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Sectoral vs. country diversification benefits and downside risk

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Editorial

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Abstract

Recently, the advantage of country diversification relative to sector diversification has been questioned especially against the background of the European monetary and financial integration. Correct estimates of the correlation matrix are central for the evaluation of the relative diversification gains. These estimates should take into account the time-varying and asymmetric behaviour of the correlation process particularly in the context of major changes in volatility and market trends. In this paper, the ADCC (Asymmetric Dynamic Conditional Correlation) model developed by Cappiello et al. (2003) is used to estimate the conditional correlation and volatility of weekly country, sector and country/sector returns indexes over 1990-2003. This model offers a relatively flexible specification for the conditional correlation process that is still computationally feasible for estimation on larger portfolios. The estimation results point to an increase in the average correlation between country indexes during the last five years, but at the same time there is an important decline in the correlation between sector indexes. This trend is observed in both the euro area and the word-wide portfolios and is therefore not specific to the European integration process. At the same time, the volatility in the sector indexes has increased remarkably and in a relatively stronger way compared to the volatility in the country indexes. Both trends tend to cancel out in the calculations of optimal portfolio variance: lower sector correlation is offset by higher sector volatility and higher country correlation is neutralised by the relative lower volatility in country indexes. Therefore no clear trend appears from comparing the relative conditional variances of sector and country portfolios. After taking into account the effect of average returns, it turns out that country diversification is still the dominant strategy for world portfolios, whereas sector diversification is more interesting for euro area portfolios.

JEL-code : C5, G15

Keywords: portfolio diversification, correlation, international finance

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1 Introduction

Traditionally, gains from diversification are higher when investors diversify their portfolio across countries, than when they diversify their portfolio across economic sectors. This has indeed been found to be the case under imperfect international risk-sharing, structurally different economies, economies in different states of the business cycle, or economies characterised by a low degree of financial and economic integration. However, recent evidence has been less conclusive, especially in the context of European monetary unification. Higher economic and financial integration should have decreased cross-country diversification benefits between countries within the euro area. The evidence in the literature however, points to mixed results.

Diversification benefits stem from imperfect correlation between asset returns. This paper investigates the role of time-variation and asymmetries in return correlation in assessing the relative importance of country vs. sector diversification benefits. Time-variation and asymmetric reaction of correlations to asset price fluctuations complicates any analysis of the gains from diversification for two reasons. First, the benefits from a particular diversification strategy depend on the variance of the portfolio associated with this particular strategy which in turn depends on the correlation between the assets included in the portfolio. However, it is an established fact since Forbes and Rigobon (2002) that correlation depends on volatility. An increase of the volatility of the assets in a particular portfolio leads to an increase in the correlation between these assets and a consequent increase in the variance of the portfolio, hence a decrease in cross-country diversification benefits. One way to take this problem into account is to use a measure for correlation that is time-varying and also corrects for volatility. Second, asymmetries in the correlation dynamics might lead to overestimation of the diversification gains. There is recent evidence that asset returns interdependence is stronger during periods of negative returns or large negative price shocks, than during periods of positive returns. This would mean that a model for asset return correlations that does not take into account this, would be underestimating correlation in bear markets and therefore be overestimating diversification benefits. For these two reasons, time-variation and asymmetric reaction to asset price fluctuations should be taken into account if the benefits from diversification are to be estimated correctly.

This paper re-examines the question of country-vs-sector diversification benefits in the euro area after EMU using the Asymmetric Dynamic Conditional Correlation (ADCC) model of Engle (2002) that corrects for asymmetries and time-variation. The contributions of this paper are twofold. First, correlations are time-varying. Our estimates show that not taking into account time-variation would underestimate market return correlations within the euro area after 1999, and would overestimate sector correlations. In particular, we find that sector correlations present a strong negative break after 1999 whereas market correlations show a positive break at the same date. The origin of the decrease in sector correlations is the idiosyncratic behaviour of the technology and non-cyclical services sectors. This is not a euro area specific situation, the rest of the world shows the same evolution. Second, we find that while the correlations between country and sector indexes have moved in opposite directions, for both types of indexes we observe a strong increase in conditional volatility. As a result, the combined effect on the sector and country portfolio variances is neutral and there seems to be no clear trend in the relative benefits from the two investment strategies.

