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# Contents

## Abstract

*The global economy is highly dependent on commodity prices, which are, by and large, the outcome of market-specific supply and demand fundamentals. As a result, driven by different determinants, financial assets and commodity prices should be negligibly correlated. However, systematically growing engagement of noncommercial investors equipped with financial engineering innovations on commodity markets, generous inflow of capital resulting from the necessity for wider diversification of investment portfolios combined with the strengthening influence of purely financial and speculative motives have led in the 2000's to a much stronger correlation between the financial and commodity markets, sparking a heated debate on the commodity markets financialisation. The empirical analysis presented here supports the claim that since 2005 commodity markets have been under heavier influence of macroeconomic, financial and speculative determinants. However, the process loses on strength since 2011. Results of the* VARX DCC GARCH *model with leverage effect and multivariate t error distribution demonstrate that the inclusion of the commodity markets' growing sensitivity to macroeconomic conditions, financial markets turmoil and the impact of speculative aspects alters the dynamic conditional correlation path between commodities and the financial markets from 2005 to 2011 signaling the process of financialisation. Additional conclusions are drawn regarding the stability of the market interdependence as well as the parameter estimates.*

**JEL:** C32, C58, E44, Q02
***Keywords:*** commodity markets, financialisation, VARX, DCC, price dynamics determinants

# 1. Introduction

The global economy is highly dependent on commodity markets. Abundant access to a variety of commodities ensures the economic growth, competitiveness on the international market and stable development. Abrupt disturbances of the effective price dynamics on the commodity markets can markedly shape inequilibria in the global economy inducing periods of stark economic slowdown or high inflation. Drastic variations in commodity prices may be the outcome of both shock changes in the market fundamentals as well as the aftermath of destabilizing speculation of financial market agents.

Abrupt changes in commodity prices can lead to the intensification of inflationary or deflationary processes in the economy in two ways: predominantly by stimulating the variations in food and energy prices as well as indirectly by encouraging the second-round effects. Therefore, from the central bank's point of view, it is desirable to monitor the developments on the commodity market, assess the temporariness of price dynamics disruption and understand the underlying nature of drastic commodity price swings for the purpose of adapting the monetary policy adequately and communicating the reasons for it properly.

Before the 2000's commodity prices included the risk premium for idiosyncratic factors and did not present a strong correlation with the financial market. Moreover, the commodity markets were subjected to a strong segmentation. After the dot-com bubble burst in 2000, institutional investors began to perceive commodity instruments as an investment opportunity, largely due to the potential benefits of between-market and within-market diversification. The inclusion of commodities in the investment portfolios of noncommercial investors has triggered a massive influx of capital on the commodity markets. Simultaneously a progressive similarity between the equity and commodity investment returns has been observed. Consequently, during the outburst of the financial crisis commodity price dynamics posed excessive volatility, not typical for a market, which until then had been presumed to be noncyclical and sensitive to market-specific fundamentals.

The generous inflow of capital caused by noncommercial investors' search for yield in the environment of low interest rates, as well as the technological advance coupled with financial engineering innovations could begin the process of commodity markets financialisation[1] inducing higher market cyclicality and sensitivity to financial market developments. On the other hand, the observed drastic commodity price swings could also be attributed to demand shocks as well as dynamically changing market fundamentals in the 2000's.

In light of the unsettled dispute on commodity markets financialisation the principal aim of this paper is to investigate further the probable presence of commodity markets financialisation and bring new evidence to light. In this paper I tackle the identification of the macroeconomic, financial and speculative determinants that could have a significant impact on the commodity prices on global markets as well as determine the relevance of a dynamically changing relationship between the global financial market and the commodity markets. Therefore I use the Dcc Garch model with Varx component, leverage effect and multivariate t distribution to illustrate the effect of separate factors impact on commodity prices developments during 2000-2013 as well as the time-variant interdependence between the equity and commodity markets. The results support the claim that since 2005 commodity markets have been under heavier influence of macroeconomic, financial and speculative determinants.

The rest of the paper is organized as follow. The literature review is conducted in section II. and presents two strands of literature: both skeptics and supporters of the presence of commodity market financialisation. Section III. is dedicated to the description of the data and the methodology of model estimation. Results are presented in section IV. and include the estimates for the whole sample, subsamples as well as additional robustness check analysis. Section V. concludes.

[1] Financialisation in this paper is understood in line with the Domanski and Heath (2007) as well as Casey (2011) definitions.

## 2. Literature review

Bessembinder (1992) as well as De Roon, Nijman, and Veld (2000) state that before the 2000's commodity prices provided investors with the risk premium only for commodity price risk and did not take into account financial developments. Greer (2000) as well as Gorton and Rouwenhorst (2006) indicate that the correlation between the commodity and financial markets historically remained negligible. Similar conclusions obtain Erb and Harvey (2006) which enables them to describe different weight schemes to aggregate commodities in a risk minimizing portfolio. Postulated commodity market segmentation stood in stark contrast to the financial assets bearing systemic risk premiums and being highly correlated both with broad market indices and between themselves (Kanas, 1998; Forbes and Rigobon, 2002; Bekaert and Harvey, 2003; Hu, 2006). Thus, after the dot-com bubble burst, institutional investors managing almost $30 trillion in their investment portfolios (Masters, 2008) and striving for their optimal diversification (Büyükşahin and Robe, 2014) began to embrace commodities in their portfolios launching an excessive influx of capital on the these markets.
The conclusions regarding the presence of commodity market financialisation are varied. Many authors suggest that commodity markets financialisation has a detrimental effect to the commodity price dynamics. However, simultaneously a strand of researchers suggests no statistical evidence of an adverse aftermath of speculative motives of noncommercial investors present on the commodity markets. This section introduces selected arguments from the empirical debate of both sides of the fence.

### *2.1. Lack of financial motives impact on commodity prices*

A popular explanation for the observed price surge in commodity markets among financialisation skeptics is the rapid growth of emerging countries as well as ongoing globalization process. Authors in this stream point out that the dynamic growth of income and the accelerated industrialization in these economies resulted in a sharp increase in import demand, exerting a strong upward pressure on commodity prices on world markets. Consequently, the global economic crisis has caused a rapid diminishment in demand resulting in a collapse in prices. This explanation is formulated among others by Kilian (2009), Hamilton (2009) and Fattouh, Kilian, and Mahadeva (2013). However, Wahl (2009) develops a critique regarding such argumentation stating that for some commodities slowly evolving preferences could not translate into swift rise of import, explain a rapid increase in prices and a subsequent collapse. On the other hand, apart from demand factors, Frankel (2014) highlights also the expansionary monetary policies of central banks, increased level of global product, fluctuations in the level of inventories as well as the spread between spot and forward prices as coincidental determinants of commodity price variations. At the same time he postulates the presence of expectations extrapolation and the bandwagon effect, suggesting the importance of herd behavior in the creation of a speculative bubble. Lastly, Kilian and Murphy (2014) indicate that mainly the demand shocks are important factors of price changes, while financialisation could only amplify the effects of strongly growing demand.
The second stream of empirical studies undermining the concept of commodity market financialistion investigates the changing commitment of investor groups identified by the CFTC. Brunetti, Büyükşahin, and Harris (2011) find no statistical evidence in 2005-2009 suggesting that the traders positions could help predict futures price changes. Sanders and Irwin (2011) advocate that the net positions of swap dealers in the market do not help predict returns of 14 commodity markets in 2006-2009. Hamilton and Wu (2015) note a substantial increase in the share of index funds maintaining long positions in commodity markets in the 2000's, but they claim that the investment positions size of investor groups identified by the CFTC does not help predict the returns of maturing in the near future contracts. However, Valiante and Egenhofer (2013) develop some criticism concerning the identification and reporting of the commodity agents motives by the CFTC leading to the questioning of the results of selected studies.

### 2.2. *Detrimental impact of financialisation*

The literature on the distorting effects of commodity markets financialisation on price dynamics is quite extensive. Tang and Xiong (2012) document that after 2004 the prices of commodity futures contracts included in broad market indices revealed a much higher correlation between themselves, the oil market as well as the financial market than futures contracts not included in commodity indices. The authors argue that the commodity markets have not been integrated with the financial market before the blossom of index investing, whereas the increasing presence of index investors has launched a gradual process of commodity markets financialisation. Pavlova and Basak (2012) state that the presence of institutional investors increases the risk of contagion effects between the futures commodity contracts included in popular market indices. As a result of index investing and the use of heuristics by noncommercial investors, supply and demand shocks specific to a chosen commodity market included in broad index begin to be strongly transmitted to other markets, whereas the price dynamics of futures not aggregated into broad indices react to shocks only locally. Lastly, Girardi (2015) states that the growing correlation of agricultural markets is a consequence of financialisation by presenting the evidence of the financial turmoil importance in shaping commodity prices.

The second strand of researchers focuses on assessing the negative impact of speculation on the price dynamics on commodity markets. Manera, Nicolini, and Vignati (2013) present evidence that scalping increases commodity prices volatility, whereas the long-term speculation does not affect the prices variability or even diminishes price fluctuations. Similar results were previously obtained by Peck (1981), Streeter and Tomek (1992) as well as Brunetti and Büyükşahin (2009). Masters (2008) claim that speculators have developed a dominant position in commodity markets by exploiting in an uncontrolled manner Commodity Index Swaps and allocating by investment strategies involving the commodity index replications increased a total of $317 billion up to July, 2008[2]. Substantial abuse of commodity instruments for the purposes of portfolio diversification against the depreciation of the dollar, stock markets, or inflation due to the low correlation of commodities vis-a-vis equity instruments has led to a sudden influx of capital on commodity markets, dragging away the prices from their fundamental levels and shaping a speculative bubble. These extreme price determinants has been studied among others by Kuralbayeva and Malone (2012) who state that global factors are more important in explaining the commodity price developments than market-specific determinants.

With respect to excessive speculation on commodities markets, concerns regarding the weakening of the efficient market hypothesis air Flassbeck, Bicchetti, Mayer, and Rietzler (2011). The authors state that financial market agents motives contradict the assumption of market atomization – their investment decisions are not solely dependent on market-specific fundamentals. Because the financial and commodity markets do not share the fundamentals and various fundamental conditions cannot simultaneously and continuously generate a similar price development[3], they conclude that it is the dominant position of financial investors on both markets that generates financial and commodity market comovements. As a result, the commodity price developments can be heavily biased allowing for departures from fundamental levels due to the limited power of arbitrageurs (Gromb and Vayanos, 2010). Finally, Gospodinov and Ng (2013) claim that the drastic rise in commodity prices cannot be explained solely by the convenience yield, interest or exchange rate, which prompts the authors to conclude that the rise in commodity prices has been speculative.

The literature documents also the excessive growth of the commodity futures market in relation to the physical ones. Basu and Gavin (2010) point out that the increase in the value of the futures market and the OTC by far exceeds the increase in production. Falkowski (2011) argues that the market for crude oil was 12-fold greater than the physical market in 2009 and the dynamic growth of the futures to spot market size

[2] The CFTC et al. (2008) estimate the institutional investors capital in the commodity markets to increase from $15 billion in 2003 to more than $200 billion in 2008. IIF et al. (2011) value the increase from approximately $10 billion to $450 billion in 2012. The capital inflow could be stimulated by the technological and financial engineering innovations minimizing transaction costs and barriers of entry (CIS vehicles, ETP, electronic and algorithmic trading platforms or index investing).

[3] Cipriani and Guarino (2008) claim that irrational behaviour of financial agents may result in excess correlation between asset prices with respect to the correlation of asset fundamentals.

ratio has been observed since the beginning of 2004. Silvennoinen and Thorp (2013) estimate that the volume of commodity futures on the stock exchange is 20-30 times greater than their physical production.

Soaring commodity prices in small open economies can heavily pass through to import, producers and consumers prices leading to the intensification of inflationary processes in the economy in two ways: by stimulating directly the rise in food and energy prices as well as enabling the second round effects and therefore significantly impact the degree to which monetary policy objectives are fulfilled (Coletti, Lalonde, Masson, Muir, and Snudden, 2012). Therefore, despite the exogeneity of the commodity price changes with respect to monetary policy in small open economies, understanding the reasons behind abrupt commodity and, in turn, consumer prices changes are of vital importance for the monetary policy stance. Proper identification of the temporal price disruption as well as suitable communication with the economic agents may help maintaining central banks credibility and consequently tame inflation by anchoring inflation expectation firmly around the inflation target (Evans and Fisher, 2011). On the other hand, Anzuini, Lombardi, and Pagano (2012) as well as Eickmeier and Lombardi (2012) present evidence that monetary policy can also affect the commodity prices but not to an overwhelmingly large extent.

## 3. Data and methodology

In the model daily observation of distinguished variables are used starting from 1 I 2000 and ending at 31 XII 2013. Macroeconomic data with lower frequency (monthly or weekly) are interpolated to daily data using the temporal disaggregation method of Denton and Cholette (Dagum and Cholette, 2006). The use of daily data was necessary - an attempt to estimate the model on monthly data failed due to the small number of observations and problems with the convergence of numerical algorithms.

### *3.1. Dependent variables*

In the conducted study the price dynamics of the financial and five main commodity markets is jointly modeled to observe the varying degree of financial and commodity market interdependence. The global financial market is reflected in the Msci world (Mxwo) - a financial market index of 1,612 world stocks. Five major commodity sectors are mirrored in the main components of the popular S&P Goldman Sachs Commodity Index – energy (hereafter Spgsen), agricultural (Spgsag), industrial metals (Spgsin), livestock (Spgslv) as well as precious metals commodity prices (Spgspm).

Figure 1 illustrates the correlation of daily logarithmic returns between the global financial market and five commodity markets computed in the rolling window of 200 days. Over the years 2000 - 2013 a changing nature of financial and commodity markets linkages can be observed. After a period of stable, low between-market correlation (or lack thereof), the gradual similarity between the equity and commodity returns is observed. This is manifested by a substantial increase in the correlation of returns peaking in the second half of 2008 and the first half of 2009, mainly due to the financial crisis outburst, contagion effects and commodity bubble burst. Interestingly, the robust market interdependence between the financial and commodity markets and elevated correlation between the commodity markets prevailed for a long period of time, until they began to drop in 2012. This changing relationship between the distinguished markets motivates further analysis.

Figure 2 presents a brief graphical analysis of the dependent variables developments. Both the financial market and commodity prices dynamics share the majority of statistical properties postulated for financial variables, among others by Cont, Da Fonseca, et al. (2002). Firstly, all variables present stochastic trends with high volatility. Secondly, the growth rate, expressed as the first difference of logarithms exhibits strong variance clustering. Thirdly, the growth rate variance calculated in a 30-day rolling window signals also changing variability in time with a significant peak during the financial crisis. Similarly, a clustering effect is resembled in the Acf for the growth rates squares. Finally, the histograms of growth rates show a slight left-sided asymmetry and the empirical distribution of growth rates presented with the use of kernel estimation (black line) is thinner than the normal distribution density function (grey line) signaling that the distribution of growth rates is leptokurtic. The conclusions from the graphical analysis are confirmed by formalized statistical methods: Ljung-Box test, Arch-Lm test for the variance clustering as well as Jarque-Bera and Anderson-Darling test for the normality of returns and presented in the first row of the figure 3. To obtain stationarity the financial and commodity indices has been log-transformed and differentiated.

### *3.2. Explanatory variables*

The exogenous variables used in this paper are chosen mainly in line with the common tendencies in the literature cited in this paper. They can be assigned to several groups depending on their economic interpretation. Table 1 displays the endogenous and exogenous variables used and summarizes the necessary variables transformations for the purpose of obtaining stationarity. Temporal disaggregation of selected variables is marked with a 'D-c' superscript.

In this study several macroeconomic, financial and speculative measures are incorporated and here briefly described. Firstly, the level of risk aversion is measured by the Vix (Chicago Board Options Exchange Market Volatility Index) measuring the level of implied volatility of options on the S&P 500 ("index of fear") and the

Baspcaaa measuring the divergence between the yield of the Moody's US corporate bonds with a rating Aaa index and the yields on US ten-year government bonds. Secondly, to control for the level of monetary policy two interest rates are included: Usgg10yr (US ten-year government bonds yield) and Libor (the three-month interest rate on interbank market). Thirdly, in order to isolate the impact of the carry trade effects, the growth of the money supply and the level of risk appetite Fxcarrsp instrument is used (Deutsche Bank G10 FX Carry Basket Spot Index) that measures the profitability of the investment strategies consisting of entering into long positions in high-yielding currency and financing them through loans at low interest rates markets. Further, expectations formulated by stock investors (their level of optimism, the inclination to take risks and expect promising rates of return in different markets in the future) is measured using a variable Sntmntdiv quantifying the divergence between the percentage of optimists and pessimists on the Us stock market over the next six months disregarding those anticipating neutral developments. Variables showing the current macroeconomic conditions in the American and Chinese economies are resembled in the Composite Leading Indicators for those countries (consequently Clius and Clichn). In the course of the analysis global trend in the industry is also accounted for in the World Pmi (Pmiwrld). Moreover, the level of global demand for commodities is measured by the Baltic Dry Index (Bdiy) indicating the change in average prices of dry bulk cargo transportation by sea. To control for the growing demand from the emerging countries the annual growth rate of China's import demand (Emgimpy) is included. One of the principal production cost – energy – has been accounted for in the energy price index published by the Imf (Imfei). Two strictly exogenous variables are also included, namely the short term drought index (Palmerz) to look for drought as a potential determinant of supply shocks on agricultural markets as well as the global temperature anomalies index (Wrldglta) published by the Noaa's Ncdc to determine the possible influence of weather on energy prices. Finally, for each of the commodity markets variables illustrating the level of speculative nature on the market are calculated: open positions of all active contracts available at chosen moment (Enaoi for energy, Inaoi for industrial metals, Pmaoi for precious metals, Agaoi for agricultural, Lvaoi for livestock and Esoi for the financial market) and the aggregated volume of all active series of contracts at chosen moment (Enavol, Inavol, Pmavol , Agavol, Lvavol and Esvol for the financial market). For each market idiosyncratic (sector-specific) risk is calculated as the weighted average of the observed implied volatilities of options on financial and commodity futures belonging to the distinguished sectors with the normalized within the sector weights that each futures contract has in the S&p Gsci, therefore creating six additional variables (Enivol, Inivol, Pmivol, Agivol, Lvivol and Spxivol). Table 2 illustrates the 5 distinguished commodity sectors from the S&p Gsci, futures contracts belonging to them, their weights in the index as of May 2008 as well as the weights used to calculate sector implied volatility.

