The Impact of Energy and Agriculture Prices on the Stock Performance of the Water Industry

Abstract:
Water issues are receiving increasing attention from policy-makers and international organizations due to water scarcity and global rising demand. Given that the demand for water is mainly driven by agriculture and energy, we use a multifactor market model to analyze the impact of agriculture and energy price trends on the price of listed companies operating in the water industry. Evidence highlights a sensitivity of water stocks returns to agriculture and energy price changes. Additionally, when using state space model to estimate dynamic beta coefficients, factor sensitivities show a time-varying behavior, especially during the 2008 economic and financial crisis.

1. Introduction

This paper aims at analyzing the impact of agriculture and energy price trends on the share price value of companies operating in the water industry, i.e. exchange-listed companies whose revenue derives largely from the potable and wastewater industry.

Our interest stems from the fact that the demand for water and water-related products is increasing, mainly driven by agriculture and energy withdrawals, which in their turn are also likely to increase in the future, as pointed out by recent research [1]. This will generate a pressure for expansion of the water industry that will be called to satisfy the growing needs of agriculture and energy. In fact, agriculture accounts for the 70% of water consumption, used for irrigation, livestock, crops and non-food crops production processes. Demand for food is expected to increase by 35% by 2030 due to global growth and changes in lifestyles, and this will consequently increase the demand for water [2]. The energy sector, on the other hand, is the second-largest consumer of water, for cooling at thermal power plants. Water withdrawals by the energy sector will increase as well. In fact, energy prices fluctuations and political considerations are generating demand for alternative energy sources that may imply intensive water usage, such as hydroelectric energy, but also biofuels and shale gas [1, 3, 4, 5], as well as energy-saving techniques [6].

Water scarcity and growing demand, together with sustainability issues[1], will drive an increase in the demand for water-related infrastructures, products and services to optimize the use of the resources. In order to meet this growing demand, companies will have to make considerable investments and will consequently need a huge amount of funds. In the water industry, companies have traditionally covered their financial needs with transfers, taxes and tariffs (3Ts), which however will not be sufficient to support the strong development required to face all the above-mentioned challenges [10]. Given the scarcity of public funds, policy intervention could be aimed at promoting and supporting the development of an additional form of finance to be channelled into the industry [11]. Funds may come from capital markets, for instance through the issue of bonds or equities, and understanding the stock price dynamics of this growing industry can inspire capital allocation decisions of investors and financial institutions. Indeed, considering that stock prices can be viewed as a stream of expected discounted cash flow, financial markets may incorporate the growth expectations of the water business into rising water stock prices, related to the growing demand for water-related products, services and infrastructures, increasing the efficiency of production processes and developing new technologies. As highlighted by Jin et al. (2015) [12], evidence on risk-returns of water stock investments is lacking. Within this framework and

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[1] For an overview of water, agriculture and energy sustainability issues see Bazilian et al., 2011 [7], Elobeid et al., 2013 [8], Peri et al., 2014 [9].

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considering that, according to financial theory, stock prices may convey information about the expected expansion of the industry [13], to accomplish our aim we use a multifactor market model where agriculture and energy prices are used as specific common macroeconomic sources of risk for the water industry, according to the above-described mechanism.

Specifically, we use a multifactor market model with state space time-varying betas estimated using Kalman filter to monitor the effect of risk factors over time. This approach is particularly valuable because it enables to study the dynamics of the water stock price and hence evaluate how the latter is affected by agriculture and energy price movements.

For the water industry, 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. For the agriculture and energy sectors, we use two sub-indexes of S&P GS-Commodity Index: the S&P Agriculture-Livestock Index and the S&P Energy Index. We use daily data spanning from November 19, 2001, to March 20, 2014. Results highlight that agriculture and energy prices are significant risk factors affecting water stock prices and have a time-varying behavior, especially during the 2008 economic and financial crisis.

We contribute to the existing literature by providing first insights on the simultaneous effect of agriculture and energy prices on water stock index prices. To our knowledge, studies have so far analyzed the economic relation only between pairs of sectors, or the technical relationship between the three, and hence none of the studies takes our perspective. We argue that understanding this relationship is of great importance from an economic, environmental and ethical perspective, as recently outlined by many international organizations [1; 2; 14]. It may help policy-makers in the decision process and in the design of appropriate policies aimed at contributing to the development and to the promotion of innovation of the water industry, as well as at fostering the channel of additional finance.

The paper is organized as follows: Section 2 focuses on the water sector and earlier literature, Section 3 presents the research methodology, Section 4 describes the data, Section 5 reports and discusses the results, and Section 6 draws the main conclusions.

2. Background

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 [15].

The activities of water-related businesses are peculiar because of the characteristics of the resource they manage and treat, i.e. water. Indeed, water has no substitute and it is essential to life. This makes its demand increase over time, as the 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 [1]. According to FAO estimates [16], 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 the population with only 28% of resources. Africa also lives a shortage in water: it hosts the 15% of world inhabitants and has access to less than 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 [17]. It is estimated that in 2050 more than half of the population will be short of water [15]. Together with natural scarcity, also economic scarcity exists in areas where water is abundant relative to demand, but malnutrition still exists, depending on socio-economic conditions, lack of water management and of proper infrastructures [1].

2.1 The water industry
Companies in the water sector play an important role in developing new technologies and processes for water sanitation, storage, distribution, reuse and recycle. 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 reuse and recycle of water, in order to optimize the use of the resources [18]; in this sense, it is believed that incremental innovation will play a major role in the sector [19]. Additionally, management tools, including the activity of data collection, data analysis, regulation and governance, need to be developed [1]. These are essential to accurately estimate the quantity and quality of water available and to manage the resource effectively, taking into account increasing uncertainty and risks.

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) [20]. Additional 18 billion US dollars are required for small-scale irrigation and $2.7 billion for large-scale irrigation systems for the next fifty years (1).