The structure of the paper is as follows. In the first section we review the literature on country vs. sector diversification benefits and motivate our modeling strategy. In section 3, we describe the ADCC model for correlations, and discuss the estimation outcomes. In section 4, we define different measures to evaluate diversification gains. We consider average correlations, the reduction of the portfolio variance achieved by the inclusion of new assets in the portfolio (Goetzmann et al. , 2001), the variance of a minimum variance portfolio, the variance of the optimal portfolio of a utility maximising investor and the associated Sharpe ratios. In the following sections we present and discuss the estimation results, we evaluate the variation of cross-sector and cross-country diversification gains over time, and discuss the relative impact of time-variation and asymmetries on the returns from diversification. The last section summarises and concludes.

2 Motivation

In this section we discuss the evidence on whether cross-sector diversification benefits within the euro area have increased after the introduction of the euro and motivate why we re-examine this question using a different estimation approach.

There is a vast literature on the gains resulting from adopting a country vs. sector portfolio diversification strategy. During the pre-EMU era, the main conclusion on diversification gains within the euro area was that investing in assets from different markets resulted in larger gains than investing in a variety of sectors within the same country. This result was reached using various methods.

Using a factor model on returns Heston and Rouwenhorst (1994), Griffin and Karolyi (1998) and Rouwenhorst (1999), find that the country factor is dominant in explaining the variance of returns. After the introduction of the euro, the evidence points to both directions. Some papers find increasing industry effects. Arnold (2001) extends the Rouwenhorst dataset to include information up to 2001, and finds dominant industry effects since 1999. Baca, Garbe and Weiss (2000), find that country and industry effects have become equal and Cavaglia et al. (2000) find that industry factors have become more important since 1997. Other papers, such as, Isakov and Sonney (2003) find dominant country effects over the 1997-2000 period but, dominant industry effects since 2000. Galati and Tsatsaronis (2001) using data on large capitalisation stock returns find that the industry factor has been dominant since a few months before the introduction of the euro, and that the country factor has been insignificant since 1992. Other papers, such as Gerard et al. (2002) and Adjaoute and Danthine (2003) find that even though the domination of country effects has diminished, industry factors are still less important than country factors.

Another strand of the literature uses alternative methods to investigate the importance of country vs. sector diversification benefits. Hardouvelis et al. (2001) estimate the cost of capital by sector in the EU and find that the cost of capital tends to be the same in one sector across different countries whereas it differs across sectors. DeSantis and Gerard (1997) use an asset pricing model to study the impact of monetary unification on financial integration and find that European convergence and the single currency was probably not the main event since the major impact of financial convergence had already been realised over the 90s. In fact they show that it is difficult to identify an effect specific to the introduction of the euro because, since 1999, euro area market behaviour has been rather specific with respect to its history, following the global upturn and then the downturn.

Looking at disaggregated (sectoral) data other papers try to disentangle the Euro-specific effect from the technology bubble influence. Brooks and DelNegro (2002) find a strong positive trend in the correlation between the US and European returns. This could be due to a decrease in the home bias of investors and an increase in financial integration. Rather they find that once they exclude the technology sector from their data set, the trend in the correlation disappears.

To summarise, the literature has traditionally pointed to important country factors in stock returns which lead to low cross-country correlations and important gains from cross-country diversification strategies. Since 1999 and the introduction of the Euro, the evidence has been mixed. Some papers point to an increase of the importance of sector effects to a point were cross-sector diversification strategies become more interesting than cross-country diversification strategies. Others point out that the effect is temporary rather than permanent, and due to the technology sector bubble, and that otherwise country diversification benefits still remain important.

It is possible however, that these results are influenced by two mismeasurement problems: time-variation in conditional correlations and the influence of downside risk are not taken into account in the aforementioned papers. First, there has been increasing empirical evidence that correlations depend on both volatility and the market trend, so they may not be constant over time. Already King et al. (1994) stressed the role of an (unobservable) international "crisis" factor in explaining international stock return correlations. Lin and Ito (1994) find that the occurrence of a large common price shock increases stock correlations. Longin and Solnik (1995) find that an increase in US stock market correlations can be explained not only by an increase in stock market integration but also by the abnormal volatility in the US stock market. As Boyer et al. (1999) and Forbes and Rigobon (2002) have shown, conditional correlations suffer from heteroskedasticity bias. Second, De Santis and Gerard (1998), Ang and Bekaert (2001), Ang and Chen (2001) and Longin and Solnik (2001) have shown that there exists an asymmetric response of asset returns correlations to joint bad news (joint negative returns).