### *3.3. Model and estimation procedure*

In this paper I use the Dcc Garch introduced by Engle and Sheppard (2001). Multivariate Garch processes are a generalization of univariate models and allow for the study of asset interconnectedness, volatility transmission, the changing correlation between assets as well as potential spillovers and contagion effects presented among others by Tse and Tsui (2002) or Bae, Karolyi, and Stulz (2003). An exhaustive review of multivariate Garch models as well as estimation guidelines are presented in Silvennoinen and Teräsvirta (2008) as well as in Bauwens, Laurent, and Rombouts (2006). The estimated model (1) is as follows:

$$r_t = u_t + a_t \tag{1}$$

$$u_t = A_0 + A_1 u_{t-1} + B_0 x_t \tag{2}$$

$$a_t = H_t^{\frac{1}{2}} z_t \tag{3}$$

$$H_t = D_r R_t D_t \tag{4}$$

The mean equation $u_t$ is modeled by the vector autoregression process (2) with exogenous variables (Varx). The optimal lag structure is determined by minimizing the Schwarz Bayesian Information Criterion. In order to extract the influence of macroeconomic, financial and speculative variables affecting only the chosen commodity market, zero restrictions are imposed upon the parameter matrix $B_0$. Table 3 illustrates the structure of the mean equation with dependent variables in upper row and explanatory variables in the first column. Zeros indicate variable exclusion from the equation of the chosen dependent variable. This construction is aimed at identifying the macroeconomic, financial as well as speculative determinants influencing the price dynamics on the commodity markets.

The variance equation $a_t$ is modeled by the Dcc Garch process (3, 4). The $r_t$ is the $6\times1$ vector of logarithmic returns on financial and distinguished commodity markets at time $t$, $a_t$ is a $6\times1$ vector of mean-corrected returns of 6 abovementioned assets at time $t$, i.e. $E[a_t]=0 \wedge Cov[a_t]=H_t$, $u_t$ is the $6\times1$ vector of the expected value of the conditional $r_t$, $H_t$ is a $6\times6$ matrix of conditional variances of $a_t$ at time $t$, $H_t^{\frac{1}{2}}$ is any $n\times n$ matrix at time $t$ such that $H_t$ is the conditional variance matrix of $a_t$ and may be obtained by a Cholesky factorization of $H_t$, $D_t$ is the $6\times6$ diagonal matrix of conditional standard deviations of $a_t$ at time $t$ and $R_t$ is $6\times6$ conditional correlation matrix of $a_t$ at time $t$.

Starting parameters for the Dcc Garch are determined with the use of estimated univariate Garch models. Optimal univariate Garch model is chosen from a variety of Garch specifications for all dependent variables. The description of these specifications can be found among others in Teräsvirta (2006). The algorithm minimizes Bic for Garch(1,1)[4] with Arima(1,0,1), constant term, no in-Mean effect with changing error distribution and Garch type[5]. Table 11 summarizes the optimal specification of the univariate Garch models. In order to fit the Dcc two-step estimation is used[6]: firstly a Garch-Normal model is fitted to the univariate data and then the algorithm proceeds to estimate the Dcc structure in the second step based on the chosen multivariate distribution. In this paper three multivariate error distributions are selected: Normal, t-Student and Laplace. In total, I estimate 12 Dcc(1,1) models allowing for or disregarding the presence of the Varx component in the mean equation, the asymmetry term in the Dcc structure as well as different error distribution. After estimation I discriminate between them with the use of the information criteria as well as the dynamic conditional correlation paths. For the analysis I select the model with the minimal information criteria. I compute also 95% bootstrap confidence intervals for the Ccc Garch presented by Bollerslev (1990) in a sample of 10 000 simulations. The intervals are built with the use of the percentile method. Then I calculate the percentage of Dcc observations outside the confidence bands. This simple exercise indicates whether the Dcc is formed mainly within the bands indicating a stable relationship between markets or outside them, suggesting time-varying market interdependence.

All estimations are calculated in the following periods of time: 2000-2004, 2005-2013 and 2000-2013. The breaking point (end of 2004) was chosen on the basis of common agreement in the literature regarding the starting point of commodity market financialisation. The influence of global factors, such as the global financial crisis can also be assessed from the perspective of parameter estimates stability. I check whether the Varx aDcc Mvt Garch estimates vary significantly depending on the sample size. Therefore I conduct a recursive estimation in an expanding window. I start by estimating the model on the period 2000-2004 and then recursively reestimate the model's parameters in the 60-days expanding window. Chosen models are also evaluated with the use of statistical tests.

[4] Poon and Granger (2003) suggest that such Garch specification yields in most cases the best results.

[5] The algorithm chooses between standard Garch, exponential Garch and gjrGarch as well as error distribution: normal, t-Student, Ged and their skew generalizations, Gh, Nig and Johnson SU distribution.

[6] Under certain conditions the method of pseudo-maximum likelihood returns consistent and asymptotically normal estimators (Engle and Sheppard, 2001). Jondeau and Rockinger (2005) consider the full maximum likelihood method and the two-step method and finds that both methods return very similar results. Jensen and Lunde (2001) and Venter and de Jongh (2002) also postulate that a change in the distribution of errors in the second step does not affect the estimation of the parameters.

# 4. Results

This section discusses the results of the Varx Dcc Garch model with the asymmetry term and multivariate t distribution that aims to explain the determinants of commodity price changes and the intermarket dependences. The results of the estimated mean equation are presented in section IV.I. The estimated dynamic conditional correlation paths between the financial and commodity markets are described in section IV.II. Section IV.III. discusses the results of subsample analysis illustrating the structural changes on these markets and section IV.IV demonstrates shortly the stability of the parameter estimates.

## *4.1. Commodity price determinants*

In this subsection the estimates of the mean equation modeled as the Varx process obtained in the whole sample are presented. Tables 4 - 9 exhibit the parameter estimates along with their significance. Each table contains the estimates for one of the six Varx equations in the whole sample and in subsamples. Statistical analysis results of the estimated model in the whole sample and in subsamples are provided in table 10.

Firstly, the evidence of the macroeconomic conditions impact on commodity markets in the whole sample is mixed. Throughout the sample, the global demand and the economic expansion of emerging markets creates and upward pressure only on energy prices. Surprisingly, the global macroeconomic conditions of the Us and the Chinese economy do not help explain the commodity prices fluctuations (with the exception of the livestock and precious metals market). As expected, the global energy costs put an upward pressure on the agricultural as well as industrial metals prices. Interestingly, both in the cases of agricultural and energy markets the exogenous variables that should influence commodity prices in short-term have an overall negligible impact. The short-term drought index and the index of temperature anomalies do not change the commodity prices in the sample.

In the analyzed period there is no direct relationship between the short-term interest rate and commodity prices (apart from the agricultural commodities). However, there is a positive, quite robust connection between the Us ten-year bond yield and commodity prices. In the whole sample, prices of all commodities except for the precious metals[7] represent a positive relationship between the level of the Us government bonds yield. With the decline in interest rates (as a result of an expansionary monetary policy), the government bonds yields decline and simultaneously commodity prices drop. There are two explanations for it. Firstly, the positive relationship between the interest rate and the price of the futures results naturally from the model of futures contract pricing model. Secondly, the yield curve lowering could indicate an economic downturn triggering growing expectations for expansionary monetary policy which in turn could result in a commodity prices decline. On the other hand, the effect of a loose monetary policy affecting positively the commodity prices is picked up by the variable reflecting the profitability of the carry trade investments. Indeed, there is a quite strong relationship between the commodity price dynamics and the profitability of the carry trade investments, which could indicate common fundamentals for these two apparently independent processes. The expansive monetary policy has led to a growth in money supply and introduced a long period of low capital acquisition cost. An observed strong increase in cheap money supply encouraged investors to change their risk preferences (increased their susceptibility to risk-taking) and to seek profits in an unconventional manner by exploiting the interest rates disparities or by targeting the commodity markets and financing the investments on the debt market. The persisting low interest rates facilitated the generous inflow of capital on commodity markets and enabled the prices surge.

Secondly, there is some evidence on the influence of the factors of financial and speculative nature on commodity prices dynamics. According to the mean equation estimates, commodity prices depend positively on the short-term price dynamics of the global financial markets, which indicates to a certain extent the

[7] Futures precious metals prices should rise when yields drop because of being a popular instrument during turbulent economic periods.

adaptive expectations of investors as well as the existent comovements between the financial and commodity markets. Investors sentiment and their evaluation of global macroeconomic conditions affect the commodity prices also through the risk aversion channel. An increase in the global risk aversion measured by the fear index is accompanied usually by a drop in equity and commodity prices. There is also an evidence of the prices of precious metals sensitivity to the financial turmoil measures as the yield spread between the corporate AAA-rated bond and Treasury securities. Moreover, financial and energy markets react negatively to an increase in idiosyncratic risk, which is often dictated by a swift change in market-specific fundamentals due to exogenous factors like droughts or geopolitical tensions. Interestingly, the investor's expectations measured as the subjective perception of the probability for the bulls and bear market development in the next 6 months does not help explaining commodity price changes except for the industrial metals commodity prices and the equity market. Finally, prices of most commodities increase due to a financial escalation of the market. Apart from the industrial metals prices, which remain resistant to the level of short and long term speculation, the prices of other commodities rise with respect to the increase in short-term capital (the aggregated volume) or the increase in long-term capital (the aggregated open interest). The sensitivity to the increase of volume and open interest is characteristic for the commodity prices, whereas the equity prices remain insensitive to volume and open interest fluctuations. This in turn suggests that the equity market is highly liquid (mature), whereas the futures commodity markets remained in the development stage in the 2000's being sensitive to generous capital inflow.

Statistical properties of the Varx process are summarized in table 10. The model is stationary with roots within the unit circle. Individual equations differ significantly in terms of the coefficient of determination with the best fit for the equation of Mxwo variable (amounting to approximately 55%). The other equations are characterized by a low $R^2$ coefficient, however the F statistic indicates the overall significance of all equations. Such low fit could stem from the problem of omitted variables. Due to the difficulties in reflecting the demand-supply conditions of the commodity sectors, these important in shaping the price dynamics variables have been omitted. Taking into account the supply-demand fundamentals would be a very complicated task here as some important problems arise concerning e.g. the aggregation methods to sector indicators, lack of appropriate data or its very low frequency. A natural problem for high frequency financial data is the presence of strong autocorrelation and variance clustering. Arch-Lm, Ljung-Box and Breusch-Godfrey test results indicate that the residuals are heavily autocorrelated and heteroskedastic. The Jarque-Berry test results show that error term is not normally distributed. These model shortcomings will be adjusted by the Dcc component. Finally the likelihood ratio test implies that the introduction of zero restrictions does not significantly limit the explanatory power of the model.

The major role of the Varx component is to highlight statistically significant determinants of the commodity price dynamics and provide insight how it alters the market interdependence. The unexplained volatility of the Varx component is addressed by the Dcc part.

### *4.2. Market interdependence*

The study of variance equation is the central point of this paper. After controlling for the impact of various macroeconomic, financial and speculative factors affecting the price dynamics on the financial and commodity markets, the time-varying interdependence between distinguished markets is established and here presented. I start with selecting the optimal model and examining the Dcc paths sensitivity to different model specifications. The upward panel of the figure 8 illustrates the information criteria for different models specifications in the whole sample. Based on these estimates I discriminate between the twelve estimated models with different adopted specification regarding the mean equation, the asymmetry term and the multivariate error distribution and conclude that the optimal model is the one including Varx component in the mean equation as well as asymmetry term and multivariate t error distribution in the variance equation (Varx aDcc Mvt Garch). Correspondingly to small changes in the information criteria, the discrepancies between the models, conditional on the inclusion of asymmetry term as well as type of multivariate error distribution, are insignificant, which is indicated by small changes in the dynamic conditional correlation paths presented on figures 9 - 10. One can easily observe that the Dcc paths of differently specified models (grey lines) do not deviate significantly from the path of the chosen model (black line). However, the differences between the models including and disregarding the Varx component are in some pairs of markets quite considerable. The significant divergence between the aDcc Mvt Garch model including and disregarding the Varx component will be commented on further.

Table 12 presents the estimates and the significance levels of the univariate Garch processes as well as the chosen multivariate Garch process in the whole sample and in subsamples. All univariate Garch processes exhibit a very high level of inertia (low influence of previous shock coupled with very strong influence of previous conditional variance), statistically significant leverage effect as well as the shape and skewness parameters indicating fat-tailed and asymmetric errors distributions. Based on the estimates of the Dcc structure it can be concluded that the multivariate process is also highly persistent and the multivariate error distribution is largely leptokurtic. However, the asymmetry term here is statistically insignificant.

The dynamic conditional correlation paths between the distinguished commodity and financial markets are presented on figure 4. Graphs demonstrate the level of dynamic conditional correlation of aDcc Mvt Garch model including the Varx component (black line) and disregarding it (grey line). Dashed black lines designate the 95% bootstrap confidence intervals for the constant conditional correlation Garch model. Ideally, the Dcc path of the model with the mean equation adjusted by selected commodity price determinants should oscillate around zero - after controlling for the common determinants the residuals should be negligibly correlated due to the lack of markets comovenents. The illustration of the results leads to following conclusions.

Firstly, the dynamic conditional correlation of the model containing no Varx component presents a much higher variability (the relationship between chosen pairs of markets is estimated to be much stronger). Not surprisingly, the lower level of the Dcc model including the Varx component is explained by the inclusion of macroeconomic, financial and speculative determinants that commodity markets began to share with financial markets after 2004. The much lower Dcc path for the model incorporating Varx component from 2007 onwards seems to be of particular interest. After a prolonged period of low market interdependence and lack of sharing fundamentals by the financial and commodity markets, the unadjusted conditional correlation between these markets begin to rise. Moreover, since the outbreak of the global financial crisis the paths of the two studied models diverge significantly. Therefore, it appears to be a natural ascertainment that the finacialisation - growing influence of macroeconomic, financial and speculative determinants - significantly affected the price dynamics on the commodity markets and, in fact, explains a strong increase in intermarket connectedness. However, it should be stated that whereas the divergence is clearly seen between the financial market and commodity market, the differences between the correlations of different commodity markets are, with some exceptions, not as large.

Secondly, the strength of the interdependence between different markets is mixed. The strongest relationship can be observed between the financial and energy markets as well as the financial and industrial commodity markets (in both cases the Dcc approaches the level of 0.6 but after controlling for the distinguished factors it does not exceed 0.4). The interdependence between the financial and the agricultural as well as financial and precious commodity market is a bit weaker, but still significant. The lowest correlation in the whole sample is observed for the pair financial market - livestock commodity market. Importantly, after a period of low correlation, the relationship between chosen commodity markets in most cases begins to be robust, which indicates the process of rising price dynamics similarity between the market.

Thirdly, as already signaled, for the majority of the analyzed pairs the correlation remains stable and low up to 2004 which points out low interference of non-commercial investors in these markets. From 2005 on, the correlation is, with some exceptions, growing with a significant surge observed on all pairs during 2007-2009. The stable growth of the correlation can be explained by the financialisation effect. Moreover, the abrupt rise of correlation is most probably the consequence of the outburst of the financial crisis inducing herding behavior of financial agents.

Fourthly, after a prolonged period of elevated correlation, in recent years the Dcc paths are subordinated to a downward trend suggesting weakening market interdependence. In addition, the path convergence of models including and disregarding the Varx component may suggest the fading influence of macroeconomic and financial determinants. This in turn may indicate a rising influence of market fundamentals on the commodity price dynamics. However, for some pairs, the market interdependence is maintained at a higher level than before the collapse of Lehman Brothers. To some extent the falling correlation may be also the result of the Dodd-Frank Wall Street Reform and Consumer Protection Act introduced in 2010 that, among others, brought some significant changes to financial regulation of the commodity markets.

Finally, the 95% bootstrap confidence intervals for constant conditional correlation model contain only a small percentage of the Dcc. This demonstrates the time-variant and highly volatile market interdependence. Table 14 presents the confidence intervals in the whole sample and in subsamples and table 15 shows the percentage of the Dcc observations outside the Ccc confidence bands. The confidence intervals in the whole sample suggest weak but statistically significant correlation, but as shown on the figure 4 the majority of Dcc observations lay outside this band indicating that time-variant specification is more proper.

Lastly, the standardized residuals of the chosen model were tested for the presence of variance clustering and normality of error term distribution. Table 13 presents the test results in the whole sample and in subsamples. Both Arch-Lm and Ljung-Box test for squared residuals reject the null hypothesis at significance level $\alpha = 0.05$ in the case of Mxwo and Spgsen equations suggesting that the variance clustering effect is particularly strong on these markets, whereas the rest of the residuals are cleared from the conditional variance effect in the whole sample. However, based on Jarque-Bera and Anderson-Daring tests, non-normality of residuals persists but is considerably weaker because of controlling for leptokurtic distribution.

### *4.3. Subsamples analysis*

In order to verify the presence of structural changes in the commodity markets the analysis was also conducted in subsamples. Many papers suggest a gradual commodity market financialisation starting from 2005 onwards. Therefore, I split the whole sample into two periods: 2000-2004 and 2005-2013 and conduct the analysis in both samples in an analogous manner. The analysis of the models estimated in subsamples brings the following conclusions.

Based on the information criteria estimates provided in the second and third row of the figure 8, the Varx component included in the mean equation does not differentiate significantly between different models included in this study in both subsamples. Evidently, the influence of distinguished factors determining the price dynamics on the commodity markets during 2000-2004 is negligible - the majority of variables are statistically insignificant and the coefficient of determination is particularly low, which leads to a belief that until 2005 the price dynamics remained under the strong influence of market-specific fundamentals[8].

The situation changes significantly after 2005. Global and idiosyncratic risk aversion start to negatively impact the commodity markets. Increasing money supply resulting from expansionary monetary policy and falling interest rates as well as the increase in appetite for risk reflected in higher activity on carry trade investments also influence positively commodity markets. Positive relationship between the macroeconomic determinants in developed and developing countries creates an upward pressure on selected prices, so does the increase in the cost factors or the increase in speculation. The distinguished variables become significant and compared to the whole sample estimation their influence is stronger.

[8]The estimated Varx model in subsamples was also subjected to statistical quality assessment. Table 10 presents the results of these analysis. In both subsamples there is a strong Arch effect and autocorrelation in the majority of equations as well as non-normality of error distribution in all equations. Imposing zero restrictions does not cause a statistically significant deterioration of the model quality in both subsamples. The coefficient of determination is particularly low in the first subsample but considerably rises in the second subsample for the majority of equations.