Tariffs, taxation 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. Even recent analysis of water governance arrangements in OECD countries flagged the lack of finance as a major and recurrent gap in water policies [11]. Indeed, in the last few years, the water industry has started attracting interest by numerous types of investors, such as private equity and venture capital funds, but also ETFs, hedge funds and wealthy individuals[2]. These investors can provide funds for the different activities related to water withdrawal, storage, distribution and reuse and recycle. With reference to this issue, Roca et al. (2013) [22] examined the portfolio returns of water investments and find that this industry outperforms traditional assets and enables better diversification especially during times of market stress. Also, Jin et al. (2014) [23] find similar results.

In this regard, to date, markets have developed some instruments to cope with climate change[3] and specifically for the water industry, some indexes that follow exclusively the dynamics of the water sector – besides the ones which include water business in the utilities universe – (e.g. the S&P Global Water Index, the Nasdaq Water Index, the ISE Water Index, etc.). As also underlined by Rompotis (2009), the advantage of investing in a water index is to gain exposure to the entire water market rather than in a specific water company. Indeed, most of the indexes include firms that operate in the water and wastewater industry, according to the broad definition of hydrocommerce. Moreover, a number of Exchange Traded Funds (ETFs) have been built on these indexes, in order

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[2] According to the statistics provided by State Street Global Advisors, the total AUM of the 7 ETFs on Water businesses amount to $1,199 million, around 0.07% of the total AUM invested in equity in the developed markets. Among the US listed ETFs, the three ETFs First Trust ISE Water Index (FIW), Powershare Global Water (PIO) and Guggenheim S&P Global Water Index ETF (CGW) have an overall market capitalization of $827 million on a total market capitalization of the ETFs in the US of $1,450.72 billion, according to XTF.
[3] For a discussion of green bonds, see Flaherty et al. 2016 [21].

to track their trends and benefit from the expected expansion of the industry (e.g. the IShares Global Water Etf, the Invesco PowerShares Global Water Resources, the Lyxor Etf World Water, etc.).

2.2 Earlier literature

Recent empirical papers provide only a few attempts at frameworks aimed at analyzing the effect of agriculture or energy on the water sector from an economic perspective and on a global scale. Generally, this topic was analyzed in the literature following different approaches – technical or economic – and different fields of application (or points of view) – agricultural to water, energy to water separately, or jointly agriculture and energy to water.

The technical approach has been addressed more often to analyze the relationship between energy and water. Studies mainly focus on energy consumption and water use applying life-cycle evaluation or numerical simulation (24; 25; 26). Among the most recent papers focusing on the energy-water nexus, Gu et al. (2014) [6] use input-output tables to describe the supply consumption relationship between water supply and primary energy sectors, while Nogueira Vilanova and Perrella Balestrieri (2015) [28] focus on the case of Brazil. Works considering jointly agriculture, energy and water are less common (among others see [8, 9, 29, 30, 31]). These studies analyze the technical connection that exists between the three elements in order to highlight the need for a joint policy aimed at ensuring a sustainable development.

Conversely, the studies following a strictly economic approach focus only on pairs of relationships separately, i.e. agriculture-water or energy-water.

As far as agriculture and water, few studies deal with the effect of agricultural prices on water demand and management. Lipton et al. (2003) [32] finds that the decline in investment in irrigation is largely ascribed to the falling economic rate of return of irrigation projects and this is, in part, due to declining agricultural prices together with technical reasons. This would mean that in a world with falling agricultural prices, water companies have fewer resources to be invested and this, in the end, would bring to declining revenues for water companies that finally translate into decreasing stock prices. In the same fashion go the work by Bjornlund and Rossini (2005) [33] and Brennan (2006) [34] who find that water demand is positively related to commodity prices, although the latter appears to be less important than water scarcity. Von Braun (2008) [35] states that the food price crisis has increased competition for land and water resources for agriculture, and declining capital for long-term investment due to the credit crunch has resulted in a re-evaluation of natural resources. Finally, Wheeler et al. (2008) [36] use a wide variety of agricultural prices to estimate water allocation, but they find that none displayed any significance in the tested model.

Because of the relationships above described, and summarizing the contribution of the literature, we

can expect that increasing agricultural prices will generate a pressure on the water industry for developing more efficient water distribution techniques that will yield, in the last instance, to investments and higher returns in the water industry [2].

H1: agriculture price trends positively influence water stock returns.

A wider strand of literature, focusing on pricing issue in the water sector, has provided numerous contributions, but lies beyond our scope: the reader might refer to Bar-Shira et al. (2006) [37]; Galioto et al. (2013) [38]; Vasileiou et al. (2014) [39]; Yang et al. (2003) [40]. Additionally, other studies with on a microeconomic approach study the firm-specific determinants of the water industry stock returns [22, 41]. In particular, Roca et al. (2015) [41] analyze the impact of balance sheet variables on the WOWAX index and find that sales and administration expenses and account receivables have a positive impact on abnormal returns, while EBIT, account payable and labor force have a negative one.

To the best of knowledge, there are only two studies considering the economic relation in energy-water that directly focus on the impact of energy prices on water sector [3, 42]. The authors find that rising energy prices increase costs for water extraction and conveyance thus altering water allocation and distribution. Indeed, energy is an input in the water business: as such, rising energy prices increase the marginal cost of water, with a depressing effect on profitability and, as a consequence, on water stock prices. These considerations bring us to elaborate the following hypothesis:

H2a: energy price trends negatively influence water stock returns.

Despite this, the effect of energy on water stock prices is still an understudied issue and factual explanations suggest that also a positive relationship may hold. In fact, a positive relationship would mean that the energy sector is a demand source of water which is employed for production purposes (e.g. shale gas). This increased demand translates into higher water stock prices because of the financial mechanisms already explained above. Additionally, the development of technologies to extract water more cheaply and transport water more efficiently can offset the effects of rising energy prices, which are expected to induce adoption of new and better technologies, stimulating investments and future revenues in the water industry, that are incorporated in rising stock returns.

H2b: energy price trends positively influence water stock returns.

The novelty of our paper is to provide first insights on the economic relation not only between energy and water or agriculture and water but considering how both agriculture and energy simultaneously influence the water sector using water stock prices.