An increase in the correlation between asset returns during periods of negative returns or high volatility would imply that diversification gains may disappear when the investor needs them most. It is important therefore to evaluate the impact on correlation and diversification gains of a negative trend or increased volatility. For example Butler and Joaquin (2002) find that in bear markets the gains from diversification are lower compared to those generated by a normal or even a Student–t distribution, and that benefits from international diversification have been overestimated for this reason by nearly 3 percent.

In this paper we use the conditional correlation between index returns to estimate diversification benefits associated with a specific investment strategy. We consider different measures for diversification benefits, some of them are based on the variance of a diversified portfolio, others take into account the expected return on this portfolio and the degree of risk aversion of the investor. In every case, we are interested in the benefits that accrue to the investor when foreign indexes are added to a home market or sector index. Each measure corresponds to a set of assumptions with respect to the behaviour of the investor and the correlation matrix will always play a key role in determining how much he should invest in each asset.

We focus on the importance of the changing structure of correlations in asset returns for asset management. This type of approach contrasts with Rouwenhorst (1999), DelNelgro and Brooks (2002) and others who look at the importance of industry and country factors in explaining stock returns. The questions we concentrate on are more related to the implications for an investor's portfolio decision from a reduction of country effects or an increase in sector effects within the euro area or in the world.

3 ADCC structural model for correlations

In this section, we present the model we use to estimate correlations, i.e. the Asymmetric Dynamic Conditional Correlation (ADCC) model. Before doing so, we discuss alternative models for conditional correlations and explain why the ADCC is the most suitable model in our case.

Time-variation in asset return second moments, which has been found to be present in weekly and daily returns, has been modelled in a variety of ways. The feature of volatility clustering was first incorporated in the ARCH model of Engle (1982) and generalised by Bollersev (1986) to the GARCH model. In a multivariate setting, BEKK models (Engle and Kroner (1995)) are an extension of the univariate GARCH models, where variances and covariances are a function of their past and innovations. These models are quite general and flexible but the number of parameters to estimate is too large when the dynamics of more than a few assets are considered. Another approach developed by Alexander (2000) is estimation of second moment using an O-GARCH, i.e. an orthogonal GARCH, which uses a few principal components of the variance -covariance matrix of the standardised residuals, to reduce the number of parameters that need to be estimated in the multivariate GARCH model. This is an interesting approach but is not flexible enough if we need to take into account asymmetric effects in the second moments of the return distribution. Another parsimonious approach is the Constant Correlation (CC) model by Bollersev (1990). Given the evidence on time-varaition in correlations between asset returns, the CC model is too restrictive. The Dynamic Conditional Correlation model (Engle, 2002) is an extension of the Bollersev model.

Furthermore, the asymmetric response of correlation between asset returns to negative price shocks has been modelled in two ways. In the multivariate GARCH model with asymmetric effects as in Kroner and Ng (1998) negative return shocks increase correlations more strongly than positive shocks reduce them. This type of asymmetry is also present in volatilities[1]. The second approach is the Asymmetric Dynamic Conditional correlation model of Cappiello et al.(2003). We use the second approach because of its flexibility and parsimoniousness, and explain it in detail in the next section.

3.1 Model specifications and likelihood ratio test

The model for the returns correlation process is the Cappiello et al.(2003) asymmetric version of the Dynamic Conditional Correlation model of Engle (2002). The dynamic correlation model allows for correlations to change over time and gives a GARCH-like structure to the conditional correlation processes of the assets. The model can be estimated using a two step procedure. This is a particularly interesting feature when the number of assets is relatively large.

Assume a $kx1$ vector of asset returns r_t , conditionally normal with mean zero and covariance matrix H_t :

$$r_t \mid I_{t-1} \sim N(0, H_t)$$

where I_{t-1} is information set up to t. The covariance matrix H_t can be decomposed as follows:

$$H_t = D_t R_t D_t$$

where D_t is the kxk diagonal matrix of time-varying standard deviations from univariate GARCH models with $\sqrt{h_{it}}$ on the i^{th} diagonal and R_t is the (possibly) time-varying correlation matrix[2]. The loglikelihood function can be written as:

[1] Hentschell (1995) proposes a general model that accomodates several types of univariate asymmetric GARCH parameterisations.