The initial lack of market interdependence and a gradual increase of markets comovements are mirrored in the estimated Dcc paths. Figure 5 demonstrates the largely stable, weak and in many cases statistically insignificant market interdependence. The Dcc paths remain mainly inside the confidence intervals of the Ccc. The differences between the model including and disregarding the Varx component during 2000-2004 are negligible. Thus there are no joint fundamentals for the commodity and financial markets. The situation reverses in the second subsample. Figure 6 illustrates the same model estimated in the second sample. During 2005-2013 the Dcc is highly variable, considerably growing before the outburst of the financial crisis and remaining elevated afterwards. The inclusion of the Varx component leads to a significant reduction in the dynamic conditional correlation path signaling the sharing by the financial and commodity markets fundamentals[9]. These results are confirmed by the analysis of bootstrap confidence intervals. Again, table 14 shows the estimated 95% Ccc confidence intervals and table 15 provides information about the percentage of Dcc observations laying outside the Ccc confidence bands in the whole sample and in subsamples. During 2000-2004 the market interdependence is very weak - in many cases the 95% confidence intervals include zero indicating statistically insignificant relation. However, during 2005-2013 the market interdependence rises significantly compared to the period of 2000-2004. Substantial shift is observed predominantly between the financial and the commodity markets signaling significant similarities between the price dynamics on these markets and presence of the pooling effect. The confidence intervals calculated for the whole sample are slightly lower due to the inclusion of the weak market interdependence period. Moreover, whilst during 2000-2004 the vast majority of the Dcc moved within the confidence bands of the Ccc indicating a time-invariant relationships between the distinguished markets, during 2005-2013 most of the Dcc was outside the confidence intervals illustrating that the market interdependence become highly volatile. The results of this informal test suggest that during 2000-2004 the market interdependence was stable and low, in some cases even insignificant, which stemmed from little markets comovements, whereas from 2005 onwards financial and commodity market interdependence began to rise and change considerably in time.

### *4.4. Stability of estimates*

Figure 7 presents the stability of parameter estimates. For the univariate Garch processes it can be concluded that the influence of the lagged conditional variance (parameter $\beta$) remains elevated throughout the whole sample at a very high level close to 1, whereas the influence of the previous shocks (parameter $\alpha$) generally declines. All in all, the univariate conditional variance inertia remains very high. Before the financial crisis outbreak the leverage effect (parameter $\gamma$) strengthened. Interestingly, the skewness (parameter $\lambda$) of the error distributions for the two models accounting for this factor diminishes throughout time. The distribution's shape parameter $\theta$ generally declines, peaking only during the crisis, which indicates fatter tails. In case of the Dcc parameters, the influence of previous shocks (parameter $A$) rises significantly in the sample but the level remains low. The influence of the lagged conditional variance-covariance matrix (parameter $B$) fluctuates insignificantly remaining close to 1. As a results, the inertia of the multivariate conditional variance is also very high in the whole sample. The leverage effect for the multivariate distribution (parameter $\Gamma$) remains insignificant oscillating throughout the whole sample near zero, whereas the parameter responsible for the shape of the distribution ($\Theta$) rises up to the financial crisis and then begins to diminish. This shows that the developments on the financial market significantly influenced the price dynamics on the commodity markets.

[9]The significance of differences between the selected model specifications were analyzed also in the subsamples and the conclusions are similar - regardless of the adopted structure of the Dcc, its paths are largely insensitive to model specification. Statistical analysis was also conducted. Table 13 presents the test results for variance clustering and standardized error term normality of distribution. Based on the Arch-Lm and Ljung-Box test results there is no evidence of variance clustering in both subsamples. Also in these cases the standardized model residuals are not normally distributed, which is confirmed by the Jarque-Bera and Anderson-Darling test results.

## 5. Concluding remarks

The principal aim of this study was to investigate the existence of commodity markets financialisation. This paper tackled two problems: *i)* the identification of macroeconomic, financial and speculative determinants of commodity price changes and *ii)* the evaluation of the time-varying interdependence and its strength between the financial and commodity markets. For this purpose I presented the Varx Dcc Garch with leverage effect and multivariate t distribution that addresses both these problems. For robustness check a variety of additional exercises were introduced as well.

Firstly, based on the results of the mean equation of the model it should be noted that financial market developments, global demand and import demand from emerging economies, monetary policy, changing preferences of risk-taking as well as speculation have a significant effect on selected commodity prices. This fact, in turn, can be interpreted as the growing importance of factors other than supply-demand determining the commodity prices. Importantly, the analysis in the subsamples suggests that most of the factors do not exert a significant impact on prices during 2000-2004, whereas the situation has changed substantially since 2005, thus confirming the hypothesis of commodity market financialisation.

Secondly, the analysis of variance equation shows that equity and commodity price developments underwent from 2005 onwards a systematic convergence, reaching the highest level of similarity during the commodity price boom and the subsequent outburst of the financial crisis. The inclusion of the Varx component in the mean equation of the Dcc Garch model leads to a significant drop of the dynamic conditional correlation path between the financial and commodity prices. Elevated correlation can be interpreted as sharing of market fundamentals and the strong presence of the financial motives between the distinguished markets. However, the results indicate that this process has lately considerably weakened. The analysis of bootstrap estimates of the confidence intervals for the Ccc Garch in subsamples suggests a structural change in the market interdependence. During 2000-2004 the interdependence between the distinguished markets was predominantly low, quite stable and statistically insignificant, whereas the situation has changed considerably since 2005 with the interdependence rising strongly, exhibiting greater volatility and being statistically significant. The recursive estimation also showed the influence of the financial crisis on parameter estimates. The model is insensitive to specification changes.

The dynamically changing commodity prices developments are of vital importance for the monetary policy authorities. Excessive commodity price swings can have a detrimental effect to small open economies leading to swift changes in inflation, triggering second-round effects and consequently preserving imbalances. Therefore, monitoring the financialisation effect should also be a part of central banks activity, as the process may be perceived as cyclical periodically leading to the commodity price dynamics unification regardless of the market fundamentals, increase in prices volatility and contagion, spillover effects. Central banks authorities should also scrutinize, whether in the environment of persistently low interest rates an abundant access to financial innovations such as commodity index investing or ETPs would not create pressure on commodity prices.

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# A. Data

**Table 1: Endogenous variables, exogenous variables entering the mean equation of the model and their transformation to stationary representation**

| *Economic interpretation* | *Variable* | *Transformation* |
|---|---|---|
| Global financial market | Mxwo | $\Delta ln(\cdot)$ |
| Commodity markets | Spgsen, Spgsag, Spgsin, Spgslv, Spgspm | $\Delta ln(\cdot)$ |
| Macroeconomic conditions | $\text{Clius}^{\text{D-C}}$, $\text{Clichn}^{\text{D-C}}$, $\text{Pmiwrld}^{\text{D-C}}$ | $\Delta ln(\cdot)$ |
| Monetary policy | Libor, Usgg10yr | $\Delta ln(\cdot)$ |
| Foreign exchange | Fxcarrsp | $\Delta ln(\cdot)$ |
| Investor's sentiment | $\text{Sntmntdiv}^{\text{D-C}}$ | – |
| Global risk aversion | Vix, Bspcaaa | $\Delta ln(\cdot)$ |
| Idiosyncratic risk | Spxivol, Enivol, Inivol, Pmivol, Agivol, Lvivol | $\Delta ln(\cdot)$ |
| Global demand | Bdiy | $\Delta ln(\cdot)$ |
| Emerging market demand | $\text{Emgimpy}^{\text{D-C}}$ | – |
| Production costs | $\text{Imfei}^{\text{D-C}}$ | $\Delta ln(\cdot)$ |
| Meteorological conditions | $\text{Palmerz}^{\text{D-C}}$ | – |
| | $\text{Wrldglta}^{\text{D-C}}$ | $\Delta$ |
| Speculation: total volume | Esvol, Enavol, Inavol, Pmavol, Agavol, Lvavol | $\Delta ln(\cdot)$ |
| Speculation: total open interest | Esoi, Enaoi, Inaoi, Pmaoi, Agaoi, Lvaoi | $\Delta ln(\cdot)$ |

**Table 2: Commodity markets weights in distinguished commodity sectors computed based on the commodity futures weights in the S&P GSCI**

| *Commodity Market* | *Commodity* | *Weight in S&P* | *Sector weight* |
|---|---|---|---|
| SPGSEN | Brent Crude Oil | 18,40% | 26,74% |
| | WTI Crude Oil | 30,00% | 43,60% |
| | GasOil | 8,00% | 11,63% |
| | Heating Oil | 5,20% | 7,56% |
| | Unleaded Gas | 4,90% | 7,12% |
| | Natural Gas | 2,30% | 3,34% |
| SPGSAG | Cocoa | 0,20% | 1,29% |
| | Coffee | 0,60% | 3,87% |
| | Corn | 5,00% | 32,26% |
| | Cotton | 1,00% | 6,45% |
| | Soybeans | 2,70% | 17,42% |
| | Sugar | 1,60% | 10,32% |
| | Wheat | 3,40% | 21,94% |
| | Red Wheat | 1,00% | 6,45% |
| SPGSIN | Aluminium | 2,10% | 30,00% |
| | Lead | 0,40% | 5,71% |
| | Nickel | 0,60% | 8,57% |
| | Zinc | 0,60% | 8,57% |
| | Copper | 3,30% | 47,14% |
| SPGSLV | Feeder Cattle | 0,50% | 10,00% |
| | Lean Hogs | 1,50% | 30,00% |
| | Live Cattle | 3,00% | 60,00% |
| SPGSPM | Gold | 3,10% | 86,11% |
| | Silver | 0,50% | 13,89% |

**Figure 1: Correlation between the equity and commodity market returns in a 200-day rolling window**

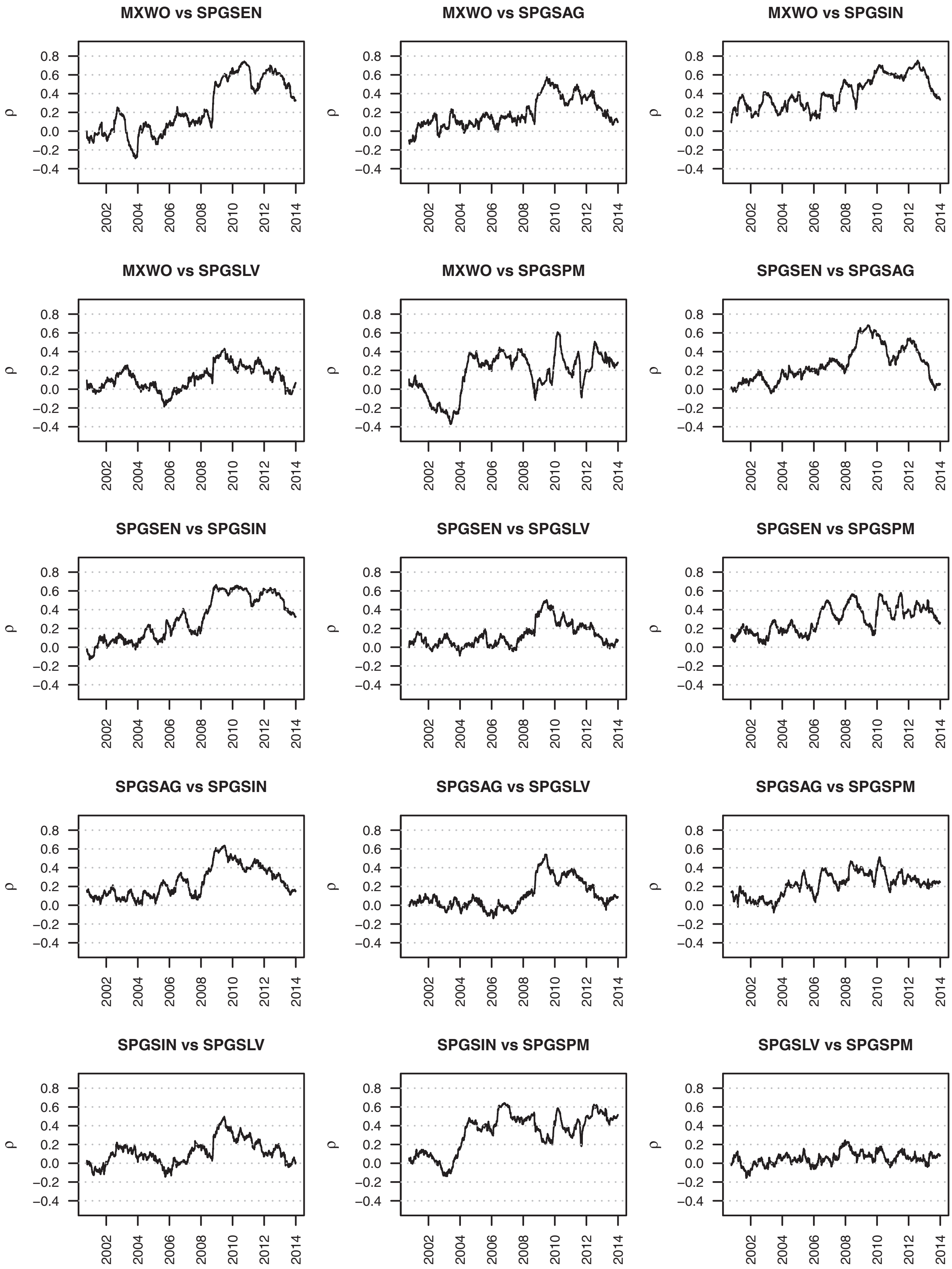
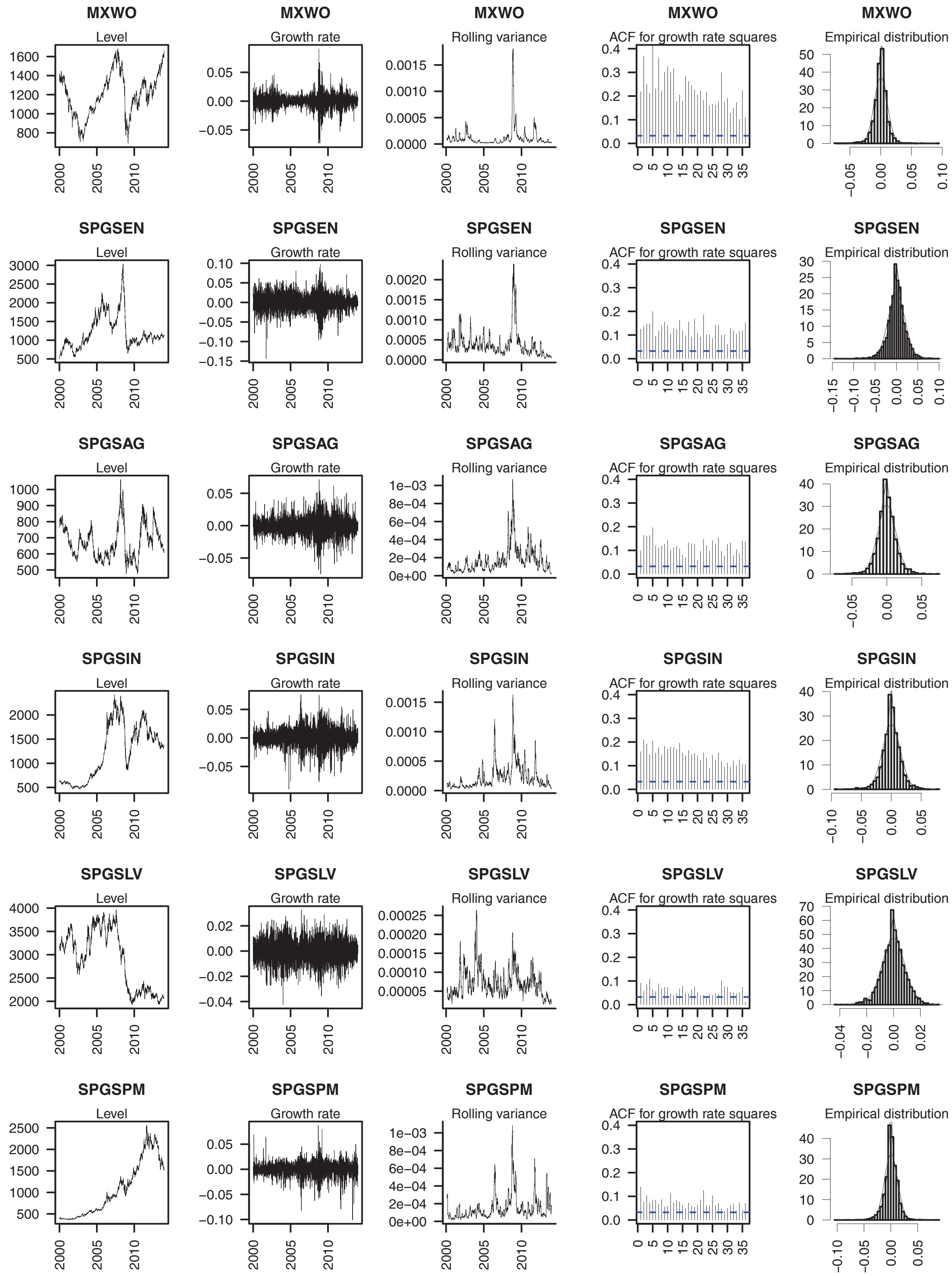


**Figure 2: Price developments, growth rates, growth rates variance in a 30-day rolling window, ACF for the growth rates squares and the empirical distributions of the dependent variables**