3. The multifactor market model

3.1 Theoretical approach

To analyze the impact of agricultural and energy price trends on the share price value of water companies we use a multifactor market model.

Multifactor models are an extension of single-factor Capital Asset Pricing Model (CAPM). As known, the single-factor CAPM model uses only the market index, while multifactor models employ a multidimensional set of common factors in addition to the market factor to explain the performance of a security or a portfolio of securities. The basic idea behind these models is that the common variation in asset returns is determined by multiple common components, or risk factors [43; 44; 45; 46; 47; 48; 49; 50 for recent empirical applications see: 51; 52; 53; 54; 55; 56].

The general form of a multifactor model is:

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

Where:

i=1,..., n: number of factors

R_t: excess equity returns at time t

F_{it}: factor i at time t

b_i: sensitivity of the returns to changes in factor i

e_t: random component.

Among the several characterizations of the multifactor models (i.e. macroeconomic, fundamental, momentum, or statistical factors – 57; 58; 59), this study employs a macroeconomic approach.

The use of multifactor models with macroeconomic factors is common in the empirical literature on the stock prices of commodity-related industries. Among others, Sadorsky and Henriques (2001) [61] apply a multifactor market model to evaluate the returns of Canadian paper and forest products companies. The factors are commodity prices returns, together with market index returns, interest rates and exchange rates. Also Boyer and Filion (2007) [62] use a multifactor market model with macroeconomic factors, to test the dynamics of Canadian oil and gas stocks prices using crude oil return and natural gas returns, the market return, exchange rates, while Ramos and Vega (2011) [63] use market portfolio, currency rates and oil prices to investigate oil and gas industry returns in developed and emerging markets. Among the most recent analyses that apply the multifactor model, Mo et al. (2012) [54] choose four factors to proxy the performance of European electricity

corporations: overall market return, electricity price changes, oil price changes and EUA (EU emission allowance) price changes.

The model, in addition to the market factor, selects two specific common macroeconomic sources of risks that best fit the analysis framework: energy and agriculture price trends. This choice is justified by the following considerations: oil price is generally included among the set of systematic risk factors since fluctuations in energy prices can be expected to have an effect on security prices given the global economy relies on oil as a major energy resource. Its fluctuations and effects can be severe especially in extreme market conditions [60]. Besides energy, for the specific purpose of this study, the price of agriculture commodities is introduced in the model as a further common factor that can have an impact on water companies equity returns.

The model is hence specified as follows:

$$Y_t = \alpha + \beta_1 X_{1t} + \beta_2 X_{2t} + \beta_3 X_{3t} + e_t \qquad (2)$$

with t = 1,…, T

Y_t is the excess daily return on the water stock index; X_1 is the excess daily return to the market index; X_2 is the daily return to agricultural prices; X_3 is the daily return to energy prices, and e_t is the idiosyncratic error. β_1 is the market beta, β_2 is the agricultural beta that is the sensitivity of water stock index to agricultural price changes and β_3 is the energy beta that is the sensitivity of water stock index to energy prices changes. Excess returns are measured by daily indexes returns minus the three-month US Treasury bill rate that is commonly employed as a reference for the free risk rate of return[4].

Given that we use daily data[5] we expect that the series exhibit volatility across time and that the conditional variance during some periods may be unusually large. In this case, heteroscedasticity could lead to incorrect inferences and employing estimation methods that use conditional variances appears more appropriate for this type of data. Between several approaches dealing with heteroscedasticity, the Generalised ARCH (GARCH) model allows the conditional variance to follow an ARMA process for both auto-regressive and moving average components in the heteroscedastic variance. Because of these reasons, this paper uses GARCH(1,1) to estimate the variance-covariance matrix of returns, in order to obtain the estimates of beta. We consider the following specification:

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[4] See also the webpage by Kenneth French (http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html) who employs US T bill for the computation of European and developed markets factors. We thank an anonymous referee for remarking this.

[5] Data are better described in section 4.

$$Y_t = \beta X_t' + e_t \qquad (3)$$

$$\sigma_t^2 = \omega + \alpha e_{t-1}^2 + \beta \sigma_{t-1}^2 \qquad (4)$$

Eq.(3) is the mean equation. Y_t is the dependent variable, $X_t's$ are regressors as in eq.(2) and e_t is the error term.

Eq. (4) is the variance equation. σ_t^2 is the one-period-ahead forecast variance based on past information and it is called the *conditional variance*. ω is the constant term, e_{t-1}^2 is the ARCH term and σ_{t-1}^2 is the GARCH term.

3.2 Time-varying betas

When applying the CAPM in its basic form, it is generally assumed that the beta coefficients are constant over time. However, betas can vary because of several factors, such as the leverage effect induced by fluctuations of stock prices, information asymmetries in the market, the dependence of systematic risk on the level of the risk-free interest rate, which also changes over time (see 58, for a general overview). Additionally, also econometric arguments support time-variation in betas, as the stylized fact of volatility clustering.

Although a number of studies have questioned the stability of betas, only a few authors explicitly model the time-varying behavior of systematic risk, also thanks to more recent advancement in estimation techniques [53; 64; 65; 66; 67; 68].

This study considers the case for non-constant betas. To this end, we employ a three-step procedure. First, we use estimation methodologies for regression models which allow for a change in betas, according to the Bai (1997) [64] and Bai and Perron (1998) [70] techniques. They perform linear regression models that are subject to structural changes where regime breakpoints are not known and specified a priori but are estimated. In particular, we use a "pure" breakpoint specification in which all of the regressors have regime specific coefficients varying between regimes. GARCH approach is used in this step.

Second, the evolution of the relationship between excess returns in the water industry and betas is traced using rolling OLS estimates. This procedure tracks an evolving system (i.e. time-varying parameters) and allows evaluating the evolution of the relation of the series over time, requiring the definition of the length of a rolling window.

Third, we employ the state space representation to treat the time-varying coefficients to allow the direct estimation of the time-varying betas. In fact, although various models have been developed to

allow the coefficients to follow a dynamic process, the literature finds evidence that the state space model provides more accurate estimates of systematic risk when using daily market data [71; 72; 73].