[2] The assumption of conditional normality is not crucial and in the absence of conditional normality, these results have a standard QML interpretation.

$$
\begin{aligned}
L &= -\frac{1}{2}\sum_{t=1}^{T}(k\log(2\pi)+\log(|H_t|)+r_t'H_t^{-1}r_t) \\
&= -\frac{1}{2}\sum_{t=1}^{T}(k\log(2\pi)+\log(|D_tR_tD_t|)+r_t'D_t^{-1}R_t^{-1}D_t^{-1}r_t) \\
&= -\frac{1}{2}\sum_{t=1}^{T}(k\log(2\pi)+2\log(|D_t|)+\log(|R_t|)+\varepsilon_t'R_t^{-1}\varepsilon_t \\
&= -\frac{1}{2}\sum_{t=1}^{T}(k\log(2\pi)+2\log(|D_t|)+r_t'D_t^{-1}D_t^{-1}r_t \\
&\quad ... -\varepsilon_t'\varepsilon_t+\log(|R_t|)+\varepsilon_t'R_t^{-1}\varepsilon_t \\
&= L_v(\theta)+L_c(\theta,\phi)
\end{aligned}
$$

where $\varepsilon_t = D_t^{-1}r_t$ are the residuals standardised by their standard deviation and $\varepsilon_t \mid I_{t-1} \sim N(0, R_t)$.The likelihood function can be written as the sum of a volatility part $L_v(\theta)$ and a correlation part $L_c(\theta, \phi)$.The volatility part of the likelihood is the sum of individual GARCH likelihoods, which is maximised by separately maximising each term of:

$$L_v(\theta) = -\frac{1}{2}\sum_{t=1}^{T}\sum_{i=1}^{k}(\log(2\pi)+\log(h_{it})+\frac{r_{it}^2}{h_{it}})$$

Because the squared residuals do not depend on the correlation parameters, a two-step approach can be used to maximise the likelihood. First, the univariate volatility models are estimated:

$$\widehat{\theta} = \arg\max\{L_v(\theta)\}$$

Then, taking these parameters as given, the second stage is performed :

$$\max_{\phi}\left\{L_c(\widehat{\theta}),\phi\right\}$$

In the first step, k GARCH models for r_{it} are estimated:

$$h_{it} = \omega_i + \alpha_i r_{it-1}^2 + \beta_i h_{it-1}$$

In the second step, the standardised residuals, $\varepsilon_{it} = r_{it}/\sqrt{h_{it}}$, are used to estimate the correlation process parameters.

The original DCC estimator (Engle, 2002) had the dynamics of correlation involving as a scalar process with single news impact parameters (effect of innovation on volatility) and a single smoothing parameter for all assets. However, as the number of asset increases these assumptions become too restrictive, and Generalised DCC models, which capture asset heterogeneity, were developed. Six different models are considered in this paper. Because the models are nested in one another , we can use likelihood ratio tests to find the model that fits best the correlation process.

Equation *1* is the standard scalar DCC (Engle, 2002) model:

$$\begin{aligned} Q_t &= (1-a-b)\overline{Q} + a\varepsilon_{t-1}\varepsilon'_{t-1} + bQ_{t-1} \\ R_t &= Q_t^{*-1} Q_t Q_t^{*-1} \end{aligned} \tag{1}$$

where $\overline{Q} = E\left[\varepsilon_t \varepsilon'_t\right]$, and a and b are scalars. $Q_t^* = [q_{ii,t}^*] = [\sqrt{q_{ii,t}}]$ is a diagonal matrix with the square root of the diagonal element of Q_t on its i^{th} diagonal position. Q_t^* is a matrix that guarantees that $R_t = Q_t^{*-1} Q_t Q_t^{*-1}$ is a correlation matrix with ones on the diagonal and every other element less than one in absolute value. This will occur as long as Q_t is positive definite[3]. The typical element of R_t will be of the form $\rho_{ij,t} = q_{ij,t}/\sqrt{q_{ii,t}q_{jj,t}}$.