# B. Mean equation - VARX estimates and test results

**Table 3: Parameter restriction matrix for the mean equation VARX model. Zeros indicate variable exclusion**

| | | Dependent variables | | | | | |
|---|---|---|---|---|---|---|---|
| | | Mxwo | Spgsen | Spgsag | Spgsin | Spgslv | Spgspm |
| Var(1) | $\text{Mxwo}_{t-1}$ | 1 | 1 | 1 | 1 | 1 | 1 |
| | $\text{Spgsen}_{t-1}$ | 1 | 1 | 1 | 1 | 1 | 1 |
| | $\text{Spgsag}_{t-1}$ | 1 | 1 | 1 | 1 | 1 | 1 |
| | $\text{Spgsin}_{t-1}$ | 1 | 1 | 1 | 1 | 1 | 1 |
| | $\text{Spgslv}_{t-1}$ | 1 | 1 | 1 | 1 | 1 | 1 |
| | $\text{Spgspm}_{t-1}$ | 1 | 1 | 1 | 1 | 1 | 1 |
| | Const | 1 | 1 | 1 | 1 | 1 | 1 |
| Exogenous variables | Vix | 1 | 1 | 1 | 1 | 1 | 1 |
| | Baspcaaa | 1 | 0 | 1 | 1 | 1 | 1 |
| | Usgg10yr | 1 | 1 | 1 | 1 | 1 | 1 |
| | Libor | 1 | 1 | 1 | 1 | 1 | 1 |
| | Fxcarrsp | 1 | 1 | 1 | 1 | 1 | 1 |
| | Sntmntdiv | 1 | 1 | 1 | 1 | 1 | 1 |
| | Emgimpy | 0 | 1 | 1 | 1 | 1 | 1 |
| | Bdiy | 0 | 1 | 1 | 1 | 1 | 1 |
| | Imfei | 0 | 0 | 1 | 1 | 1 | 0 |
| | Clius | 1 | 1 | 1 | 1 | 1 | 1 |
| | Clichn | 0 | 1 | 1 | 1 | 1 | 1 |
| | Pmiwrld | 1 | 1 | 1 | 1 | 1 | 1 |
| | Palmerz | 0 | 0 | 1 | 0 | 1 | 0 |
| | Wrldglta | 0 | 1 | 0 | 0 | 0 | 0 |
| | Enavol | 0 | 1 | 0 | 0 | 0 | 0 |
| | Inavol | 0 | 0 | 0 | 1 | 0 | 0 |
| | Pmavol | 0 | 0 | 0 | 0 | 0 | 1 |
| | Agavol | 0 | 0 | 1 | 0 | 0 | 0 |
| | Lvavol | 0 | 0 | 0 | 0 | 1 | 0 |
| | Enaoi | 0 | 1 | 0 | 0 | 0 | 0 |
| | Inaoi | 0 | 0 | 0 | 1 | 0 | 0 |
| | Pmaoi | 0 | 0 | 0 | 0 | 0 | 1 |
| | Agaoi | 0 | 0 | 1 | 0 | 0 | 0 |
| | Lvaoi | 0 | 0 | 0 | 0 | 1 | 0 |
| | Enivol | 0 | 1 | 0 | 0 | 0 | 0 |
| | Inivol | 0 | 0 | 0 | 1 | 0 | 0 |
| | Pmivol | 0 | 0 | 0 | 0 | 0 | 1 |
| | Agivol | 0 | 0 | 1 | 0 | 0 | 0 |
| | Lvivol | 0 | 0 | 0 | 0 | 1 | 0 |
| | Esvol | 1 | 0 | 0 | 0 | 0 | 0 |
| | Esoi | 1 | 0 | 0 | 0 | 0 | 0 |
| | Spxivol | 1 | 0 | 0 | 0 | 0 | 0 |

**Table 4: VARX estimates in the whole sample and in subsamples. Estimates for MXWO equation**

| | Varx estimates in the whole sample and in subsamples | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Equation: Mxwo | | | | | | | | | | | |
| | 2000:2013 (3650 observations) | | | | 2000:2004 (1303 observations) | | | | 2005:2013 (2346 observations) | | | |
| | estimate | std. error | t statistic | p-value | estimate | std. error | t statistic | p-value | estimate | std. error | t statistic | p-value |
| Mxwo$_{t-1}$ | 0,1490 | 0,0132 | 11,2920 | 0,0000 | 0,1681 | 0,0200 | 8,4050 | 0,0000 | 0,1316 | 0,0173 | 7,6120 | 0,0000 |
| Spgsen$_{t-1}$ | -0,0011 | 0,0067 | -0,1630 | 0,8702 | 0,0151 | 0,0088 | 1,7250 | 0,0848 | -0,0130 | 0,0099 | -1,3210 | 0,1868 |
| Spgsag$_{t-1}$ | -0,0025 | 0,0102 | -0,2470 | 0,8051 | -0,0070 | 0,0190 | -0,3690 | 0,7120 | -0,0015 | 0,0120 | -0,1280 | 0,8984 |
| Spgsin$_{t-1}$ | -0,0436 | 0,0097 | -4,4840 | 0,0000 | -0,0390 | 0,0184 | -2,1230 | 0,0340 | -0,0383 | 0,0115 | -3,3350 | 0,0009 |
| Spgslv$_{t-1}$ | -0,0028 | 0,0145 | -0,1930 | 0,8472 | 0,0165 | 0,0204 | 0,8100 | 0,4183 | -0,0114 | 0,0193 | -0,5940 | 0,5528 |
| Spgspm$_{t-1}$ | 0,0071 | 0,0108 | 0,6610 | 0,5088 | 0,0408 | 0,0209 | 1,9540 | 0,0509 | 0,0072 | 0,0125 | 0,5740 | 0,5658 |
| const | -0,0002 | 0,0001 | -1,5340 | 0,1251 | -0,0007 | 0,0002 | -2,8530 | 0,0044 | 0,0000 | 0,0002 | 0,1630 | 0,8708 |
| Vix | -0,0813 | 0,0032 | -25,3710 | 0,0000 | -0,1215 | 0,0048 | -25,1550 | 0,0000 | -0,0502 | 0,0049 | -10,1670 | 0,0000 |
| Baspcaaa | -0,0047 | 0,0027 | -1,7580 | 0,0789 | 0,0011 | 0,0049 | 0,2280 | 0,8199 | -0,0040 | 0,0032 | -1,2580 | 0,2085 |
| Usgg10yr | 0,0847 | 0,0076 | 11,1840 | 0,0000 | 0,1005 | 0,0138 | 7,3030 | 0,0000 | 0,0745 | 0,0090 | 8,2530 | 0,0000 |
| Libor | -0,0045 | 0,0112 | -0,4020 | 0,6875 | -0,0025 | 0,0188 | -0,1330 | 0,8943 | -0,0138 | 0,0137 | -1,0030 | 0,3159 |
| Fxcarrsp | 0,2638 | 0,0203 | 12,9740 | 0,0000 | -0,0220 | 0,0438 | -0,5030 | 0,6154 | 0,3502 | 0,0234 | 14,9570 | 0,0000 |
| Sntmntdiv | 0,0000 | 0,0000 | 4,6850 | 0,0000 | 0,0000 | 0,0000 | 3,4020 | 0,0007 | 0,0000 | 0,0000 | 4,6100 | 0,0000 |
| Clius | 2,9720 | 1,1740 | 2,5320 | 0,0114 | 1,3810 | 2,0370 | 0,6780 | 0,4979 | 2,6540 | 1,4690 | 1,8060 | 0,0711 |
| Pmiwrld | 0,0700 | 0,0952 | 0,7350 | 0,4623 | 0,0311 | 0,1204 | 0,2580 | 0,7963 | 0,1202 | 0,1409 | 0,8530 | 0,3935 |
| Esvol | 0,0002 | 0,0001 | 1,6590 | 0,0973 | 0,0004 | 0,0002 | 2,9650 | 0,0031 | 0,0001 | 0,0003 | 0,3080 | 0,7585 |
| Esoi | -0,0011 | 0,0012 | -0,9580 | 0,3382 | 0,0011 | 0,0022 | 0,5080 | 0,6115 | -0,0011 | 0,0016 | -0,6560 | 0,5117 |
| Spxivol | -0,0255 | 0,0028 | -9,0210 | 0,0000 | -0,0115 | 0,0031 | -3,7020 | 0,0002 | -0,0502 | 0,0052 | -9,6740 | 0,0000 |
| $R^2$ | 0,5571 | | | | 0,5608 | | | | 0,5854 | | | |
| F | 253,8000 | df: 18 & 3632 | | 0,0000 | 91,1500 | df: 18 & 1285 | | 0,0000 | 182,6000 | df: 18 & 2328 | | 0,0000 |

**Table 5: VARX estimates in the whole sample and in subsamples. Estimates for SPGSEN equation**

| | Varx estimates in the whole sample and in subsamples | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Equation: Spgsen | | | | | | | | | | | |
| | 2000:2013 (3650 observations) | | | | 2000:2004 (1303 observations) | | | | 2005:2013 (2346 observations) | | | |
| | estimate | std. error | t statistic | p-value | estimate | std. error | t statistic | p-value | estimate | std. error | t statistic | p-value |
| Mxwo$_{t-1}$ | 0,0822 | 0,0346 | 2,3770 | 0,0175 | 0,0248 | 0,0639 | 0,3890 | 0,6975 | 0,1413 | 0,0410 | 3,4480 | 0,0006 |
| Spgsen$_{t-1}$ | -0,0483 | 0,0179 | -2,7000 | 0,0070 | -0,0423 | 0,0283 | -1,4960 | 0,1348 | -0,0673 | 0,0237 | -2,8360 | 0,0046 |
| Spgsag$_{t-1}$ | 0,0251 | 0,0269 | 0,9320 | 0,3512 | 0,0693 | 0,0611 | 1,1340 | 0,2569 | 0,0122 | 0,0289 | 0,4220 | 0,6728 |
| Spgsin$_{t-1}$ | -0,0347 | 0,0258 | -1,3470 | 0,1782 | 0,1158 | 0,0592 | 1,9570 | 0,0505 | -0,0890 | 0,0275 | -3,2350 | 0,0012 |
| Spgslv$_{t-1}$ | -0,0088 | 0,0383 | -0,2300 | 0,8179 | 0,0504 | 0,0656 | 0,7680 | 0,4427 | -0,0378 | 0,0463 | -0,8160 | 0,4146 |
| Spgspm$_{t-1}$ | -0,0251 | 0,0285 | -0,8820 | 0,3777 | -0,1526 | 0,0668 | -2,2830 | 0,0226 | 0,0278 | 0,0300 | 0,9280 | 0,3537 |
| const | -0,0005 | 0,0005 | -0,9660 | 0,3340 | -0,0008 | 0,0013 | -0,6070 | 0,5439 | 0,0000 | 0,0005 | 0,0010 | 0,9994 |
| Vix | -0,0278 | 0,0056 | -4,9600 | 0,0000 | -0,0068 | 0,0120 | -0,5700 | 0,5686 | -0,0305 | 0,0061 | -5,0260 | 0,0000 |
| Usgg10yr | 0,1124 | 0,0179 | 6,2940 | 0,0000 | 0,0156 | 0,0424 | 0,3680 | 0,7130 | 0,1250 | 0,0187 | 6,6800 | 0,0000 |
| Libor | 0,0383 | 0,0301 | 1,2730 | 0,2032 | 0,0171 | 0,0603 | 0,2840 | 0,7763 | 0,0648 | 0,0336 | 1,9260 | 0,0542 |
| Fxcarrsp | 0,3842 | 0,0539 | 7,1270 | 0,0000 | -0,0333 | 0,1407 | -0,2370 | 0,8128 | 0,4123 | 0,0561 | 7,3560 | 0,0000 |
| Sntmntdiv | 0,0000 | 0,0000 | 0,3210 | 0,7483 | 0,0000 | 0,0000 | -0,1420 | 0,8868 | 0,0000 | 0,0000 | 0,3450 | 0,7303 |
| Emgimpy | 0,0000 | 0,0000 | 1,7050 | 0,0882 | 0,0001 | 0,0000 | 1,4370 | 0,1511 | 0,0000 | 0,0000 | -0,6240 | 0,5327 |
| Bdiy | 0,0326 | 0,0177 | 1,8440 | 0,0652 | 0,1425 | 0,0615 | 2,3190 | 0,0206 | 0,0167 | 0,0173 | 0,9660 | 0,3343 |
| Clius | 3,3970 | 3,4670 | 0,9800 | 0,3272 | -8,5150 | 6,9040 | -1,2330 | 0,2177 | 11,0200 | 4,1270 | 2,6710 | 0,0076 |
| Clichn | -0,7914 | 2,5900 | -0,3060 | 0,7599 | 2,3980 | 6,3000 | 0,3810 | 0,7035 | -8,0850 | 3,0310 | -2,6670 | 0,0077 |
| Pmiwrld | 0,3658 | 0,2644 | 1,3830 | 0,1667 | 0,1967 | 0,3928 | 0,5010 | 0,6167 | 0,8442 | 0,3704 | 2,2790 | 0,0227 |
| Wrldglta | 0,0034 | 0,0131 | 0,2560 | 0,7976 | 0,0082 | 0,0214 | 0,3850 | 0,7006 | 0,0027 | 0,0165 | 0,1650 | 0,8693 |
| Enavol | -0,0001 | 0,0015 | -0,0560 | 0,9554 | -0,0010 | 0,0026 | -0,3790 | 0,7046 | -0,0002 | 0,0019 | -0,1160 | 0,9074 |
| Enaoi | 0,0865 | 0,0175 | 4,9550 | 0,0000 | 0,0575 | 0,0203 | 2,8360 | 0,0046 | 0,3543 | 0,0520 | 6,8180 | 0,0000 |
| Enivol | -0,0194 | 0,0036 | -5,4380 | 0,0000 | -0,0070 | 0,0052 | -1,3320 | 0,1832 | -0,0339 | 0,0050 | -6,7760 | 0,0000 |
| $R^2$ | 0,0838 | | | | 0,0268 | | | | 0,1698 | | | |
| F | 15,8000 | df: 21 & 3629 | | 0,0000 | 1,6840 | df: 21 & 1282 | | 0,0273 | 22,6400 | df: 21 & 2325 | | 0,0000 |

**Table 6: VARX estimates in the whole sample and in subsamples. Estimates for SPGSAG equation**

Varx estimates in the whole sample and in subsamples

Equation: Spgsag

| | 2000:2013 (3650 observations) | | | | 2000:2004 (1303 observations) | | | | 2005:2013 (2346 observations) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | estimate | std. error | t statistic | p-value | estimate | std. error | t statistic | p-value | estimate | std. error | t statistic | p-value |
| Mxwo$_{t-1}$ | 0,0628 | 0,0226 | 2,7780 | 0,0055 | -0,0063 | 0,0290 | -0,2160 | 0,8286 | 0,1278 | 0,0319 | 4,0120 | 0,0001 |
| Spgsen$_{t-1}$ | -0,0278 | 0,0116 | -2,3970 | 0,0166 | 0,0061 | 0,0128 | 0,4780 | 0,6324 | -0,0698 | 0,0183 | -3,8180 | 0,0001 |
| Spgsag$_{t-1}$ | 0,0231 | 0,0174 | 1,3280 | 0,1843 | -0,0046 | 0,0277 | -0,1660 | 0,8679 | 0,0294 | 0,0222 | 1,3240 | 0,1857 |
| Spgsin$_{t-1}$ | -0,0530 | 0,0166 | -3,1870 | 0,0015 | -0,0014 | 0,0267 | -0,0540 | 0,9572 | -0,0647 | 0,0212 | -3,0600 | 0,0022 |
| Spgslv$_{t-1}$ | -0,0386 | 0,0248 | -1,5550 | 0,1200 | -0,0345 | 0,0297 | -1,1620 | 0,2453 | -0,0266 | 0,0356 | -0,7460 | 0,4560 |
| Spgspm$_{t-1}$ | 0,0128 | 0,0184 | 0,6960 | 0,4864 | 0,0128 | 0,0303 | 0,4220 | 0,6731 | 0,0193 | 0,0231 | 0,8320 | 0,4054 |
| const | -0,0001 | 0,0003 | -0,4290 | 0,6680 | -0,0008 | 0,0006 | -1,4130 | 0,1579 | 0,0000 | 0,0004 | -0,0400 | 0,9684 |
| Vix | -0,0223 | 0,0036 | -6,1770 | 0,0000 | -0,0106 | 0,0054 | -1,9430 | 0,0522 | -0,0255 | 0,0046 | -5,5180 | 0,0000 |
| Baspcaaa | 0,0016 | 0,0046 | 0,3490 | 0,7273 | -0,0034 | 0,0071 | -0,4800 | 0,6310 | 0,0025 | 0,0059 | 0,4200 | 0,6745 |
| Usgg10yr | 0,0396 | 0,0130 | 3,0540 | 0,0023 | 0,0088 | 0,0199 | 0,4390 | 0,6606 | 0,0458 | 0,0166 | 2,7500 | 0,0060 |
| Libor | 0,0461 | 0,0196 | 2,3540 | 0,0186 | 0,0051 | 0,0276 | 0,1860 | 0,8525 | 0,0808 | 0,0261 | 3,0920 | 0,0020 |
| Fxcarrsp | 0,2764 | 0,0348 | 7,9440 | 0,0000 | 0,0873 | 0,0635 | 1,3750 | 0,1694 | 0,2793 | 0,0431 | 6,4860 | 0,0000 |
| Sntmntdiv | 0,0000 | 0,0000 | 0,1840 | 0,8544 | 0,0000 | 0,0000 | -0,0260 | 0,9791 | 0,0000 | 0,0000 | 0,2490 | 0,8033 |
| Emgimpy | 0,0000 | 0,0000 | 0,0590 | 0,9530 | 0,0000 | 0,0000 | 1,2010 | 0,2298 | 0,0000 | 0,0000 | -0,1260 | 0,8999 |
| Bdiy | 0,0090 | 0,0114 | 0,7860 | 0,4318 | -0,0049 | 0,0277 | -0,1760 | 0,8605 | 0,0058 | 0,0133 | 0,4410 | 0,6594 |
| Imfei | 0,1572 | 0,0563 | 2,7920 | 0,0053 | -0,0443 | 0,0646 | -0,6860 | 0,4930 | 0,3244 | 0,0874 | 3,7130 | 0,0002 |
| Clius | -0,8394 | 2,2550 | -0,3720 | 0,7097 | -0,9528 | 3,1400 | -0,3030 | 0,7616 | -3,1550 | 3,2250 | -0,9780 | 0,3280 |
| Clichn | 2,5750 | 1,6760 | 1,5370 | 0,1244 | 3,5370 | 2,9050 | 1,2170 | 0,2236 | 3,0830 | 2,3440 | 1,3150 | 0,1887 |
| Pmiwrld | -0,1168 | 0,1774 | -0,6580 | 0,5105 | 0,0901 | 0,1861 | 0,4840 | 0,6284 | -0,2902 | 0,2954 | -0,9830 | 0,3259 |
| Palmerz | -0,0001 | 0,0001 | -0,9000 | 0,3684 | -0,0004 | 0,0002 | -2,6080 | 0,0092 | 0,0000 | 0,0002 | 0,2230 | 0,8235 |
| Agavol | -0,0011 | 0,0008 | -1,3200 | 0,1868 | -0,0017 | 0,0009 | -1,8420 | 0,0657 | -0,0005 | 0,0012 | -0,3940 | 0,6936 |
| Agaoi | 0,0705 | 0,0133 | 5,3140 | 0,0000 | 0,0319 | 0,0115 | 2,7710 | 0,0057 | 0,2186 | 0,0319 | 6,8490 | 0,0000 |
| Agivol | 0,0489 | 0,0037 | 13,2460 | 0,0000 | 0,0336 | 0,0043 | 7,7990 | 0,0000 | 0,0587 | 0,0054 | 10,8980 | 0,0000 |
| $R^2$ | 0,1110 | | | | 0,0631 | | | | 0,1523 | | | |
| F | 19,6900 | df: 23 & 3627 | | 0,0000 | 3,7460 | df: 23 & 1280 | | 0,0000 | 18,1500 | df: 23 & 2323 | | 0,0000 |