This model was introduced in the sixties in the engineering field and, only after many years, it has been used in economics due to the computational complexity. Surveys on the applicability of the state space approach to economics and finance can be found in Hamilton (1994) [74] and Kim and Nelson (1989) [75]. In agricultural economics, the space state models became popular mainly around the nineties (see Bessler et al., 2010 for a review [76]), while the model has been applied to energy issues only more recently (see 77; 78; 79; 80). Also in the financial field applications are various. Among the most recent contributions, Al-Anaswah and Wilfling (2011) [81] use the methodology to study the behavior of speculative bubbles on stock markets, while Berger and Pozzi (2013) [82] study the time-varying degree of world stock market integration in the latest forty years using a state space approach.

Following these consideration, we model eq.(2) in the state space form as follows[6]:

$$Water_t = \alpha_t + \beta_{M,t}\, S\&P_t + \beta_{A,t}\, Agr_t + \beta_{E,t}\, Energy_t + \varepsilon_t \qquad (5)$$

Where the dependent variable and the factors are the same as in eq. (2) , α_t, $\beta_{M,t}$, $\beta_{A,t}$ and $\beta_{E,t}$ are the time-varying coefficients and are assumed to evolve as a pure random walk.

The unknown parameters in such a system can be estimated via the Kalman filter, a very powerful and flexible recursive algorithm that compute the optimal estimates of the state variables for each period t, conditional on the information set available at time t (see [83] for use in econometrics). We use this technique to calculate maximum likelihood estimates of σ^2_{ε}, σ^2_{v} and Q to obtain the filtered values of α_t and $\beta_{k,t}$ variables. We set the initial one-step-ahead predicted values for the state variables equal to the OLS estimates from the static model in eq. (3).

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[6] In its general form, the state-space model of eq.(3) is as follows:

$R_t = \alpha_t + \sum_{k=1}^{3} \beta_{k,t} F_{k,t} + \varepsilon_t \qquad$ (a)

$\alpha_t = \alpha_{t-1} + v_t, v \sim N(0, \sigma_v^2) \qquad$ (b)

$\beta_{k,t} = \beta_{k,t-1} + \eta_t, \eta_t \sim N(\bar{0}, Q) \qquad$ (c)

Where ε_t, $_t$ and η_t are errors terms normally distributed and serially uncorrelated with zero mean and variances σ^2_{ε} and σ^2_{v}, and diagonal covariance matrix Q, respectively. Equation (a) is called observation equation and relates the observed variables to the unobserved state vector while eq.(b) and (c) formulate the dynamics of the state variables.

4. Data

The analysis presented in this paper makes use of daily data supplied by Datastream Thomson Reuters and spanning from November 19, 2001, to March 20, 2014, for a total of 3,219 observations. The water series is the S&P Global Water Index that is composed of 50 liquid and tradable companies from around the world that are involved in water businesses. Specifically, the 50 constituents of the index are equally distributed between two distinct clusters of water-related activities: Water Utilities & Infrastructure (water supply, water utilities, wastewater treatment, water purification, water well drilling, water testing, water sewer and pipeline construction) and Water Equipment & Materials (water treatment chemicals, water treatment appliances, pumps and pumping equipment, plumbing pipes, fluid power pumps and motors, fluid meters and counting devices). Of the 50 constituents, 22 were from the US and weighted for more than 39% on overall capitalization. The total market capitalization of each constituent is greater than $250 million; the median market capitalization is slightly above $3,000 million; stocks are traded on developed market exchanges. The index is "capitalization-weighted", that is the components are weighted according to the total market value of their outstanding shares. The series is "price" indexes, expressive of the dynamics of stock prices alone and without the component of income represented by the distribution of dividends[7].

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[8]. The weight of each commodity in the index is determined by the average quantity of production over the last five years of available data. Moreover, as reported by the S&P company, to be included in the Commodity index, the commodity must be denominated in US dollars but traded in a trading venue located in one of the OECD countries. Given the above, the water, agriculture and energy indexes show coherence in terms of coverage of markets.

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[7] The choice of the S&P Global Water Index has been determined by various considerations on the quality of the Index and on the evaluation of the characteristics of the other indexes available. S&P Global Water provides exposure to a higher number of companies operating in the water related business if compared to other indexes, like the Nasdaq OMX Global water or the ISE Water Index. Additionally, despite not being the oldest index on water, it is the index we identified on the markets as the most often used as benchmark for Water ETFs; while for instance, the ISE Water Index is replicated by only an ETF, to the best of our knowledge.

[8] The S&P GSCI Agriculture and Livestock Index comprises 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, Gas Oil and Natural Gas.

We also use the S&P 500 to measure the equity market performance of developed and emerging markets. This index represents one of the most common benchmarks used in the literature to evaluate the performance of a global investment strategy[9].

Finally, we employ the yield on a 3-month US Treasury Bill as a proxy for the risk-free asset.

We use daily data to obtain the continuously compounded returns, which are given by the following equation:

$R_{i,t} = 100 * \ln(p_{i,t}/p_{i,t-1})$

Where $p_{i,t}$ is the daily closing price of the index *i* on day *t*; ln is the natural logarithm.

Figure 1 shows the trend for Global Water index, Agricultural and Energy indexes and S&P. All the series show a 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 a different rate.

Figure 1 – Agriculture, energy, water indexes and S&P index (2001=100)

Source: our elaboration on Datastream data

Table 1 shows the 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 indexes' means are statistically insignificant from zero. Skewness is negative for all the indexes; this may be an indication that large negative returns occur more often than large positive returns. The water index returns also display a stronger amount of kurtosis than Agricultural and Energy indexes. The higher the kurtosis coefficient is above the normal level, the more likely future returns will be either extremely large or extremely small (fat tails), that is large outlying observations occur more often than can be expected under the assumption of normality. This fact suggests the need to account for the presence of volatility in our models, using an Autoregressive Conditional Heteroskedasticity (ARCH) approach.