Equation 2 extends equation 1 for structural breaks (at τ) in the mean or the dynamics: let d be 0 for $t < \tau$ and $d = 1$ for $t \geq \tau$. Then to examine whether such a structural break in the mean has occurred, the standard scalar DCC model in equation 1 is modified to:

$$\begin{aligned} Q_t &= \left(\overline{Q} - d\widetilde{Q} - a\overline{Q} + da\widetilde{Q} - b\overline{Q} + db\widetilde{Q}\right) \\ &\quad + a\varepsilon_{t-1}\varepsilon'_{t-1} + bQ_{t-1} \end{aligned} \tag{2}$$

where $\overline{Q} = E\left[\varepsilon_t \varepsilon'_t\right]$,with $0 < \ t < \tau$ and $\widetilde{Q} = \overline{Q} - E\left[\varepsilon_t \varepsilon'_t\right]$, with $t \geq \tau$, which is equivalent to the following parameterisation (where $\overline{Q}_1 = E\left[\varepsilon_t \varepsilon'_t\right], \ t < \tau$ and $\overline{Q}_2 = E\left[\varepsilon_t \varepsilon'_t\right], \ \ t \geq \tau$), when the mean reversion is forced:

$$\begin{aligned} Q_t &= (\overline{Q}_1 - a\overline{Q}_1 - b\overline{Q}_1)(1-d) + \\ &\quad + \left(\overline{Q}_2 - a\overline{Q}_2 - b\overline{Q}_2\right) d + \\ &\quad + a\varepsilon_{t-1}\varepsilon'_{t-1} + bQ_{t-1} \end{aligned} \tag{3}$$

Equation 4, the diagonal DCC model, extends the scalar DCC model (equation 1) to allow for asset specific dynamics (Cappiello et al. ,2003)) :

$$Q_t = \left(\overline{Q} - A'\overline{Q}A - B'\overline{Q}B\right) + A'\varepsilon_{t-1}\varepsilon'_{t-1}A + B'Q_{t-1}B \tag{4}$$

and the Asymmetric Diagonal DCC model in equation 5, extends Diagonal DCC model to allow for asset specific asymmetries (Cappiello et al.,2003):

$$Q_t = \left(\overline{Q} - A'\overline{Q}A - B'\overline{Q}B - G'\overline{N}G\right) + A'\varepsilon_{t-1}\varepsilon'_{t-1}A + B'Q_{t-1}B + G'n_{t-1}n'_{t-1}G \tag{5}$$

[3] Q_t will be positive definite with probability one if $(\overline{Q} - A'\overline{Q}A - B'\overline{Q}B - G'\overline{Q}G\ )$ is positive definite. During estimation, to solve numerical problems and to guarantee that $(\overline{Q} - A'\overline{Q}A - B'\overline{Q}B - G'\overline{Q}G\ )$ will be positive definite we use a penalty function.

where A, B and G are diagonal parameter matrices, $n_t = I[\varepsilon_t < 0] \odot \varepsilon_t$, with $\odot$ indicating the Hadamard, or element-by-element product and $\overline{N} = E[n_t n_t']$. For $\overline{Q}$ and $\overline{N}$, expectations are infeasible and are replaced by sample analogues, $T^{-1}\sum_{t=1}^{T}\varepsilon_t\varepsilon_t'$ and $T^{-1}\sum_{t=1}^{T}n_t n_t'$ respectively.

To extend these diagonal models for structural breaks (at τ) in the mean or the dynamics define, as before, d be 0 for $t < \tau$ and $d = 1$ for $t \geq \tau$. Then, in equations 6 and 7, we introduce the dummy variable in the Diagonal DCC model (equation 4) and the Asymmetric Diagonal DCC model (equation 5):

$$\begin{aligned} Q_t &= \left(\overline{Q} - d\widetilde{Q} - A'\overline{Q}A + dA'\widetilde{Q}A - B'\overline{Q}B + dB'\widetilde{Q}B\right) \\ &\quad + A'\varepsilon_{t-1}\varepsilon_{t-1}'A + B'Q_{t-1}B \end{aligned} \tag{6}$$

$$Q_t = (\overline{Q} - d\widetilde{Q} - A'\overline{Q}A + dA'\widetilde{Q}A - B'\overline{Q}B + dB'\widetilde{Q}B \tag{7}$$
$$-G'\overline{N}G + dG'\widetilde{N}G) + \tag{8}$$
$$+A'\varepsilon_{t-1}\varepsilon_{t-1}'A + B'Q_{t-1}B + G'n_{t-1}n_{t-1}'G$$

where $\overline{Q} = E[\varepsilon_t\varepsilon_t']$, $t < \tau$ and $\widetilde{Q} = \overline{Q} - E[\varepsilon_t\varepsilon_t']$, $t \geq \tau$, with $\overline{N}$ and $\widetilde{N}$ analogously defined.