**Table 7: VARX estimates in the whole sample and in subsamples. Estimates for SPGSIN equation**

Varx estimates in the whole sample and in subsamples

Equation: Spgsin

| | 2000:2013 (3650 observations) | | | | 2000:2004 (1303 observations) | | | | 2005:2013 (2346 observations) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | estimate | std. error | t statistic | p-value | estimate | std. error | t statistic | p-value | estimate | std. error | t statistic | p-value |
| Mxwo$_{t-1}$ | 0,1002 | 0,0260 | 3,8590 | 0,0001 | 0,0953 | 0,0316 | 3,0160 | 0,0026 | 0,1195 | 0,0373 | 3,2030 | 0,0014 |
| Spgsen$_{t-1}$ | 0,0126 | 0,0133 | 0,9470 | 0,3438 | 0,0193 | 0,0140 | 1,3800 | 0,1678 | -0,0021 | 0,0215 | -0,0960 | 0,9232 |
| Spgsag$_{t-1}$ | 0,0176 | 0,0200 | 0,8800 | 0,3787 | 0,0197 | 0,0299 | 0,6570 | 0,5110 | 0,0151 | 0,0260 | 0,5820 | 0,5604 |
| Spgsin$_{t-1}$ | -0,1294 | 0,0191 | -6,7710 | 0,0000 | -0,0734 | 0,0290 | -2,5320 | 0,0115 | -0,1431 | 0,0248 | -5,7640 | 0,0000 |
| Spgslv$_{t-1}$ | -0,0114 | 0,0285 | -0,4000 | 0,6890 | 0,0201 | 0,0322 | 0,6250 | 0,5323 | -0,0286 | 0,0418 | -0,6850 | 0,4937 |
| Spgspm$_{t-1}$ | 0,0152 | 0,0212 | 0,7190 | 0,4723 | 0,0416 | 0,0330 | 1,2630 | 0,2069 | 0,0231 | 0,0271 | 0,8510 | 0,3948 |
| const | -0,0001 | 0,0004 | -0,2530 | 0,8001 | -0,0008 | 0,0006 | -1,3090 | 0,1907 | 0,0001 | 0,0005 | 0,1280 | 0,8979 |
| Vix | -0,0391 | 0,0041 | -9,4520 | 0,0000 | -0,0287 | 0,0059 | -4,8550 | 0,0000 | -0,0403 | 0,0054 | -7,4410 | 0,0000 |
| Baspcaaa | 0,0021 | 0,0053 | 0,3950 | 0,6928 | 0,0150 | 0,0077 | 1,9600 | 0,0503 | -0,0037 | 0,0069 | -0,5390 | 0,5896 |
| Usgg10yr | 0,0701 | 0,0149 | 4,7060 | 0,0000 | -0,0035 | 0,0217 | -0,1610 | 0,8723 | 0,0855 | 0,0195 | 4,3840 | 0,0000 |
| Libor | 0,0350 | 0,0225 | 1,5590 | 0,1190 | 0,0240 | 0,0299 | 0,8020 | 0,4226 | 0,0502 | 0,0305 | 1,6440 | 0,1003 |
| Fxcarrsp | 0,3810 | 0,0399 | 9,5400 | 0,0000 | 0,0116 | 0,0691 | 0,1680 | 0,8663 | 0,4270 | 0,0504 | 8,4700 | 0,0000 |
| Sntmntdiv | 0,0000 | 0,0000 | 2,0630 | 0,0392 | 0,0000 | 0,0000 | 2,2870 | 0,0224 | 0,0000 | 0,0000 | 1,4500 | 0,1471 |
| Emgimpy | 0,0000 | 0,0000 | 0,2710 | 0,7861 | 0,0000 | 0,0000 | 0,8960 | 0,3703 | 0,0000 | 0,0000 | 0,0700 | 0,9443 |
| Bdiy | -0,0027 | 0,0131 | -0,2030 | 0,8391 | 0,0212 | 0,0301 | 0,7030 | 0,4824 | -0,0083 | 0,0155 | -0,5370 | 0,5913 |
| Imfei | 0,1700 | 0,0644 | 2,6390 | 0,0083 | 0,0575 | 0,0692 | 0,8310 | 0,4061 | 0,2632 | 0,1023 | 2,5730 | 0,0102 |
| Clius | 3,8390 | 2,5720 | 1,4920 | 0,1357 | 2,3390 | 3,4120 | 0,6860 | 0,4930 | 2,2070 | 3,7410 | 0,5900 | 0,5554 |
| Clichn | 2,3060 | 1,9230 | 1,1990 | 0,2304 | 1,0590 | 3,1590 | 0,3350 | 0,7374 | 1,4170 | 2,7340 | 0,5180 | 0,6042 |
| Pmiwrld | 0,0915 | 0,2037 | 0,4490 | 0,6531 | -0,1189 | 0,2025 | -0,5870 | 0,5573 | 0,5125 | 0,3458 | 1,4820 | 0,1384 |
| Inavol | -0,0002 | 0,0005 | -0,3650 | 0,7154 | 0,0003 | 0,0005 | 0,6610 | 0,5087 | -0,0007 | 0,0008 | -0,9360 | 0,3493 |
| Inaoi | 0,0010 | 0,0036 | 0,2760 | 0,7826 | 0,0021 | 0,0029 | 0,7410 | 0,4590 | -0,0014 | 0,0102 | -0,1380 | 0,8899 |
| Inivol | -0,0015 | 0,0022 | -0,6820 | 0,4956 | 0,0024 | 0,0019 | 1,2670 | 0,2053 | -0,0096 | 0,0044 | -2,1840 | 0,0291 |
| $R^2$ | 0,1196 | | | | 0,0469 | | | | 0,1508 | | | |
| F | 22,4100 | df: 22 & 3628 | | 0,0000 | 2,8650 | df: 22 & 1281 | | 0,0000 | 18,7600 | df: 22 & 2324 | | 0,0000 |

### Table 8: VARX estimates in the whole sample and in subsamples. Estimates for SPGSLV equation

Varx estimates in the whole sample and in subsamples

Equation: Spgslv

| | 2000:2013 (3650 observations) | | | | 2000:2004 (1303 observations) | | | | 2005:2013 (2346 observations) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | estimate | std. error | t statistic | p-value | estimate | std. error | t statistic | p-value | estimate | std. error | t statistic | p-value |
| Mxwo$_{t-1}$ | 0,0205 | 0,0148 | 1,3810 | 0,1673 | -0,0060 | 0,0265 | -0,2280 | 0,8197 | 0,0333 | 0,0183 | 1,8140 | 0,0699 |
| Spgsen$_{t-1}$ | -0,0033 | 0,0076 | -0,4360 | 0,6631 | -0,0039 | 0,0117 | -0,3310 | 0,7407 | -0,0053 | 0,0105 | -0,5070 | 0,6124 |
| Spgsag$_{t-1}$ | -0,0042 | 0,0114 | -0,3720 | 0,7102 | -0,0125 | 0,0253 | -0,4950 | 0,6206 | -0,0045 | 0,0128 | -0,3500 | 0,7267 |
| Spgsin$_{t-1}$ | -0,0258 | 0,0109 | -2,3580 | 0,0184 | -0,0146 | 0,0243 | -0,6010 | 0,5482 | -0,0314 | 0,0122 | -2,5800 | 0,0099 |
| Spgslv$_{t-1}$ | -0,0127 | 0,0164 | -0,7770 | 0,4375 | -0,0301 | 0,0273 | -1,1010 | 0,2710 | -0,0019 | 0,0206 | -0,0930 | 0,9256 |
| Spgspm$_{t-1}$ | -0,0193 | 0,0121 | -1,5940 | 0,1109 | -0,0223 | 0,0277 | -0,8060 | 0,4202 | -0,0162 | 0,0133 | -1,2140 | 0,2248 |
| const | -0,0005 | 0,0002 | -2,1220 | 0,0339 | -0,0002 | 0,0005 | -0,4160 | 0,6772 | -0,0005 | 0,0002 | -2,0980 | 0,0360 |
| Vix | -0,0091 | 0,0024 | -3,8430 | 0,0001 | -0,0079 | 0,0050 | -1,5920 | 0,1116 | -0,0086 | 0,0027 | -3,2600 | 0,0011 |
| Baspcaaa | 0,0017 | 0,0030 | 0,5480 | 0,5840 | -0,0031 | 0,0064 | -0,4760 | 0,6345 | 0,0051 | 0,0034 | 1,5140 | 0,1302 |
| Usgg10yr | 0,0148 | 0,0085 | 1,7380 | 0,0822 | 0,0367 | 0,0182 | 2,0130 | 0,0443 | 0,0039 | 0,0096 | 0,4070 | 0,6838 |
| Libor | -0,0014 | 0,0128 | -0,1120 | 0,9109 | 0,0109 | 0,0252 | 0,4310 | 0,6666 | -0,0058 | 0,0151 | -0,3890 | 0,6975 |
| Fxcarrsp | 0,0599 | 0,0229 | 2,6200 | 0,0088 | -0,0863 | 0,0580 | -1,4880 | 0,1370 | 0,0965 | 0,0248 | 3,8900 | 0,0001 |
| Sntmntdiv | 0,0000 | 0,0000 | -0,2450 | 0,8068 | 0,0000 | 0,0000 | -0,2780 | 0,7813 | 0,0000 | 0,0000 | -0,3860 | 0,6997 |
| Emgimpy | 0,0000 | 0,0000 | 1,5300 | 0,1262 | 0,0000 | 0,0000 | 0,6780 | 0,4976 | 0,0000 | 0,0000 | 1,0440 | 0,2965 |
| Bdiy | 0,0129 | 0,0075 | 1,7170 | 0,0860 | 0,0216 | 0,0253 | 0,8570 | 0,3915 | 0,0123 | 0,0076 | 1,6070 | 0,1083 |
| Imfei | -0,0488 | 0,0370 | -1,3190 | 0,1873 | -0,0069 | 0,0592 | -0,1160 | 0,9077 | -0,0714 | 0,0503 | -1,4190 | 0,1562 |
| Clius | 1,4890 | 1,4800 | 1,0060 | 0,3144 | 1,7180 | 2,8780 | 0,5970 | 0,5505 | 1,6330 | 1,8600 | 0,8780 | 0,3801 |
| Clichn | -1,4960 | 1,1000 | -1,3600 | 0,1740 | -4,2960 | 2,6540 | -1,6190 | 0,1058 | -1,0710 | 1,3500 | -0,7940 | 0,4274 |
| Pmiwrld | 0,2137 | 0,1165 | 1,8350 | 0,0666 | 0,2517 | 0,1699 | 1,4820 | 0,1387 | 0,1603 | 0,1699 | 0,9440 | 0,3455 |
| Palmerz | 0,0000 | 0,0001 | -0,4210 | 0,6741 | 0,0001 | 0,0001 | 0,4520 | 0,6515 | -0,0001 | 0,0001 | -0,8840 | 0,3769 |
| Lvavol | -0,0001 | 0,0004 | -0,2190 | 0,8263 | -0,0010 | 0,0008 | -1,2820 | 0,2000 | 0,0003 | 0,0005 | 0,6400 | 0,5224 |
| Lvaoi | 0,1976 | 0,0127 | 15,5700 | 0,0000 | 0,1704 | 0,0190 | 8,9670 | 0,0000 | 0,2296 | 0,0178 | 12,8930 | 0,0000 |
| Lvivol | -0,0042 | 0,0010 | -4,1980 | 0,0000 | -0,0055 | 0,0016 | -3,3800 | 0,0007 | -0,0033 | 0,0013 | -2,5540 | 0,0107 |
| $R^2$ | 0,0930 | | | | 0,0914 | | | | 0,1069 | | | |
| F | 16,1600 | df: 23 & 3627 | | 0,0000 | 5,5950 | df: 23 & 1280 | | 0,0000 | 12,0800 | df: 23 & 2323 | | 0,0000 |

### Table 9: VARX estimates in the whole sample and in subsamples. Estimates for SPGSPM equation

Varx estimates in the whole sample and in subsamples

Equation: Spgspm

| | 2000:2013 (3650 observations) | | | | 2000:2004 (1303 observations) | | | | 2005:2013 (2346 observations) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | estimate | std. error | t statistic | p-value | estimate | std. error | t statistic | p-value | estimate | std. error | t statistic | p-value |
| Mxwo$_{t-1}$ | 0,0653 | 0,0222 | 2,9400 | 0,0033 | 0,0804 | 0,0274 | 2,9330 | 0,0034 | 0,0466 | 0,0313 | 1,4900 | 0,1364 |
| Spgsen$_{t-1}$ | 0,0108 | 0,0114 | 0,9480 | 0,3434 | -0,0023 | 0,0121 | -0,1900 | 0,8496 | 0,0229 | 0,0179 | 1,2820 | 0,2001 |
| Spgsag$_{t-1}$ | 0,0263 | 0,0171 | 1,5420 | 0,1232 | 0,0223 | 0,0260 | 0,8560 | 0,3922 | 0,0182 | 0,0218 | 0,8340 | 0,4044 |
| Spgsin$_{t-1}$ | -0,0359 | 0,0164 | -2,1970 | 0,0281 | -0,0044 | 0,0252 | -0,1740 | 0,8623 | -0,0406 | 0,0208 | -1,9510 | 0,0512 |
| Spgslv$_{t-1}$ | 0,0291 | 0,0243 | 1,1970 | 0,2314 | 0,0346 | 0,0279 | 1,2390 | 0,2154 | 0,0340 | 0,0350 | 0,9710 | 0,3317 |
| Spgspm$_{t-1}$ | -0,0345 | 0,0182 | -1,8940 | 0,0583 | -0,0937 | 0,0290 | -3,2350 | 0,0013 | -0,0238 | 0,0228 | -1,0430 | 0,2968 |
| const | 0,0001 | 0,0003 | 0,3470 | 0,7290 | 0,0001 | 0,0005 | 0,1740 | 0,8618 | 0,0001 | 0,0004 | 0,2330 | 0,8155 |
| Vix | -0,0104 | 0,0035 | -2,9350 | 0,0034 | 0,0100 | 0,0051 | 1,9410 | 0,0525 | -0,0140 | 0,0046 | -3,0560 | 0,0023 |
| Baspcaaa | 0,0157 | 0,0045 | 3,4660 | 0,0005 | 0,0058 | 0,0067 | 0,8710 | 0,3842 | 0,0171 | 0,0058 | 2,9410 | 0,0033 |
| Usgg10yr | -0,0787 | 0,0128 | -6,1730 | 0,0000 | -0,1028 | 0,0189 | -5,4510 | 0,0000 | -0,0766 | 0,0164 | -4,6830 | 0,0000 |
| Libor | 0,0005 | 0,0192 | 0,0250 | 0,9802 | -0,0547 | 0,0259 | -2,1080 | 0,0352 | 0,0308 | 0,0255 | 1,2070 | 0,2277 |
| Fxcarrsp | 0,1918 | 0,0342 | 5,6050 | 0,0000 | 0,1648 | 0,0601 | 2,7450 | 0,0061 | 0,1711 | 0,0424 | 4,0370 | 0,0001 |
| Sntmntdiv | 0,0000 | 0,0000 | 0,4720 | 0,6372 | 0,0000 | 0,0000 | -0,4490 | 0,6539 | 0,0000 | 0,0000 | 1,0080 | 0,3136 |
| Emgimpy | 0,0000 | 0,0000 | 0,8590 | 0,3902 | 0,0000 | 0,0000 | 0,7450 | 0,4563 | 0,0000 | 0,0000 | 1,1010 | 0,2710 |
| Bdiy | -0,0009 | 0,0112 | -0,0820 | 0,9345 | 0,0139 | 0,0261 | 0,5340 | 0,5936 | -0,0054 | 0,0130 | -0,4160 | 0,6772 |
| Clius | -1,0030 | 2,1970 | -0,4570 | 0,6480 | 4,4660 | 2,9440 | 1,5170 | 0,1295 | -4,7700 | 3,0990 | -1,5390 | 0,1238 |
| Clichn | 3,4070 | 1,6430 | 2,0740 | 0,0381 | 1,9320 | 2,6730 | 0,7230 | 0,4701 | 4,9720 | 2,2900 | 2,1710 | 0,0300 |
| Pmiwrld | -0,0486 | 0,1665 | -0,2920 | 0,7705 | -0,1215 | 0,1671 | -0,7270 | 0,4671 | -0,0131 | 0,2762 | -0,0470 | 0,9622 |
| Pmavol | -0,0013 | 0,0004 | -3,0760 | 0,0021 | 0,0004 | 0,0005 | 0,7240 | 0,4694 | -0,0027 | 0,0006 | -4,2600 | 0,0000 |
| Pmaoi | 0,0607 | 0,0094 | 6,4450 | 0,0000 | 0,0000 | 0,0091 | 0,0050 | 0,9961 | 0,1611 | 0,0164 | 9,8110 | 0,0000 |
| Pmivol | 0,0026 | 0,0020 | 1,3250 | 0,1851 | 0,0093 | 0,0018 | 5,1780 | 0,0000 | -0,0124 | 0,0038 | -3,2310 | 0,0013 |
| $R^2$ | 0,0421 | | | | 0,0834 | | | | 0,0782 | | | |
| F | 7,5860 | df: 21 & 3629 | | 0,0000 | 5,5570 | df: 21 & 1282 | | 0,0000 | 9,3850 | df: 21 & 2325 | | 0,0000 |