Table 1 - Descriptive statistics of daily returns (11/2001-3/2014)

	Water index	S&P	Agriculture price index	Energy price index
Obs.	3219	3219	3219	3219
Mean	0.036	0.015	0.027	0.049
Median	0.080	0.035	0.000	0.020
Std. Dev.	1.097	1.271	1.073	1.930
Kurtosis	8.369	9.507	2.794	2.336
Skewness	-0.324	-0.212	-0.211	-0.123
Minimum	-8.070	-9.470	-5.815	-9.347
Maximum	10.902	10.957	5.717	9.809
t-statistic	1.873	0.690	1.415	1.445
Sharpe ratio	*13.8%*	*10.2%*		

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 the daily closing price.

We also measure the risk-adjusted performance based on the Sharpe ratio computed as the excess return above the risk-free rate divided by the volatility over a given period of time.

Sharpe ratio = $r_i - r_f / \sigma_i$

The Sharpe ratio for the water index is higher than the one for the market, respectively 13.8% and 10%, thus highlighting a better return for unit of risk for the water industry.

5. Results and comments

5.1 Baseline results

We first apply a "pure" breakpoint Bai-Perron (1998) [70] specification to allow for the identification of multiple endogenous break dates. This enables a better understanding of the changing nature of beta coefficients in the CAPM model.

Utilizing eq. (2) the procedure finds two breaks (tab. 2) in 05/23/2003 and 05/08/2008.

Table 2 - Sequential F-statistic test to determine the number of breaks

Break Test	F-statistic	Scaled F-statistic	Critical Value [b]
0 vs. 1 [a]	39.042	156.166	16.19
1 vs. 2 [a]	12.923	51.691	18.11
2 vs. 3	3.092	12.367	18.93

[a] *Significant at the 0.05 level.*
[b] *Bai-Perron (Econometrics Journal, 2003)[79] critical values.*
Note: Break test options: Trimming 0.15, Max. breaks 5, Sig. level 0.05

We then estimate the multifactor market model by OLS for the three periods detected by Bai-Perron breakpoints. Provided that we are linking series showing an excess of kurtosis, we also account for the presence of volatility, testing the autoregressive conditional heteroskedasticity in the OLS residuals [85] by ARCH test[10].

Results suggest to carry out a generalized ARCH model (GARCH) to address the presence of heteroskedasticity. We use GARCH(1,1) for the entire period and the three sub-periods, and we obtain evidence of no ARCH effects in the residuals. Table 3 reports the estimates.

Table 3 – GARCH Estimates of multifactor model

	full period 11/19/2001-03/20/2014		1°subperiod 11/19/2001-05/23/2003		2°subperiod 05/26/2003-05/08/2008		3°subperiod 05/09/2008-03/20/2014	
	mean equation							
S&P	1.000	*0.000*	0.798	*0.000*	0.999	*0.000*	1.000	*0.000*
Agriculture	0.020	*0.119*	-0.102	*0.077*	0.036	*0.086*	0.029	*0.068*
Energy	0.018	*0.009*	-0.005	*0.805*	0.039	*0.000*	-0.013	*0.226*
C	0.000	*0.083*	0.001	*0.049*	0.001	*0.002*	0.000	*0.807*
	variance equation							
C	0.000	*0.000*	0.000	*0.049*	0.000	*0.000*	0.000	*0.001*
RESID(-1)^2	0.066	*0.000*	0.064	*0.020*	0.136	*0.000*	0.031	*0.000*
GARCH(-1)	0.920	*0.000*	0.901	*0.000*	0.816	*0.000*	0.955	*0.000*
Adjusted R2	0.998		0.7479		0.9952		0.9990	
Arch(10)	0.690		0.6798		0.4587		0.6253	
P-value	0.735		0.7436		0.9166		0.7933	

Note: P-values in italic. ARCH(10) is Lagrange multiplier (LM) tests for autoregressive conditional heteroskedasticity in the residuals [85] at lags10.

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[10] Result are available on request.

For the full period, all the common factors are positive and statistically significant. Overall, apart from the overall market conditions that of course, as expected, are key determinants of the price of the water industry stocks[11] (or any stock in general), the macroeconomic factors that proxy common shocks in the agriculture and in the energy sectors appear to be determining the behavior of the water stock returns, especially with reference to energy.

Specifically, the estimated market beta is positive and statistically significant, in line with the literature on the CAPM. Agriculture and energy betas are also positive and significant although the sensitivity of the first is rather weak.

This evidence highlights that agriculture changes positively impact the stock returns of the water industry, coherently with our hypothesis H1. This means that higher commodity prices, also driven by water scarcity, may push investments in the water industry to optimize the use of water. This, in turn, translates into higher growth expectations which are positively anticipated by financial markets with rising stock prices.

Energy also shows a positive coefficient; H2b is verified in line with the fact that energy is a driver of water demand and not only an input. Shale gas and alternative water-intensive energy production techniques may call for a strong increase in water usage which finally yields to increased expected profits for the water industry and rising returns on the stock market.

With reference to the size of the coefficients, the agriculture beta coefficient is quite higher than the energy beta; this is in line with the fact that demand for water is mainly driven by agriculture, while energy sector is the second largest consumer.

Comparison between subperiods allows us to analyze if and when agriculture and energy price changes influence differently water stock returns. In the first subperiod energy beta is not significant whereas agriculture beta is negative and significant. However, in this subperiod results may not be meaningful since there are few observations. In the second subperiod, all betas are positive and significant, that means all common factors impact positively the water excess returns. In the third period, the agriculture beta is still positive and significant whereas the energy is not significant.

The estimated ARCH and GARCH coefficients are found to be both positive and statistically significant, validating the appropriateness of the CAPM_GARCH specification. In particular, the estimated GARCH coefficient after the crisis (0.955) indicates that the volatility of price changes is a more persistent phenomenon than it appeared before the crisis.

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[11] See Jin et al. (2015) [81].

