection and storage, again with positive impacts on the water industry performance.

Table 3.
GARCH Estimates of multifactor model

	full period		after crisis period	
mean equation				
S&P	1.000	***	1.001	***
Agriculture	0.014		0.027	*
Energy	0.022	***	-0.007	
C	0.000		0.000	
variance equation				
RESID(-1)^2	0.071	***	0.063	***
GARCH(-1)	0.913	***	0.923	***
C	0.000	***	0.000	***
Adjusted R2	0.997		0.999	
ARCH(10)	0.656		0.737	
p-value	*0.766*		*0.690*	

*Notes: ***, **, * denote 1%, 5% and 10% level of significance, respectively.*
ARCH(10) is Lagrange multiplier (LM) tests for autoregressive conditional heteroskedasticity in the residuals(Engle, 1982) at lags10

7 Conclusion

The new lines upon which is based the concept of sustainable development aim to analyze jointly water, energy and food. In this context, policy makers must operate by selecting those policy instruments acted to maintain a balance between the three components in order to avoid unwanted and distorted results.
Indeed, a policy that gives priority to the support of energy development will be reflected in a decline in the availability of water for other uses (e.g. agricultural) with a consequent increase in the prices of agricultural commodities and an increase in costs for water and sanitizing. This would result in higher costs for the community. Similarly, a policy based on priority support to agriculture and devoting the major water resources to this primary sector may cause competition for human use and for energy products with a consequent increase in the prices of final products.

In a context where global economies and sectors are strongly connected, the forecast of population growth are impressive, and globalization has reduced the spatial dimension of trade, it is useful to identify pattern of sustainable development able to maintain the balance between these three areas adopting policy instrument able to avoid price shock transmission between the three sectors. Within this framework political, economic and technical tools need to be arranged in order to help policy makers to develop strategies aimed to ensure a sustainable development based on the WFE nexus.

Adopting an economic perspective, there are different ways that can be taken into account in order to provide support to policy makers to monitor these trends. In this paper, we make a small step in this direction by focusing the analysis of the dynamics of the three markets, which, as mentioned before, can be seen as a barometer to monitor the balance of the relations between WFE. Specifically we used two sub-indexes of S&P GS-Commodity Index for Agriculture-Livestock and Energy prices, while for water, given that do not exist a global price, we proxies it by using the S&P Global Water Index that provides liquid and tradable exposure of two distinct clusters of water related businesses: Water Utilities & Infrastructure and Water Equipment & Materials.

The analysis is carried out following two steps. Firstly, we applied a Multivariate GARCH model to test and quantify the presence of spillover effects between Water index, Agricultural and Energy price change.

ARCH and GARCH coefficients highlight that volatility spillovers exist between the three sectors and this result is itself relevant since it confirms the existence of a relation in the short and long term.

The Engle (2002) DCC specification of the MGARCH framework allowed us also to track the trend of the relationships between variables by the plot of the time varying dynamic conditional correlation for each pair of series. The plot clearly shows that a very strong break is evident during the economic crisis at the end of 2008. After this break the dynamic conditional correlation (water-energy and water-agriculture) is stronger in respect to the previous period, even if during the latest observation seems to revert to the level before the break. This figure highlight the existences of a financial relation between WFE that is particular exacerbate during finance turbulence suggesting to better investigate the rising relevance of water issues within the nexus.

In a second step of the study we focused on a specific component of the nexus – water - which is particularly relevant and scarcely analyzed within the context of the nexus. We performed a multifactor market model to analyze the impact of agriculture and energy price changes on the share price value of exchange-listed companies of potable and wastewater industry. Results show that the energy beta is positive and significant for all the period considered, that is the water industry performance is positively affected by the energy price changes. Agricultural return is also positive and significant, but only after 2008 global crisis.

The growing demand, the sustainability issues and the WFE relation create the prerequisite for an increase in the demand of water-related products and services and for an expansion of the sector. Financial markets incorporate those expectations, with positive externalities on the performance of the water industry. This may attract investors and increase the availability of external funds to bridge the 3Ts gap.

This is one of the first exercises trying to empirically analyze the prices relation between these sectors that are considered as the basis of the new concept of sustainable development. The complex interactions and policy implications that consider all three sectors together, need more work in order to effectively support decision-making.

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