**Table 10: Arch effect, autocorrelation, normality and likelihood ratio test results on VARX residuals**

| | | Statistical test on residuals of VARX model | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 2000:2013 | | | 2000:2004 | | | 2005:2013 | | |
| | | $\chi^2$ statistic | df | p-value | $\chi^2$ statistic | df | p-value | $\chi^2$ statistic | df | p-value |
| ARCH-LM | MXWO | 526,9271 | 4 | 0,0000 | 52,4812 | 4 | 0,0000 | 416,1441 | 4 | 0,0000 |
| | SPGSEN | 173,5220 | 4 | 0,0000 | 21,8281 | 4 | 0,0002 | 184,3495 | 4 | 0,0000 |
| | SPGSAG | 209,4185 | 4 | 0,0000 | 22,2426 | 4 | 0,0001 | 104,1706 | 4 | 0,0000 |
| | SPGSIN | 280,6759 | 4 | 0,0000 | 15,2512 | 4 | 0,0042 | 204,3080 | 4 | 0,0000 |
| | SPGSLV | 75,7854 | 4 | 0,0000 | 55,7346 | 4 | 0,0000 | 26,7825 | 4 | 0,0000 |
| | SPGSPM | 155,4341 | 4 | 0,0000 | 4,6258 | 4 | 0,3279 | 110,9093 | 4 | 0,0000 |
| Ljung-Box | $h-2$ | 98,9668 | 36 | 0,0000 | 53,5931 | 36 | 0,0298 | 103,5145 | 36 | 0,0000 |
| | $h-3$ | 153,4683 | 72 | 0,0000 | 82,8031 | 72 | 0,1804 | 163,4008 | 72 | 0,0000 |
| | $h-4$ | 183,4020 | 108 | 0,0000 | 111,9788 | 108 | 0,3772 | 204,1353 | 108 | 0,0000 |
| | $h-5$ | 222,5134 | 144 | 0,0000 | 151,2121 | 144 | 0,3238 | 247,1690 | 144 | 0,0000 |
| | $h-6$ | 267,3386 | 180 | 0,0000 | 196,7744 | 180 | 0,1860 | 288,3553 | 180 | 0,0000 |
| | $h-7$ | 320,6244 | 216 | 0,0000 | 241,9393 | 216 | 0,1088 | 333,1765 | 216 | 0,0000 |
| | $h-8$ | 379,9001 | 252 | 0,0000 | 273,6410 | 252 | 0,1667 | 383,1637 | 252 | 0,0000 |
| Breush-Godfrey | $h-1$ | 145,1340 | 36 | 0,0000 | 60,0383 | 36 | 0,0072 | 118,5962 | 36 | 0,0000 |
| | $h-2$ | 236,2920 | 72 | 0,0000 | 115,7443 | 72 | 0,0008 | 223,0010 | 72 | 0,0000 |
| | $h-3$ | 289,3250 | 108 | 0,0000 | 146,5368 | 108 | 0,0008 | 281,0785 | 108 | 0,0000 |
| | $h-4$ | 320,5040 | 144 | 0,0000 | 176,8898 | 144 | 0,0324 | 324,8703 | 144 | 0,0000 |
| | $h-5$ | 355,9700 | 180 | 0,0000 | 215,2243 | 180 | 0,0373 | 363,3927 | 180 | 0,0000 |
| | $h-6$ | 403,7690 | 216 | 0,0000 | 262,1744 | 216 | 0,1734 | 405,9489 | 216 | 0,0000 |
| | $h-7$ | 457,4590 | 252 | 0,0000 | 308,9899 | 252 | 0,0820 | 450,5027 | 252 | 0,0000 |
| | $h-8$ | 517,1160 | 288 | 0,0000 | 341,9505 | 288 | 0,0158 | 500,5528 | 288 | 0,0000 |
| JB | Multivariate | 17088 | 12 | 0,0000 | 4706 | 12 | 0,0000 | 15017 | 12 | 0,0000 |
| | Skewness | 182 | 6 | 0,0000 | 179 | 6 | 0,0000 | 130 | 6 | 0,0000 |
| | Kurtosis | 16906 | 6 | 0,0000 | 4527 | 6 | 0,0000 | 14888 | 6 | 0,0000 |
| LR | | 0,0035 | 106 | 1,0000 | 0,0047 | 106 | 1,0000 | 0,0071 | 106 | 1,0000 |

# C. Variance equation - DCC estimates and test results

**Table 11: Optimal univariate GARCH models specifications**

| *Variable* | *Mean equation* | *Variance equation* | *Error distribution* |
|---|---|---|---|
| Mxwo | Arima(1,0,1) | eGarch(1,1) | Sstd |
| Spgsen | Arima(1,0,1) | eGarch(1,1) | Ged |
| Spgsag | Arima(1,0,1) | eGarch(1,1) | Std |
| Spgsin | Arima(1,0,1) | sGarch(1,1) | Ged |
| Spgslv | Arima(1,0,1) | gjrGarch(1,1) | Ged |
| Spgspm | Arima(1,0,1) | eGarch(1,1) | Sstd |

**Table 12: Estimates of the VARX ADCC MVT GARCH model in the whole sample and in subsamples**

| | | Estimates of the univariate and multivariate Garch parameters of the Varx aDcc(1,1) Mvt Garch | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2000:2013 (3651 daily observations) | | | | 2000:2004 (1304 observations) | | | | 2005:20013 (2347 observations) | | | |
| | | 234 (Var)+31 (Garch)+4 (Dcc)+15 ($\overline{Q}$) | | | | 234 (Var)+31 (Garch)+4 (Dcc)+15 ($\overline{Q}$) | | | | 234 (Var)+31 (Garch)+4 (Dcc)+15 ($\overline{Q}$) | | | |
| | | estimate | std. error | t statistic | p-value | estimate | std. error | t statistic | p-value | estimate | std. error | t statistic | p-value |
| Univariate Garch parameter estimates | $\omega_{Mxwo}$ | -0,0440 | 0,0024 | -18,6788 | 0,0000 | 0,0000 | 0,0027 | 0,0130 | 0,9896 | -0,0571 | 0,0036 | -16,0062 | 0,0000 |
| | $\alpha_{Mxwo}$ | -0,0060 | 0,0100 | -0,5968 | 0,5507 | -0,0116 | 0,0170 | -0,6817 | 0,4954 | 0,0005 | 0,0148 | 0,0365 | 0,9708 |
| | $\beta_{Mxwo}$ | 0,9957 | 0,0002 | 5822,5556 | 0,0000 | 0,9994 | 0,0000 | 34462,0690 | 0,0000 | 0,9944 | 0,0003 | 3710,5746 | 0,0000 |
| | $\gamma_{Mxwo}$ | 0,1411 | 0,0046 | 31,0037 | 0,0000 | 0,1360 | 0,0452 | 3,0116 | 0,0026 | 0,1509 | 0,0069 | 22,0255 | 0,0000 |
| | $\lambda_{Mxwo}$ | 1,0829 | 0,0260 | 41,6255 | 0,0000 | 1,1109 | 0,0432 | 25,7380 | 0,0000 | 1,0702 | 0,0335 | 31,9413 | 0,0000 |
| | $\theta_{Mxwo}$ | 8,2308 | 0,9671 | 8,5112 | 0,0000 | 7,6374 | 1,3931 | 5,4821 | 0,0000 | 8,3572 | 1,2702 | 6,5793 | 0,0000 |
| | $\omega_{Spgsen}$ | -1,5165 | 0,2126 | -7,1337 | 0,0000 | 0,0004 | 0,0014 | 0,3126 | 0,7546 | -0,1777 | 0,0150 | -11,8220 | 0,0000 |
| | $\alpha_{Spgsen}$ | -0,0638 | 0,0224 | -2,8471 | 0,0044 | 0,0145 | 0,0120 | 1,2061 | 0,2278 | -0,0276 | 0,0129 | -2,1343 | 0,0328 |
| | $\beta_{Spgsen}$ | 0,8108 | 0,0267 | 30,3487 | 0,0000 | 0,9995 | 0,0001 | 10747,3118 | 0,0000 | 0,9788 | 0,0018 | 530,5003 | 0,0000 |
| | $\gamma_{Spgsen}$ | 0,3218 | 0,0306 | 10,5035 | 0,0000 | 0,0775 | 0,0363 | 2,1328 | 0,0329 | 0,1482 | 0,0261 | 5,6856 | 0,0000 |
| | $\theta_{Spgsen}$ | 1,3114 | 0,0468 | 28,0488 | 0,0000 | 1,4130 | 0,0996 | 14,1840 | 0,0000 | 1,4162 | 0,0690 | 20,5378 | 0,0000 |
| | $\omega_{Spgsag}$ | -0,0385 | 0,0010 | -36,7035 | 0,0000 | 0,0001 | 0,0027 | 0,0192 | 0,9847 | -0,2927 | 0,2100 | -1,3935 | 0,1635 |
| | $\alpha_{Spgsag}$ | 0,0200 | 0,0066 | 3,0130 | 0,0026 | 0,0833 | 0,0384 | 2,1687 | 0,0301 | 0,0008 | 0,0265 | 0,0293 | 0,9766 |
| | $\beta_{Spgsag}$ | 0,9957 | 0,0001 | 16322,4590 | 0,0000 | 0,9993 | 0,0001 | 11986,0000 | 0,0000 | 0,9664 | 0,0239 | 40,4485 | 0,0000 |
| | $\gamma_{Spgsag}$ | 0,0709 | 0,0052 | 13,7404 | 0,0000 | 0,0976 | 0,0576 | 1,6929 | 0,0905 | 0,1415 | 0,2932 | 0,4824 | 0,6295 |
| | $\theta_{Spgsag}$ | 7,7879 | 0,8938 | 8,7130 | 0,0000 | 2,7204 | 0,1445 | 18,8250 | 0,0000 | 8,1562 | 6,4668 | 1,2612 | 0,2072 |
| | $\omega_{Spgsin}$ | 0,0000 | 0,0000 | 0,5000 | 0,5724 | 0,0000 | 0,0000 | 0,4419 | 0,6585 | 0,0000 | 0,0000 | 1,0000 | 0,3200 |
| | $\alpha_{Spgsin}$ | 0,0431 | 0,0112 | 3,8444 | 0,0001 | 0,0364 | 0,0229 | 1,5928 | 0,1112 | 0,0530 | 0,0130 | 4,0858 | 0,0000 |
| | $\beta_{Spgsin}$ | 0,9522 | 0,0125 | 75,9269 | 0,0000 | 0,9502 | 0,0301 | 31,5200 | 0,0000 | 0,9379 | 0,0160 | 58,5323 | 0,0000 |
| | $\theta_{Spgsin}$ | 1,4443 | 0,0597 | 24,1887 | 0,0000 | 1,4091 | 0,0852 | 16,5370 | 0,0000 | 1,4903 | 0,0671 | 22,1965 | 0,0000 |
| | $\omega_{Spgslv}$ | 0,0000 | 0,0000 | 0,0000 | 0,5726 | 0,0000 | 0,0000 | 8,2891 | 0,0000 | 0,0000 | 0,0000 | 0,0040 | 0,8629 |
| | $\alpha_{Spgslv}$ | 0,0191 | 0,0044 | 4,3685 | 0,0000 | 0,0260 | 0,0110 | 2,3613 | 0,0182 | 0,0111 | 0,0034 | 3,3226 | 0,0009 |
| | $\beta_{Spgslv}$ | 0,9673 | 0,0018 | 523,1266 | 0,0000 | 0,9393 | 0,0077 | 121,9000 | 0,0000 | 0,9792 | 0,0002 | 4554,3070 | 0,0000 |
| | $\gamma_{Spgslv}$ | 0,0187 | 0,0077 | 2,4346 | 0,0149 | 0,0317 | 0,0189 | 1,6763 | 0,0937 | 0,0179 | 0,0068 | 2,6260 | 0,0086 |
| | $\theta_{Spgslv}$ | 1,5853 | 0,1092 | 14,5142 | 0,0000 | 1,5873 | 0,0912 | 17,4090 | 0,0000 | 1,6044 | 0,0998 | 16,0788 | 0,0000 |
| | $\omega_{Spgspm}$ | -0,6091 | 0,0295 | -20,6758 | 0,0000 | -0,2013 | 0,0063 | -32,1490 | 0,0000 | -0,6025 | 0,0399 | -15,0896 | 0,0000 |
| | $\alpha_{Spgspm}$ | 0,0102 | 0,0159 | 0,6439 | 0,5197 | 0,0889 | 0,0198 | 4,4943 | 0,0000 | -0,0246 | 0,0199 | -1,2399 | 0,2150 |
| | $\beta_{Spgspm}$ | 0,9319 | 0,0032 | 292,4846 | 0,0000 | 0,9785 | 0,0005 | 1850,6000 | 0,0000 | 0,9308 | 0,0044 | 210,9810 | 0,0000 |
| | $\gamma_{Spgspm}$ | 0,2004 | 0,0173 | 11,5543 | 0,0000 | 0,0911 | 0,0159 | 5,7286 | 0,0000 | 0,1944 | 0,0214 | 9,0916 | 0,0000 |
| | $\lambda_{Spgspm}$ | 0,9878 | 0,0172 | 57,3222 | 0,0000 | 1,0894 | 0,0347 | 31,4320 | 0,0000 | 0,9288 | 0,0202 | 46,0017 | 0,0000 |
| | $\theta_{Spgspm}$ | 4,5797 | 0,3798 | 12,0597 | 0,0000 | 4,8007 | 0,6831 | 7,0283 | 0,0000 | 4,7927 | 0,5019 | 9,5493 | 0,0000 |
| aDcc | A | 0,0047 | 0,0008 | 5,7764 | 0,0000 | 0,0041 | 0,0011 | 3,5608 | 0,0004 | 0,0073 | 0,0023 | 3,1823 | 0,0015 |
| | B | 0,9926 | 0,0015 | 646,6502 | 0,0000 | 0,9889 | 0,0025 | 396,0400 | 0,0000 | 0,9787 | 0,0104 | 94,1330 | 0,0000 |
| | Γ | 0,0004 | 0,0004 | 0,8642 | 0,3877 | 0,0008 | 0,0008 | 0,9595 | 0,3373 | 0,0009 | 0,0017 | 0,5568 | 0,5774 |
| | Θ | 9,5216 | 0,5307 | 17,9424 | 0,0000 | 8,7948 | 0,7412 | 11,8660 | 0,0000 | 9,6168 | 0,7115 | 13,5161 | 0,0000 |
| IC | Aic | -38,0780 | | | | -38,023 | | | | -37,9360 | | | |
| | Bic | -37,5960 | | | | -36,897 | | | | -37,2390 | | | |
| | Sic | -38,0890 | | | | -38,097 | | | | -37,9620 | | | |
| | Hqc | -37,9060 | | | | -37,601 | | | | -37,6820 | | | |

Symbols used $\omega$ - constant in univariate variance equation, $\alpha$ - univariate previous term error term, $\beta$ - univariate previous term variance, $\gamma$ - univariate leverage effect, $\lambda$ - asymmetry of univariate distribution, $\theta$ - shape of univariate distribution, $A$ - multivariate previous term error term, $B$ - multivariate previous term variance matrix, $\Gamma$ - multivariate leverage effect, $\Theta$ - multivariate distribution shape.

**Table 13: ARCH effect and normality test on standardized residuals of the VARX ADCC MVT GARCH**

| | | Tests results on standardized residuals of the Varx aDcc Mvt Garch | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 2000:2013 | | | 2000:2004 | | | 2005:2013 | | |
| | | $\chi^2$ statistic | df | p-value | $\chi^2$ statistic | df | p-value | $\chi^2$ statistic | df | p-value |
| Arch-Lm | Mxwo | 24,8877 | 12 | 0,0154 | 8,8418 | 12 | 0,7164 | 16,8987 | 12 | 0,1534 |
| | Spgsen | 65,3193 | 12 | 0,0000 | 7,4417 | 12 | 0,8271 | 5,8687 | 12 | 0,9226 |
| | Spgsag | 11,0987 | 12 | 0,5205 | 11,5626 | 12 | 0,4814 | 4,9519 | 12 | 0,9596 |
| | Spgsin | 14,3121 | 12 | 0,2812 | 13,4528 | 12 | 0,3370 | 10,0822 | 12 | 0,6088 |
| | Spgslv | 6,4737 | 12 | 0,8903 | 8,2706 | 12 | 0,7636 | 8,2711 | 12 | 0,7636 |
| | Spgspm | 7,6984 | 12 | 0,8082 | 3,6738 | 12 | 0,9886 | 14,8755 | 12 | 0,2483 |
| Ljung-Box | Mxwo | 28,2459 | 12 | 0,0051 | 9,8037 | 12 | 0,6332 | 18,6607 | 12 | 0,0971 |
| | Spgsen | 63,1011 | 12 | 0,0000 | 6,6435 | 12 | 0,8802 | 6,0195 | 12 | 0,9151 |
| | Spgsag | 11,4750 | 12 | 0,4487 | 11,6759 | 12 | 0,4721 | 5,0200 | 12 | 0,9573 |
| | Spgsin | 14,5557 | 12 | 0,2666 | 14,5543 | 12 | 0,2667 | 7,6736 | 12 | 0,8101 |
| | Spgslv | 6,5628 | 12 | 0,8851 | 8,2957 | 12 | 0,7616 | 8,2711 | 12 | 0,8101 |
| | Spgspm | 7,5452 | 12 | 0,8196 | 3,4745 | 12 | 0,9912 | 14,8755 | 12 | 0,2399 |
| Jarque-Bera | Mxwo | 395,5384 | 2 | 0,0000 | 114,4957 | 2 | 0,0000 | 263,1484 | 2 | 0,0000 |
| | Spgsen | 423,4037 | 2 | 0,0000 | 109,1964 | 2 | 0,0000 | 258,4374 | 2 | 0,0000 |
| | Spgsag | 336,3566 | 2 | 0,0000 | 74,0755 | 2 | 0,0000 | 135,2677 | 2 | 0,0000 |
| | Spgsin | 590,2816 | 2 | 0,0000 | 372,5370 | 2 | 0,0000 | 154,6768 | 2 | 0,0000 |
| | Spgslv | 52,8343 | 2 | 0,0000 | 18,5615 | 2 | 0,0000 | 37,8331 | 2 | 0,0000 |
| | Spgspm | 3942,1200 | 2 | 0,0000 | 3724,7390 | 2 | 0,0000 | 1003,7250 | 2 | 0,0000 |
| Anderson-Darling | Mxwo | 5,9023 | | 0,0000 | 2,3872 | | 0,0000 | 3,8726 | | 0,0000 |
| | Spgsen | 11,2909 | | 0,0000 | 2,2232 | | 0,0000 | 3,7833 | | 0,0000 |
| | Spgsag | 6,3638 | | 0,0000 | 2,9662 | | 0,0000 | 3,7799 | | 0,0000 |
| | Spgsin | 6,7948 | | 0,0000 | 2,7678 | | 0,0000 | 4,3896 | | 0,0000 |
| | Spgslv | 3,2503 | | 0,0000 | 1,4981 | | 0,0007 | 2,0817 | | 0,0000 |
| | Spgspm | inf | | 0,0000 | inf | | 0,0000 | 13,9460 | | 0,0000 |

**Figure 3: Tests results for the variance clustering effect and normality of returns of univariate time series (1st row), error term in the whole sample (2nd row) and in subsamples**