5. 2 Dynamic setting

The different dynamic of betas during time emerging from our first analyses (table 3) supports the hypothesis of time-varying factor sensitivities. Indeed, although the static analysis of beta coefficients brings relevant information about the financial mechanisms behind water stocks, a dynamic analysis of the time-varying behavior of factor sensitivities by application of advanced time series techniques will provide more robust insights. Therefore, we deepen our analyses by investigating the dynamic specification of the model.

To supply more information about the dynamic response of excess returns of water industry to deviations in energy and agricultural prices we first run a rolling regression that is a series of regressions with fixed sample size (called "window") in each regression, that we set at 250 days, i.e. about one financial year. We plot the agriculture and energy betas repetitively estimated together with the evolution of the point estimates of time-varying betas obtained using Kalman filter from eq. 5.

In order to assess the relative superiority of the proposed dynamic specification with a state space mechanism, in the same figure, we plot the constant GARCH estimated from table 2 both for the whole period and for three subperiods, rolling estimated and state space estimated beta coefficients. The latter are based on filtered risk factor estimates that take into account information that was available at time t and appear to be the most flexible techniques in capturing changes in sector sensitivity to the overall market over time.

Figg. 2-4 illustrate the time-varying exposure of water to the S&P, agriculture and energy spread, respectively. The agriculture beta becomes clearly positive during the 2008 economic and financial crisis, highlighting the market perception of the positive sensitivity of the water industry to agriculture price changes. One possible explanation is that, during the crisis, agriculture commodity prices grew considerably, due to the scarcity of agricultural supply. This scarcity derives from different contingencies: among these, the biofuel competition, the increasing food demand from China and India and, last, but not least, adverse weather conditions that led to severe drought and heavy flooding, especially in those areas affected by arrears hydraulic systems.

Given the financial theory that claims that stock prices can be viewed as a stream of expected discounted cash flow, financial markets may have incorporated into water stock prices the growth expectations of the water business and the positive role water management will play in producing sufficient food supplies. These expectations are linked to the ability of the water industry to satisfy the growing demand for water-related products, services and infrastructures, increasing the efficiency of production processes and developing new technologies. It is not therefore surprising that financial markets are able to better anticipate and capture these expectations when the markets

live extreme conditions, such the increase of commodity prices, which might create worries by the policy-makers and the economic community, especially when the increase in commodity prices affects food aspects of population and sustainability issues.

As far as energy, the sensitivity of the water sector alternates between positive and negative domain. Indeed, generally speaking, since energy is an input in production, the increase in prices determines a reduction in expected profits, with a subsequent negative effect on stock returns. Nevertheless, with reference to stock returns in the water industry, an opposite effect might also hold. In fact, a rise in oil price may drive an increase in demand for alternative energy sources. Among others, these alternative energy sources might come from the hydroelectric sector and from shale gas that makes intensive use of water during the extraction process.

As we can see from figure 4, water returns are most frequently positively related to energy price changes, but during the economic crisis, when the estimated betas become negative, highlighting how in this period the extreme increase in prices, due to the oil price bubble, makes the input effect to prevail.

5.3 Geographical patterns

To better investigate the dynamic behavior of prices, we further perform our analysis differentiating on the geographical area (fig. 5 and 6). In this respect, we use a water index that comprises only water firms operating in the US[12], where for instance, the shale gas extraction methodology has received an important support for its development and expansion. In fact, when isolating the US water index in relation to the energy sector, we obtain an interesting, although not surprising, result: the energy beta becomes positive during the crisis in line with the hypothesis that water is important when developing an alternative to traditional energy sources. As far as the agricultural sector, however, there is no evidence of significant differences between the World and North America.

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[12] PowerShares Water Resources (PHO) is a full replication exchange traded fund that follows the NASDAQ OMX US Water IndexSM, which tracks the performance of companies creating products that conserve and purify water for homes, businesses and industries listed on an US exchange.

Figure 2 – Dynamic and static estimates of S&P beta on water industry performances
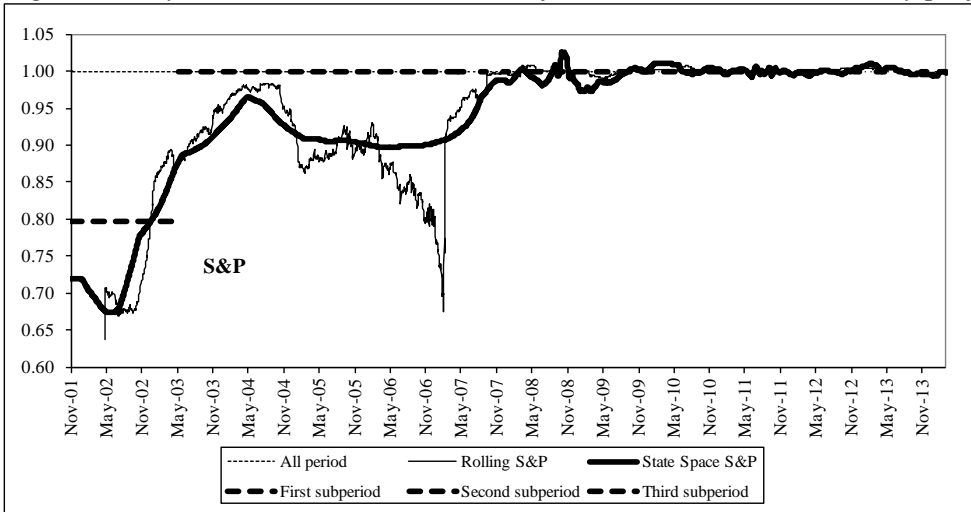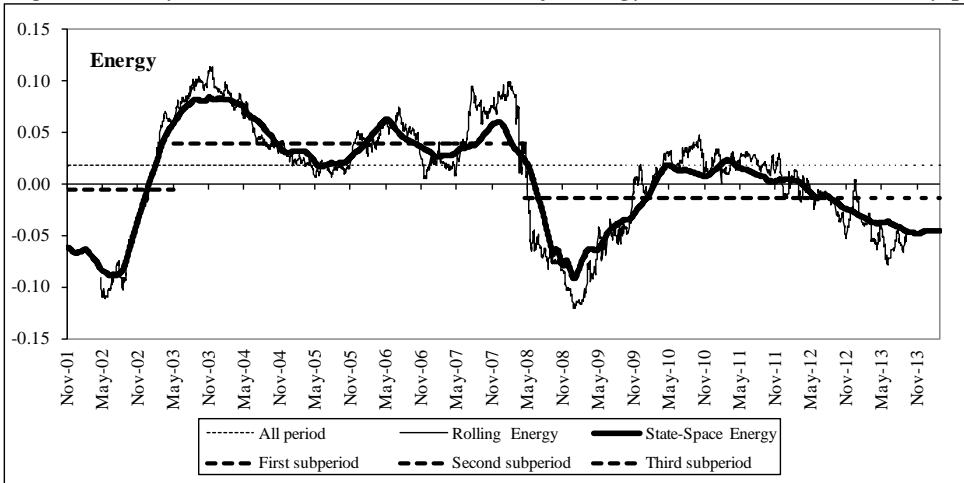