Finally, three more models are estimated and tested: a constant correlation model (CDCC) equivalent to setting the autoregressive and moving average parameters equal to zero, in the scalar or the diagonal model , i.e. $Q_t = \overline{Q}$, a model with a deterministic trend in the mean and an integrated DCC model (scalar model). The integrated DCC defines Q_t as:

$$Q_t = \lambda\varepsilon_{t-1}\varepsilon_{t-1}' + (1-\lambda)Q_{t-1} \tag{9}$$

As one model nests the other, it is straightforward to test for time-variation in the conditional correlation, for the diagonal vs. the scalar model, for the presence of asymmetries, for the presence of breaks in the mean of the process and for the presence of a deterministic or a stochastic trend by using the likelihood ratio test with the appropriate degrees of freedom[4].

3.2 Data

To assess the benefits of international portfolio diversification from a variety of domiciles and sectors, we measure the correlation between market returns in 24 countries broken down into 10 sectors. The list of sectors and countries is presented in Table 1. More specifically, we consider four datasets: market returns for 24 countries worldwide, 10 sector indexes worldwide, 10 sector indexes euro area-wide, and a set of 10x24 disaggregated country/sector indexes[5]. We

[4] The degrees of freedom for the chi-square test equals the difference between the number of parameters of the unrestricted model and the number of parameters of the restricted model.

[5] Data were not always available for every country/sector combination.

use both euro -area and worldwide data so as to investigate whether there is a specific effect of monetary unification on correlations and portfolio risk diversification. Sectoral breakdown is performed according to Datastream level 3. We include country/sector indexes in order to identify specific sector effects and their contribution to the overall results.

The sample consists of continuously compounded USD currency returns measured as log-differences in index prices over 713 weeks from January 1990 through September 2003. The sample starting date was chosen in a way to allow us to include the largest possible number of country/sector European indexes in our data set, in particular to include country/sector returns from Portugal, Finland and Greece. This is important in order to distinguish between sectoral effects of large and older European markets and those from young markets. Returns were expressed in USD terms in order to make results more easily comparable with the rest of the literature but calculations were repeated using Euro (BEF before 1999) returns instead of USD returns and results were robust to the change of currency[6] .

We have estimated the alternative model specifications over a total of 14 models: a world country model estimated over the 24 market return indexes, a world sector model estimated over the 10 world sector indexes, a euro area country model estimated over 11 euro area countries, a euro area sector model estimated over 10 euro area sector indices and finally, ten country/sector models, i.e. one model estimated for each sector over all country/sector index returns available for that sector.

(Insert Table 1 here)

Table 1 presents the basic statistics for the country and sector USD return indexes (the statistics for the detailed country/sector indexes are not reported). We observe that, as expected, returns are characterised by high skewness and kurtosis and that average correlation between world sector returns is higher than average correlation between market returns. euro area sector return correlations are not very different from world sector correlations. The right-hand side of the table presents correlations in three partitions of returns. Each partition is defined in a way that lets one-third of the returns' joint distribution to fall into each 'bear', 'normal', or 'bull' market category[7]. There appear to be large differences in the correlations between bear and normal partitions especially in the case of market returns and euro area sectors. The difference between the normal and bull partitions appear to be smaller. This could indicate the presence of asymmetric behaviour in correlations. In the next section, we present the results from the model estimation and the significance of each specification.

[6] We need to express all returns in one common currency because we use sectoral indexes which are aggregates of country sector returns. The choice of USD as the benchmark currency is made to facilitate comparison with the results in the previous studies.

[7] Higher apparent correlations during volatile markets are a natural characteristic of the multivariate normal distribution with constant unconditional correlations. In particular, if normally distributed returns are partitioned as described above, then correlations calculated over turbulent periods will be greater than correlations over calm periods by construction (more on this point in Butler and Joaquin, 2002).