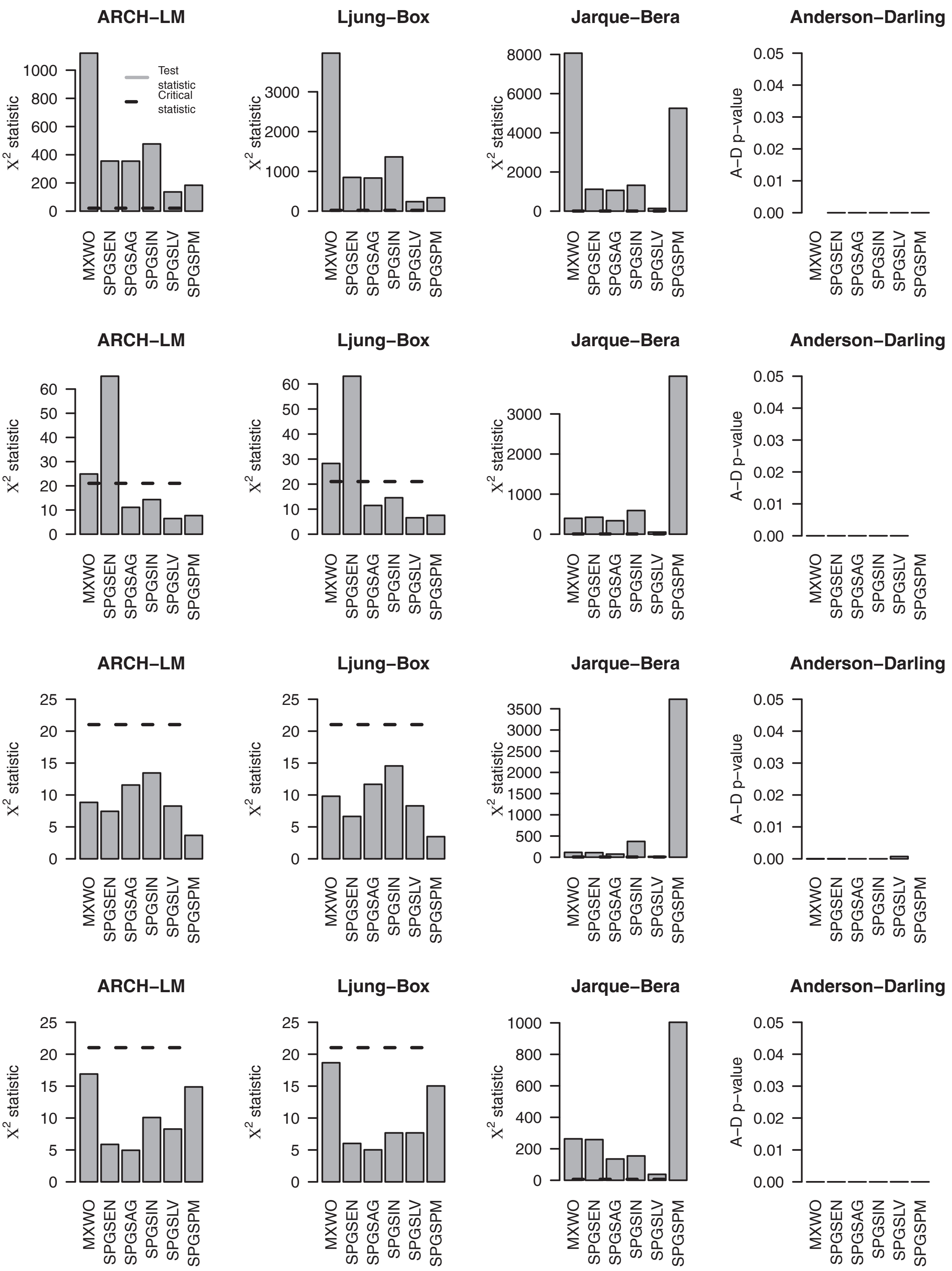


**Figure 4: Dynamic conditional correlation between the distinguished equity and commodity markets from the VARX DCC GARCH with asymmetry term and multivariate t distribution in 2000-2013**

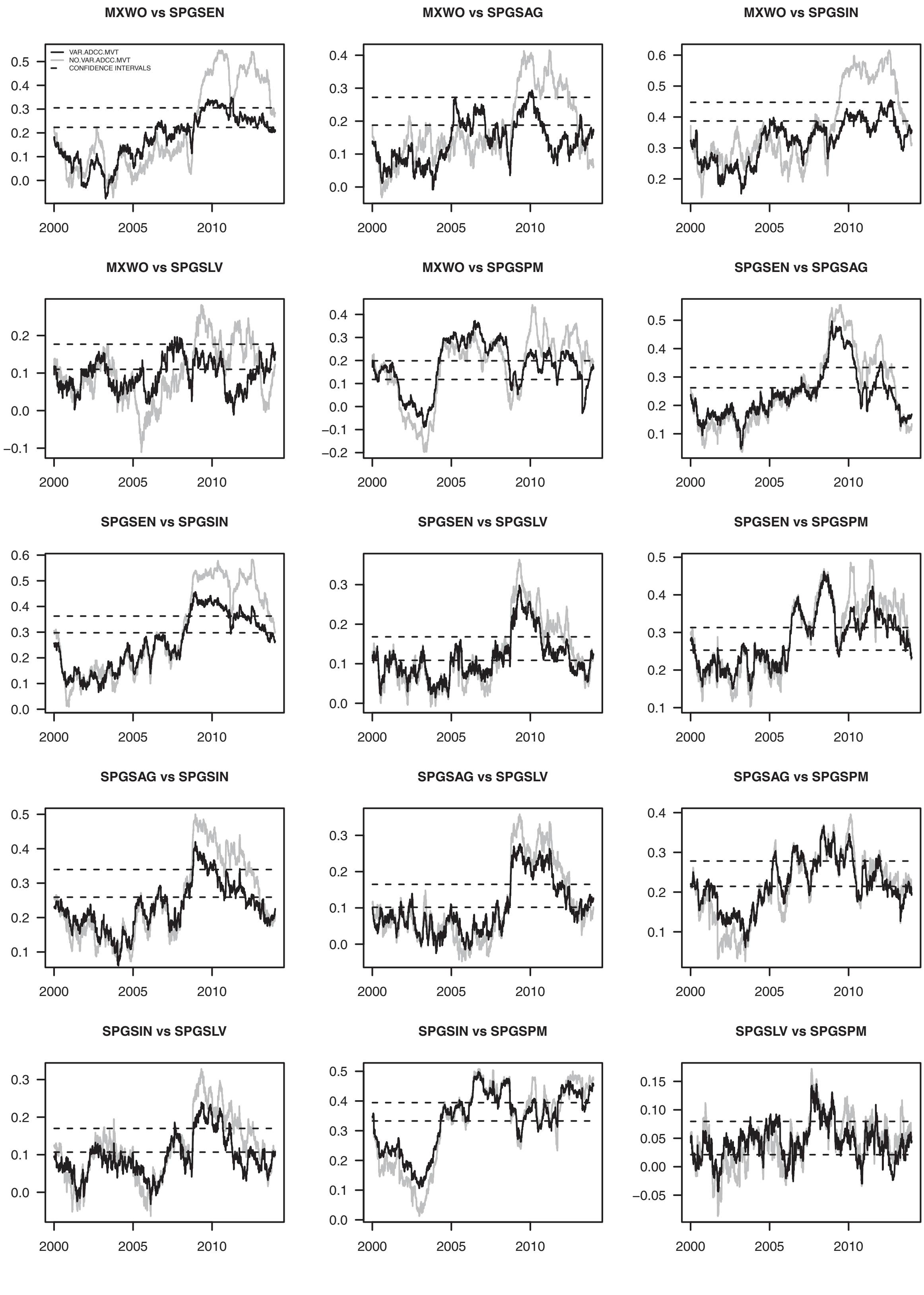


**Figure 5: Dynamic conditional correlation between the distinguished equity and commodity markets from the VARX DCC GARCH with asymmetry term and multivariate t distribution in 2000-2004**

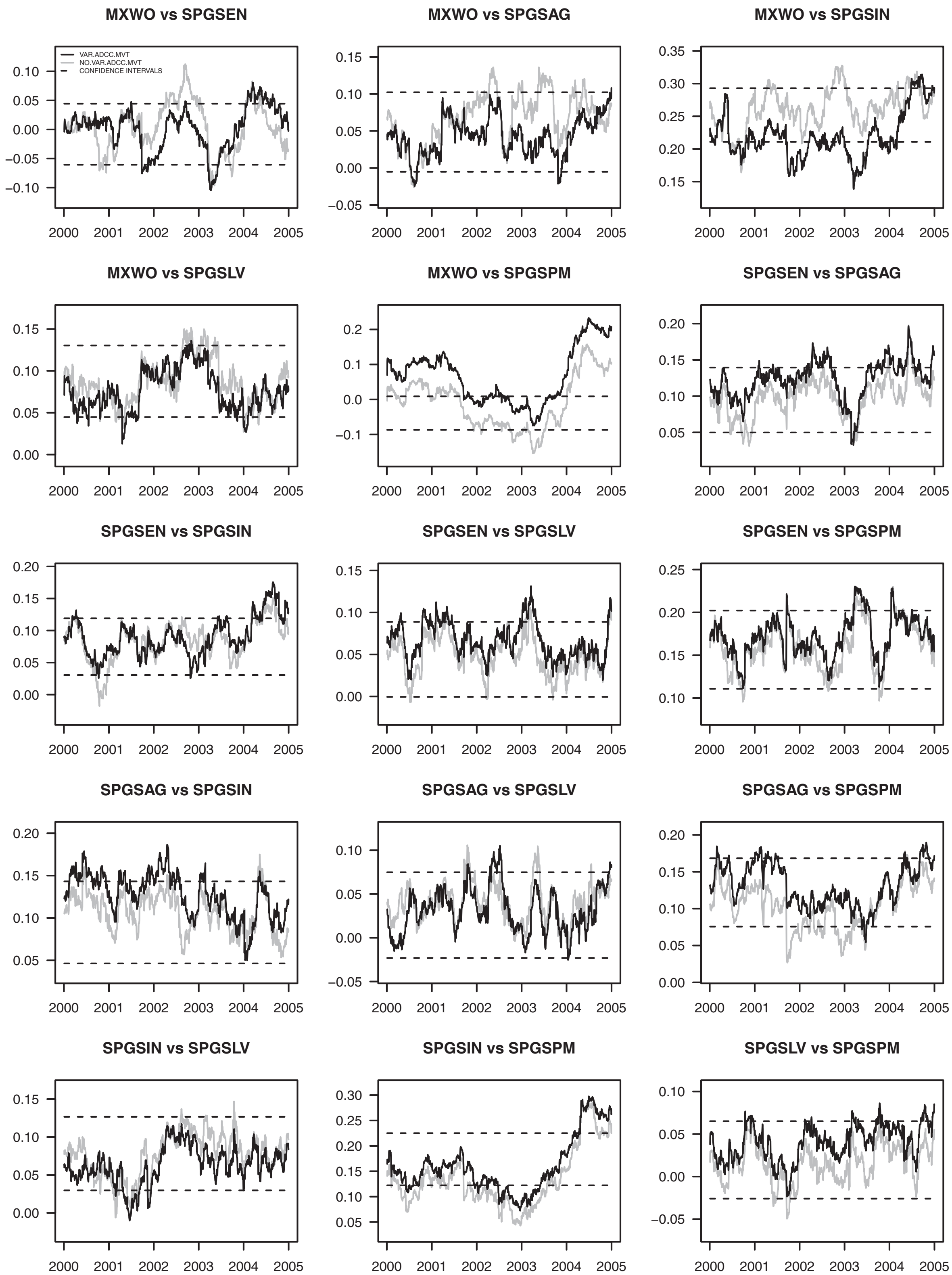


**Figure 6: Dynamic conditional correlation between the distinguished equity and commodity markets from the VARX DCC GARCH with asymmetry term and multivariate t distribution in 2005-2013**

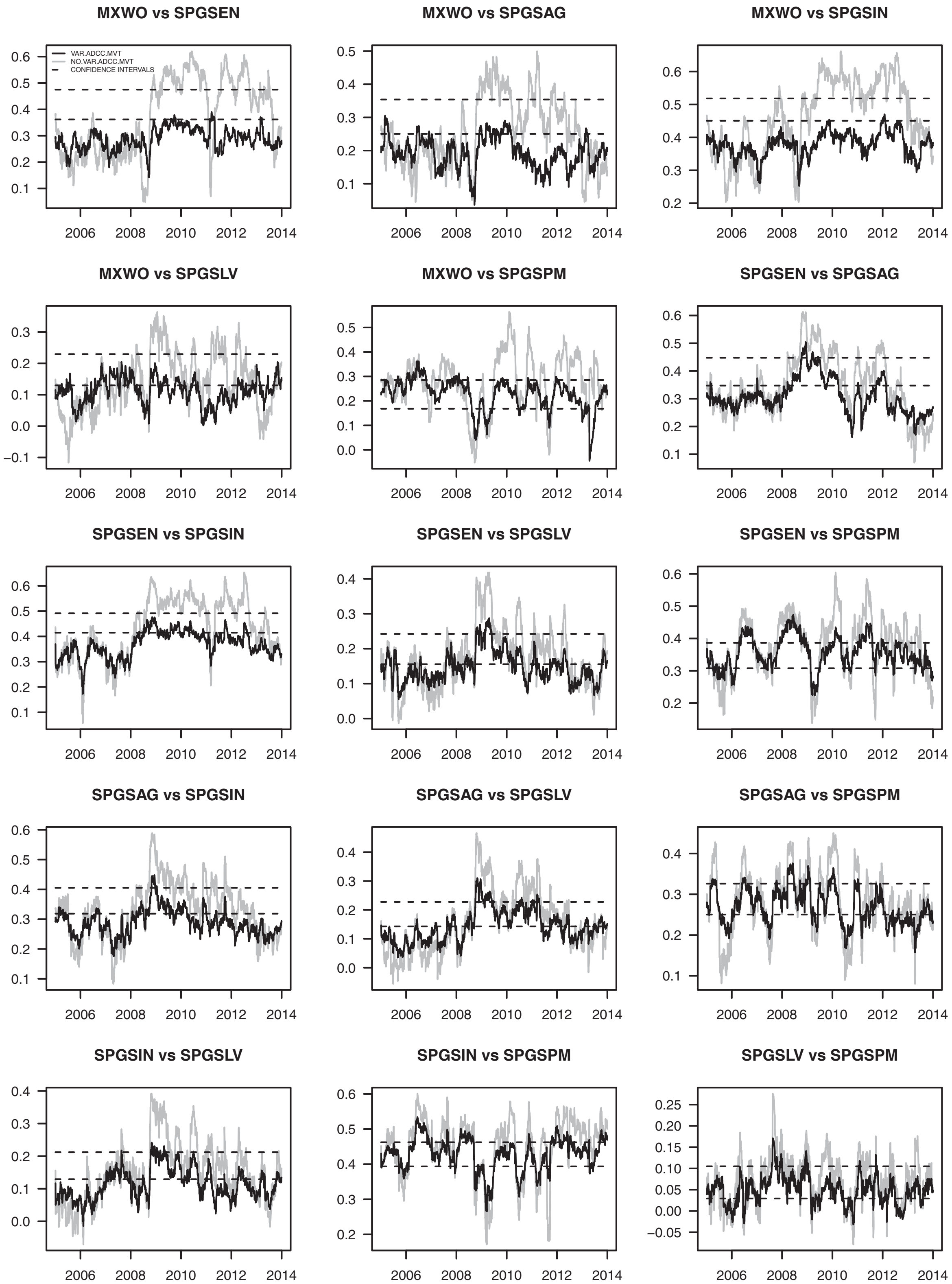
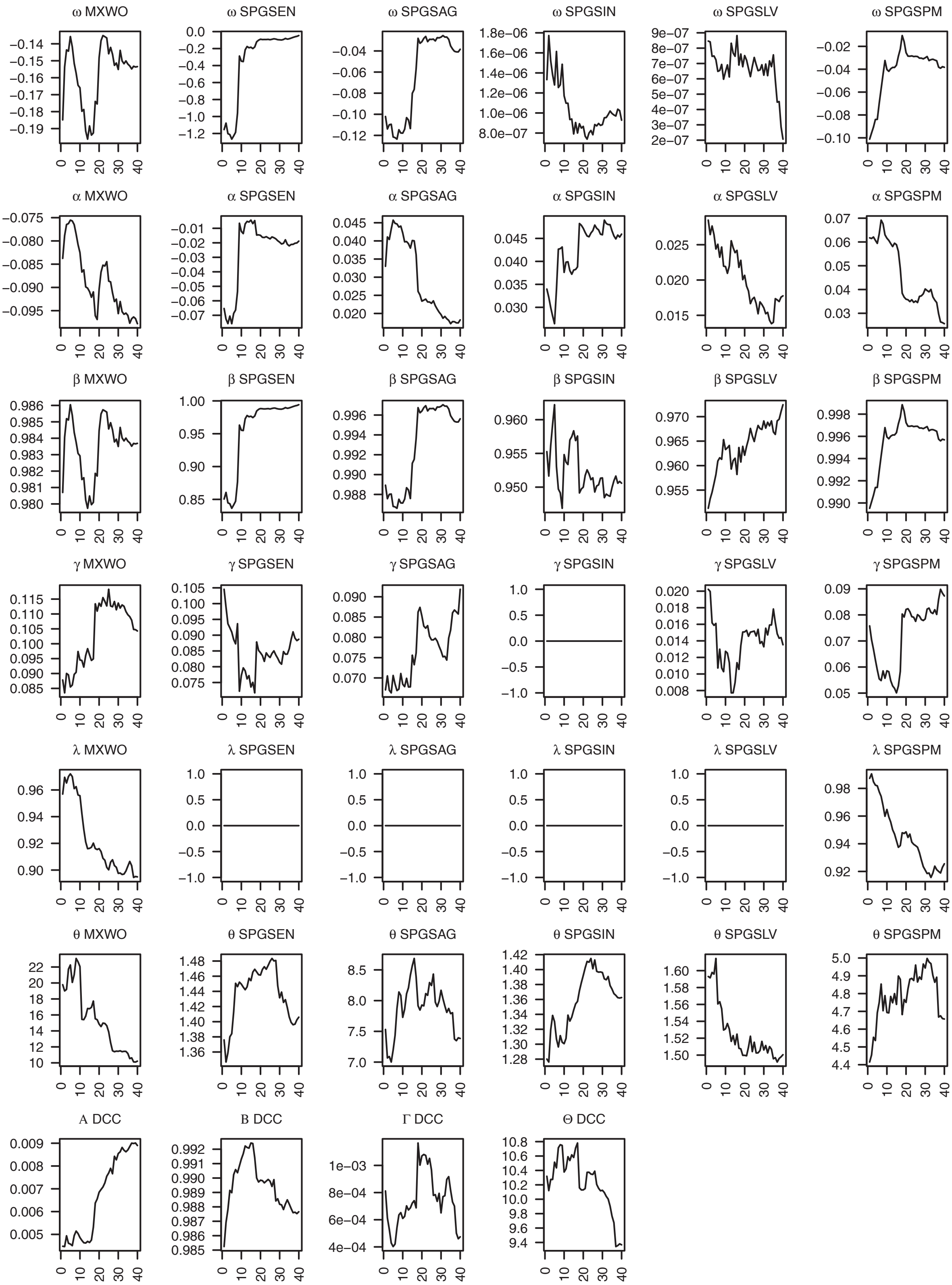


**Figure 7: Stability of estimates computed in a recursive estimation in expanding window**




Symbols used $\omega$ - constant in univariate variance equation, $\alpha$ - univariate previous term error term, $\beta$ - univariate previous term variance, $\gamma$ - univariate leverage effect, $\lambda$ - asymmetry of univariate distribution, $\theta$ - shape of univariate distribution, $A$ - multivariate previous term error term, $B$ - multivariate previous term variance matrix, $\Gamma$ - multivariate leverage effect, $\Theta$ - multivariate distribution shape.