Note: The dotted lines represent the constant GARCH estimates for the whole period and for the three subperiods detected by Bay-Perron (1998) [70] procedure. The thin line represents rolling estimates beta coefficients and the bold line represents Kalman filter betas obtained by State Space model.

Figure 3 – Dynamic and static estimates of agriculture beta on water industry performances
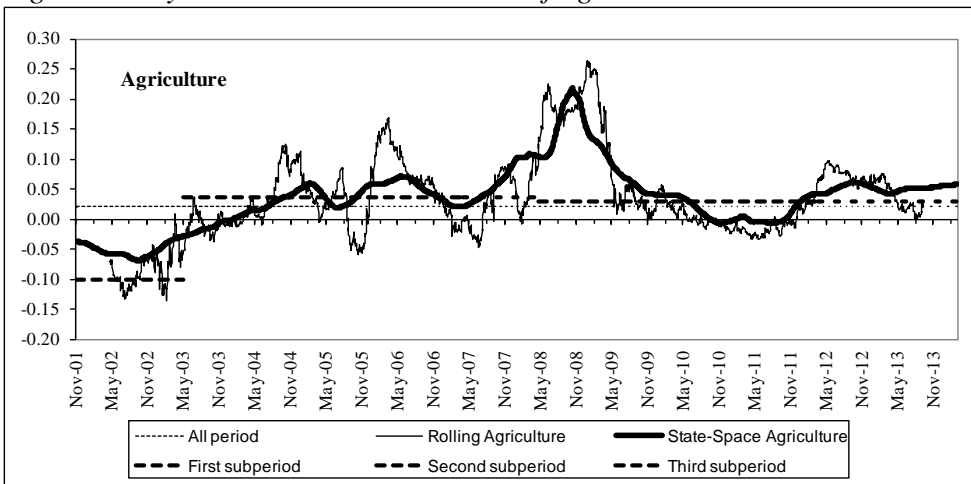
Note: The dotted lines represent the constant GARCH estimates for the whole period and for the three subperiods detected by Bay-Perron (1998) [70] procedure. The thin line represents rolling estimates beta coefficients and the bold line represents Kalman filter betas obtained by state space model.

Figure 4 – Dynamic and static estimates of energy beta on water industry performances

Note: The dotted lines represent the constant GARCH estimates for the whole period and for the three subperiods detected by Bay-Perron (1998) [70] procedure. The thin line represents rolling estimates beta coefficients and the bold line represents Kalman filter betas obtained by State Space model.

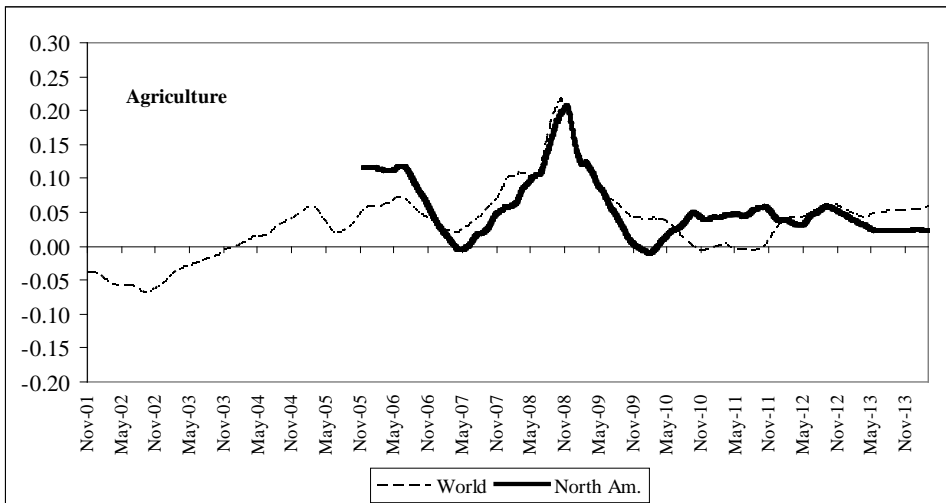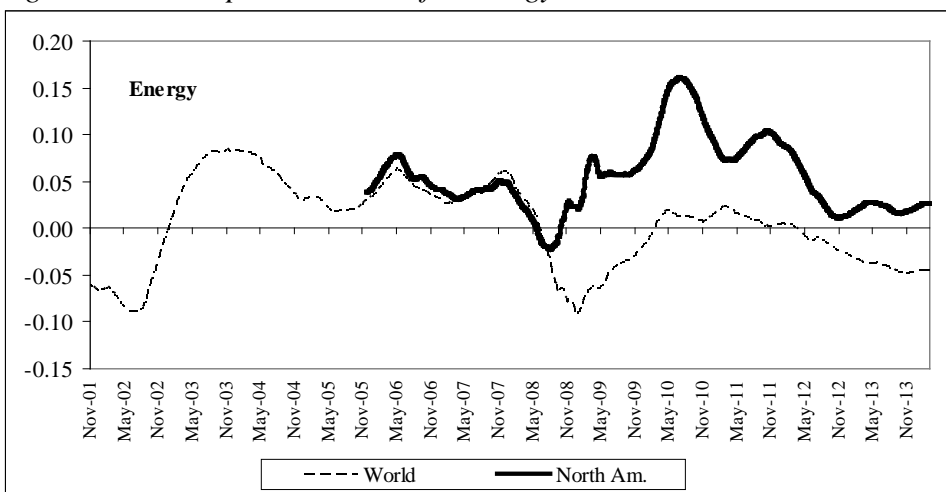*Figure 5 – State-space estimates for agriculture beta: World and North America*