**Table 14: 95% bootstrap confidence intervals for constant conditional correlation in the whole sample and in subsamples**

| | *95% bootstrap confidence intervals for the* Ccc | | | | | |
|---|---|---|---|---|---|---|
| | 2000-2004 | | 2005-2013 | | 2000-2013 | |
| | Lci | Uci | Lci | Upi | Lci | Uci |
| $\rho$(Spgsen,Mxwo) | -0,0607 | 0,0444 | 0,3617 | 0,4748 | 0,2233 | 0,3054 |
| $\rho$(Spgsag,Mxwo) | -0,0051 | 0,1022 | 0,2503 | 0,3540 | 0,1877 | 0,2722 |
| $\rho$(Spgsin,Mxwo) | 0,2108 | 0,2929 | 0,4505 | 0,5183 | 0,3871 | 0,4476 |
| $\rho$(Spgslv,Mxwo) | 0,0448 | 0,1303 | 0,1299 | 0,2295 | 0,1100 | 0,1769 |
| $\rho$(Spgspm,Mxwo) | -0,0869 | 0,0089 | 0,1679 | 0,2854 | 0,1176 | 0,1988 |
| $\rho$(Spgsag,Spgsen) | 0,0498 | 0,1394 | 0,3473 | 0,4475 | 0,2621 | 0,3334 |
| $\rho$(Spgsin,Spgsen) | 0,0305 | 0,1190 | 0,4146 | 0,4916 | 0,2976 | 0,3625 |
| $\rho$(Spgslv,Spgsen) | -0,0006 | 0,0887 | 0,1557 | 0,2423 | 0,1086 | 0,1681 |
| $\rho$(Spgspm,Spgsen) | 0,1107 | 0,2021 | 0,3079 | 0,3865 | 0,2529 | 0,3130 |
| $\rho$(Spgsin,Spgsag) | 0,0463 | 0,1432 | 0,3185 | 0,4051 | 0,2592 | 0,3395 |
| $\rho$(Spgslv,Spgsag) | -0,0231 | 0,0749 | 0,1430 | 0,2277 | 0,1017 | 0,1649 |
| $\rho$(Spgspm,Spgsag) | 0,0756 | 0,1683 | 0,2502 | 0,3261 | 0,2144 | 0,2782 |
| $\rho$(Spgslv,Spgsin) | 0,0297 | 0,1267 | 0,1292 | 0,2121 | 0,1069 | 0,1699 |
| $\rho$(Spgspm,Spgsin) | 0,1223 | 0,2250 | 0,3936 | 0,4623 | 0,3328 | 0,3944 |
| $\rho$(Spgspm,Spgslv) | -0,0259 | 0,0651 | 0,0293 | 0,1050 | 0,0211 | 0,0796 |

**Table 15: The dynamic conditional correlation percentage outside the confidence intervals of the constant conditional correlation in the whole sample and in subsamples**

| | *The* Dcc *percentage outside the confidence intervals of the* Ccc | | | | | |
|---|---|---|---|---|---|---|
| | 2000-2004 | | 2005-2013 | | 2000-2013 | |
| | aDcc Mvt | Var aDcc Mvt | aDcc Mvt | Var aDcc Mvt | aDcc Mvt | Var aDcc Mvt |
| $\rho$(Spgsen,Mxwo) | 26,07% | 19,63% | 80,53% | 97,19% | 94,77% | 72,14% |
| $\rho$(Spgsag,Mxwo) | 17,25% | 4,06% | 74,99% | 86,62% | 91,45% | 77,32% |
| $\rho$(Spgsin,Mxwo) | 22,93% | 51,00% | 83,94% | 98,89% | 93,07% | 82,50% |
| $\rho$(Spgslv,Mxwo) | 11,89% | 7,21% | 66,04% | 66,30% | 75,87% | 64,53% |
| $\rho$(Spgspm,Mxwo) | 60,58% | 66,49% | 61,87% | 27,74% | 84,00% | 72,25% |
| $\rho$(Spgsag,Spgsen) | 9,59% | 27,84% | 76,48% | 77,80% | 88,22% | 87,87% |
| $\rho$(Spgsin,Spgsen) | 17,25% | 16,64% | 86,45% | 80,57% | 94,06% | 86,09% |
| $\rho$(Spgslv,Spgsen) | 6,52% | 18,02% | 61,57% | 66,25% | 77,54% | 67,54% |
| $\rho$(Spgspm,Spgsen) | 9,51% | 9,05% | 70,60% | 43,84% | 88,99% | 76,88% |
| $\rho$(Spgsin,Spgsag) | 4,45% | 32,13% | 62,29% | 77,03% | 88,74% | 79,21% |
| $\rho$(Spgslv,Spgsag) | 5,67% | 7,29% | 70,39% | 61,40% | 90,44% | 83,43% |
| $\rho$(Spgspm,Spgsag) | 22,24% | 13,42% | 59,95% | 49,38% | 70,20% | 70,25% |
| $\rho$(Spgslv,Spgsin) | 9,13% | 9,66% | 63,78% | 65,91% | 70,56% | 82,20% |
| $\rho$(Spgspm,Spgsin) | 61,12% | 39,95% | 74,78% | 43,50% | 78,50% | 71,51% |
| $\rho$(Spgspm,Spgslv) | 3,45% | 11,50% | 49,77% | 32,85% | 49,49% | 39,03% |

# D. Estimates sensitivity to specification change

**Figure 8: Information criteria for the estimated DCC models in the whole sample and in subsamples**

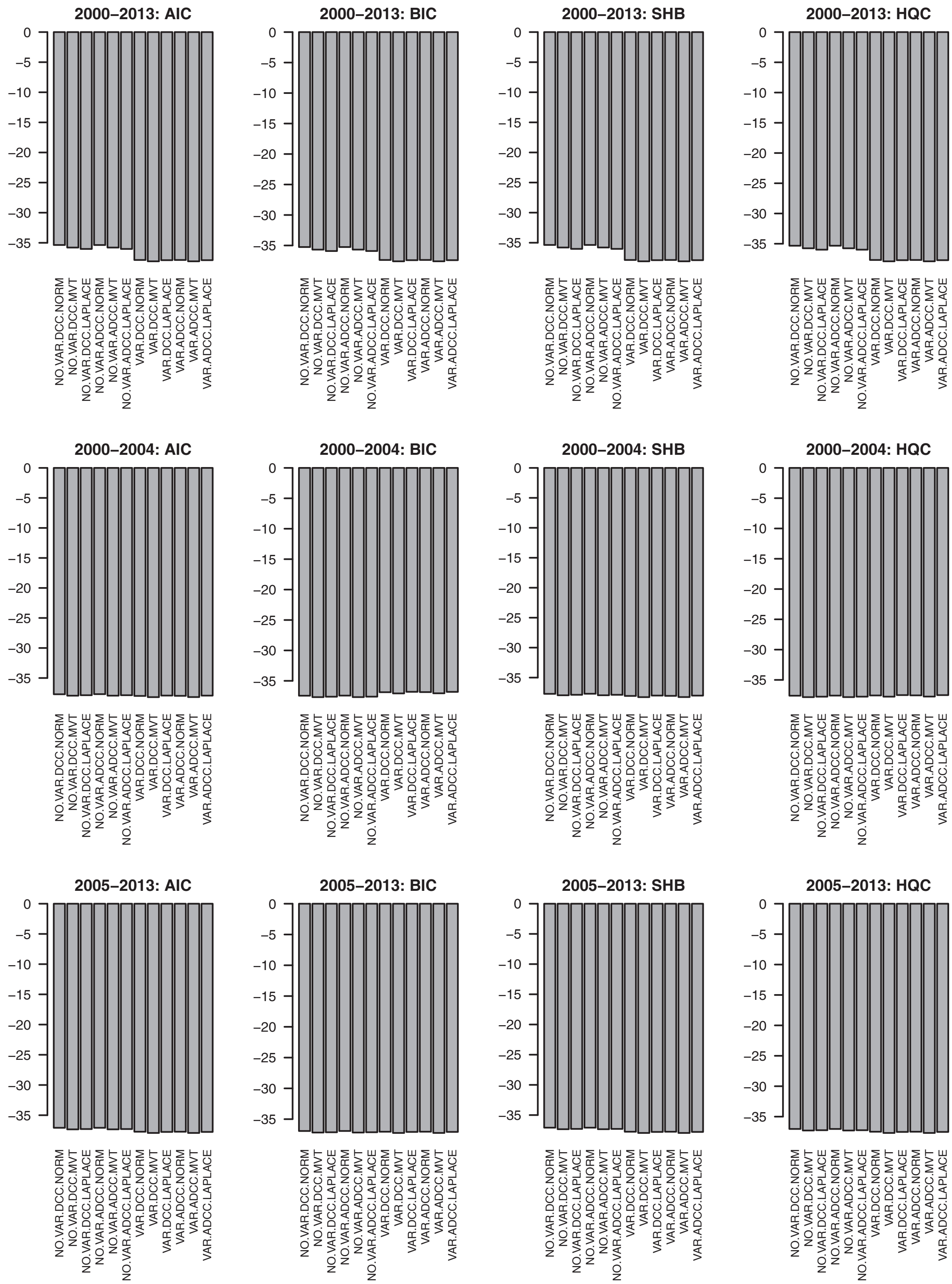


**Figure 9: Dynamic conditional correlation between the distinguished equity and commodity markets for different DCC models not including the VARX component in the whole sample**

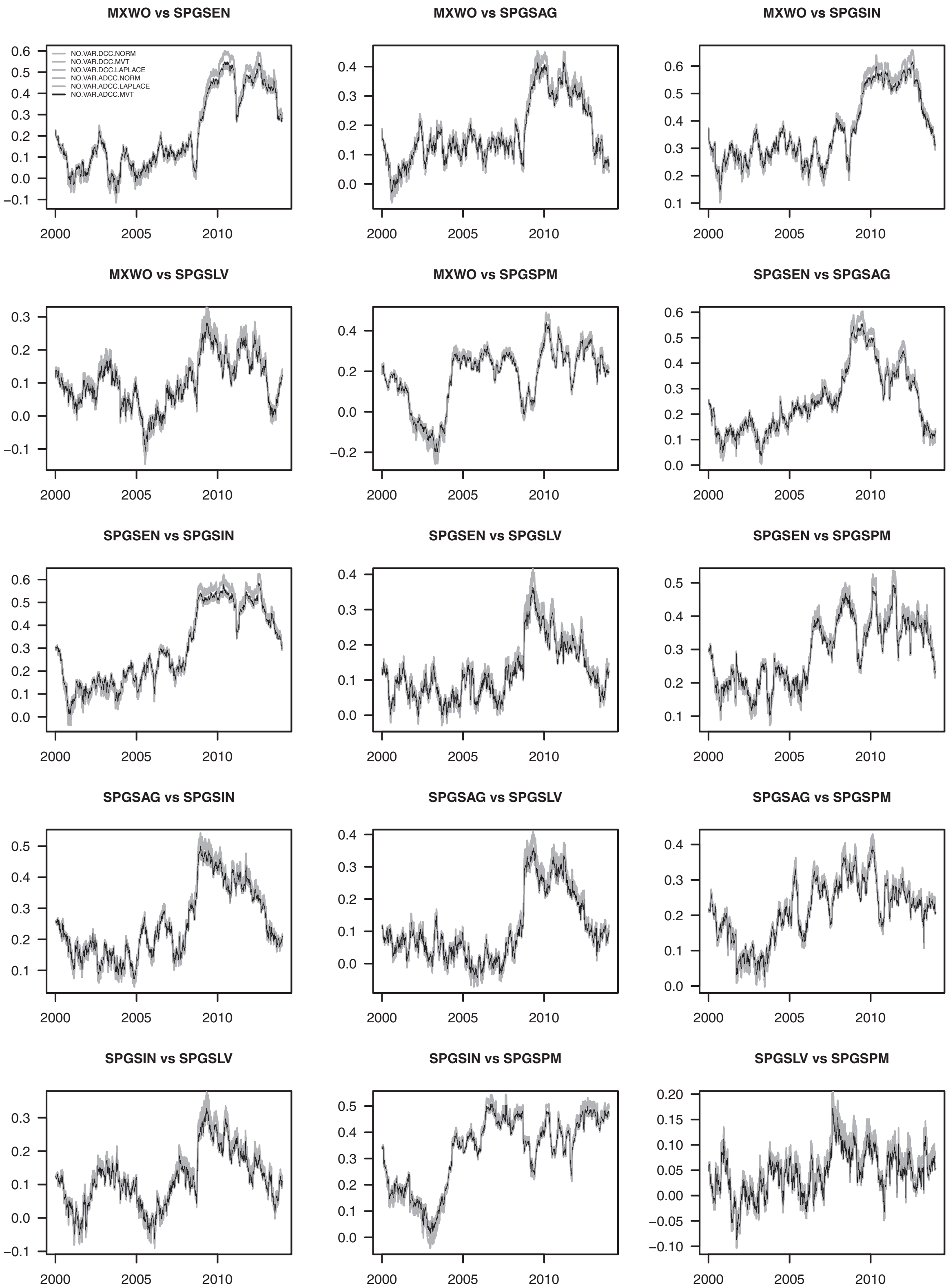
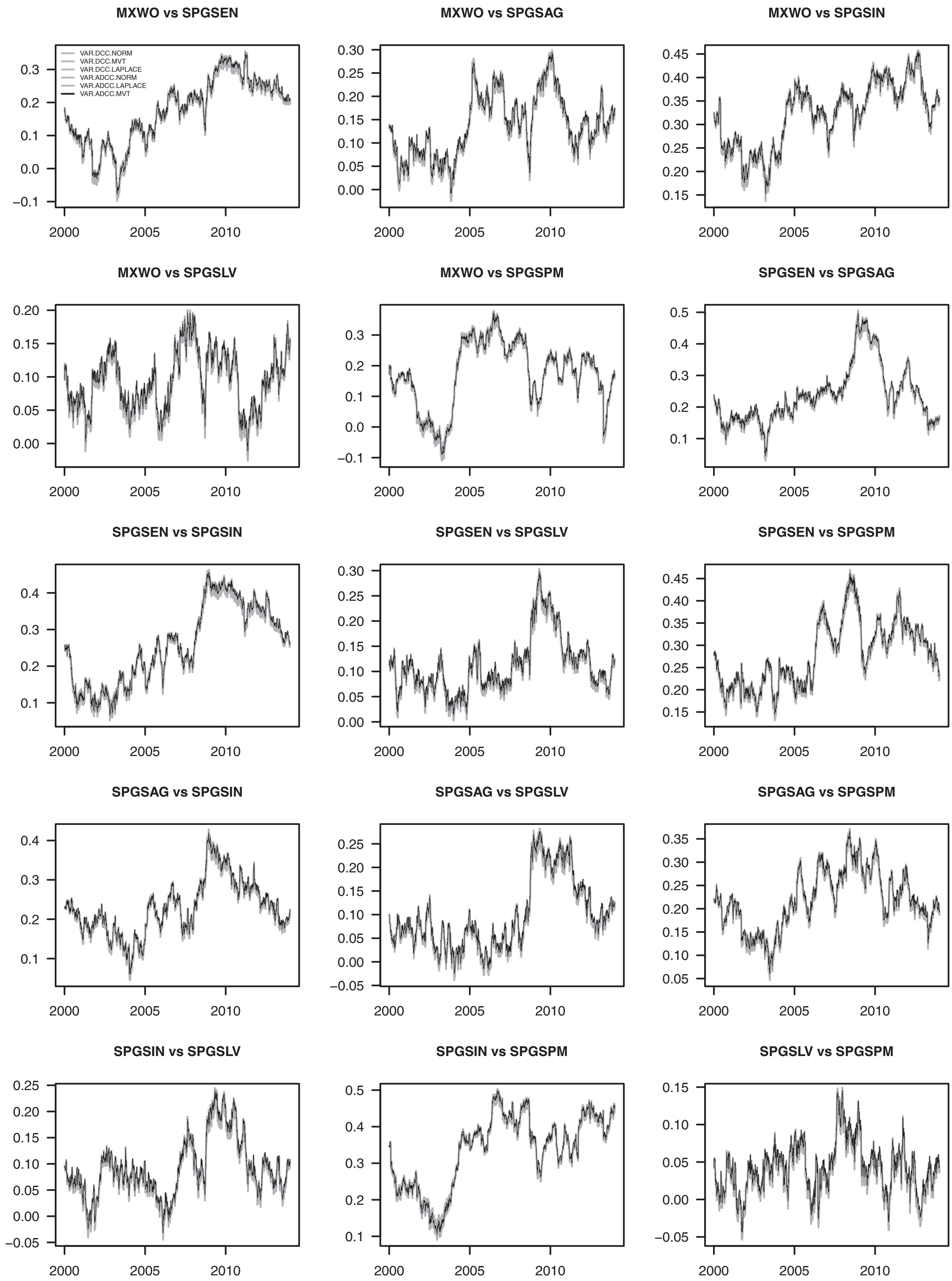


**Figure 10: Dynamic conditional correlation between the distinguished equity and commodity markets for different DCC models including the VARX component in the whole sample**



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