Figure 6 – State-space estimates for energy beta: World and North America

6. Conclusion

In the latest years, the water industry is gaining crucial importance for an economic and social development that takes a sustainability perspective. The demand for water and water-related products is increasing over time, mainly driven by the demand for agriculture and energy purposes. This generates pressures on the industry that is already facing issues deriving from the limited water availability, climate change and ageing infrastructure and that will be called to respond to these challenges by increasing efficiency and introducing innovation.

This paper aims at investigating how the water industry stock prices react to changes in agriculture and energy prices. To this end, we model a multifactor market model where the macroeconomic sources of risk are proxy by agriculture and energy commodity prices and by the excess market return.

To confirm our findings we follow three steps. First, using a GARCH approach we estimate a constant beta for different subperiods identified by a "pure" breakpoint specification; second, we use a rolling OLS estimates to trace the evolution of the relationship between excess returns and betas; third, we employ the state space representation estimating Kalman filter to treat the time-varying coefficients, according to recent advancement in econometric techniques.

Evidence shows that agriculture and energy effectively impact water stock prices, with effects varying over time. Specifically, the agriculture betas become positive during 2008 crisis, highlighting the positive sensitivity of the water industry to agriculture price changes (H1: agriculture price trends positively influence water stock returns). Indeed, agriculture prices grew considerably, among others also for the scarcity of supply and this could have stimulated an increasing demand for water and water-related infrastructures. The energy betas alternate between positive and negative domain. Energy is an input in production, the increase in prices due to the oil price bubble determines a reduction in stock returns (H2a: energy price trends negatively influence water stock returns). Nevertheless, an opposite effect might also hold. In fact, a rise in oil price may drive an increase in demand for alternative energy sources as the hydroelectric sector and from shale gas, that make intensive use of water during the extraction process (H2b: energy price trends positively influence water stock returns). During the economic crisis, the estimated betas become negative, highlighting how in this period the extreme increase in prices makes the input effect to prevail.

Given that financial theory states that stock prices can be viewed as a stream of expected discounted cash flow, financial markets may have incorporated into water stock prices the growth expectations of the water business and the positive role water management will play in producing sufficient

energy and food supplies.

The implications of our study may be relevant for policy-makers in the decision process aimed at contributing to the development and to the promotion of innovation of the water industry, as well as in fostering the channel of additional finance. Indeed, recent spikes in food prices underline the urgent need to invest in agricultural production, of which water management is a crucial part. Moreover, the negative impact of rising energy prices and the introduction of biofuels can also be partially offset by the development and adoption of new water technologies. The traditional sources of funding in the water industry (e.g. the so-called 3Ts) are not likely to satisfy the needs of the sector in the future. The investments through financial markets, made feasible by a number of instruments, such as stocks or ETFs, present an alternative suitable way of fundraising.

Last, but not least, results from this work highlight that water, agriculture and energy are related to each other. Considering the fact that the three sectors have technical relationships, in a perspective of sustainable development in this paper, we maintain that the relationships are also economic, and therefore policy-makers should consider these relationships when defining their policies. To shed additional insight on the water-food-energy "nexus" it is important that future research further investigate the issue.

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Appendix

As already highlighted in the text, indexes used have coherence in terms of geographical coverage. The only exception is the S&P500, that covers only the US, although it is commonly used as reference for the whole market. To evaluate the robustness of results to a different global market index, the estimations are additionally run also using MSCI All Countries that is a global index, although it is less commonly used than S&P 500. The dynamics of results remain substantially unchanged and this confirms the robustness of our results. Results are reported in figure A.
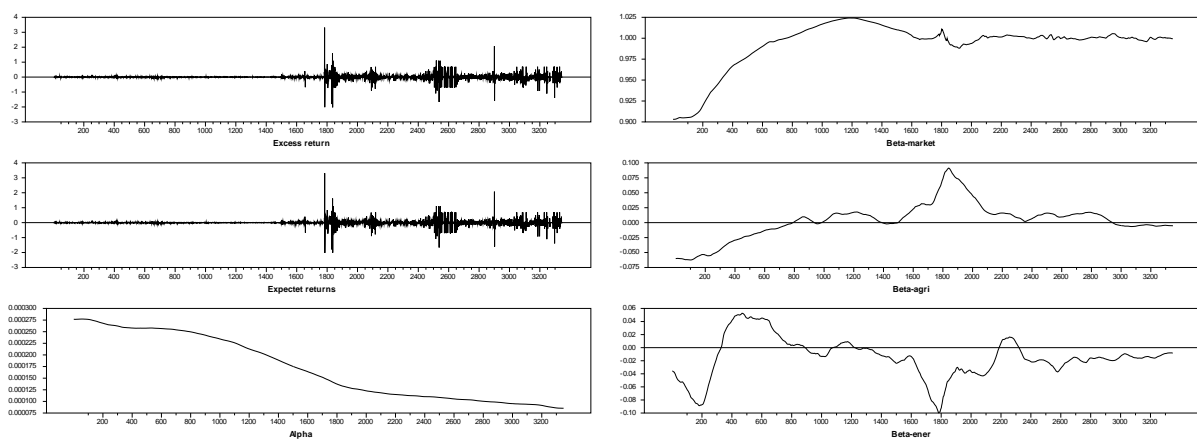

Figure A Time plots from a time-varying CAPM

The three plots on the right report dynamic of state space coefficients for MSCI, Agriculture and Energy respectively. As it can be observed, graphics are similar to those reported for S&P500 (respectively, Figure 2, 3, and 4).