3.3 Estimation results

3.3.1 Univariate GARCH models

We start by considering the estimation results from the first step, i.e. the GARCH volatility models for the individual indices. Tables 2 and 3 present the estimated coefficients for the world country model and the world sector model (euro area models and country/sector models are not reported). All GARCH model parameters are significant. Nevertheless, there are important differences in the estimated persistence $1 - \alpha - \beta$ and the size of $\frac{\omega}{1-\alpha-\beta}$ in the volatility processes over countries and sectors. As expected, volatilities are highest in emerging markets, that is Asian and Latin American markets but also in the Greek market. Within Europe, market return volatility is highest in Italy, Finland, Sweden and Greece. When we investigate further at the country/sector level (not reported), we find that the origin of the increase in volatility in these countries in technology (Italy and Finland), cyclical goods and utility (Sweden) and non cyclical goods in Greece. Most of the major markets (Canada, New Zealand, Australia; and in Europe Ireland, Denmark, and Germany, France and Spain) follow a volatility profile that resembles the volatility process of the US market, i.e. very persistent but overall at a relative low level (with a sharp increase in realised volatility after 1999). The UK and Switzerland have lower volatility and are less persistent.

From the estimates of the world sector volatility processes in Table 3, it follows that the highest overall volatility lies in information technology and total financials, as well as, but to a lesser degree in non-cyclical services, cyclical goods and cyclical services. In all these sectors, with the exception of the cyclical goods, volatility is very persistent (and with a very sharp increase after 1999). Notice that volatility is very low in the utility sector and non-cyclical goods. The results for the euro area sector volatility are similar to the world sector volatility: the highest volatility is present in total financials and cyclical goods. In fact, the characteristics of the volatility of euro area total financials resemble those of the US information technology volatility. Both increase steeply after 1999, peak before 2002 and get back to their 1999 level in 2003. The same pattern is followed by volatility in Italy, Greece, Finland, and Sweden as well as emerging Asian markets. These characterics are more extreme than those of the US market volatility and the volatility of other major markets. To summarize, US information technology and smaller/younger European markets are more volatile than the US market and other major markets. Finally, looking at the country/sector level, we find that major contributions to the increase in volatility in world and euro area sectoral indexes comes from Italy and Hong Kong for the information technology sector, Greece, Finland, France, Germany, Belgium, Norway, Hong Kong, Singapore and Mexico for the total financials sector, and Ireland, Spain, Netherlands, Sweden, Singapore and Canada for the cyclical goods sector.

3.3.2 ADCC estimation results and likelihood ratio specification test

(Insert Tables 4 and 5 here)

The conditional volatility resulting from the univariate GARCH models is used to standardise the return series. These standardised series are the input for the estimation of the different DCC model specifications that were discussed in section 3. Tables 4 and 5 summarise the results from testing one nested model against the other using the likelihood ratio test. The main conclusions are the following: The constant conditional correlation model is always rejected in favour of the dynamic correlation model. The integrated DCC estimates of the λ parameter in equation (9) almost always tends to 0 in which case the integrated DCC model reduces to the constant CDCC-model (these results are therefore not reported in Tables 4 and 5). Adding a linear trend to the scalar DCC model improves the likelihood of the model significantly for the country and the sector models (both for the world and the euro area models and for 5 out of the 10 country/sector models). Adding a break in the intercept term since 1999 improves the outcomes in practically all of the models in a very significant way, both for the scalar and the diagonal models.

As expected, the scalar model is generally too restrictive, and is always rejected in favour of the diagonal model. The presence of asymmetries is confirmed for 4 out of 10 country/sector models and for the world sector model and the euro area country model. Finally and in general, the best model is the Asymmetric Diagonal DCC model with a break since 1999. The estimated coefficients of this ADCC-d model are summarised in the right part of Tables 2 and 3. In line with the evidence of the likelihood ratio tests most of the a and b coefficients, corresponding to the diagonal elements of A and B in equation (7), are significantly different from zero. The asymmetry effect, captured by the g coefficients, is very weak for the world country model and somewhat more significant in the world sector model.

(Insert Table 6 here)

Table 6 compares the loglikelihood for different breakpoints between 1995 and 2002 for the scalar dummy model[8]. For the world and euro area country models the loglikelihood is maximised with a break in 1999. The country models are somewhat indifferent between a break since 1999 and 2000 for the euro area country model and since 1999 or 2001 for the world country model. For the world and euro area sector indexes, the most likely break seems to be situated around 1998-1999. Later dates for the break produce a much lower likelihood. This strong result for the timing of the break in the sector indexes illustrates that the break in the correlation between sector returns in the late nineties is at least as evident as the break in the country indexes. The uncertainty in the breakpoint for the country correlation is further illustrated by the country/sector models. In five out of ten country/sector models the break is preferably placed in 2001.

[8] The scalar model is used for this table to limit the computation time. Results from the ADCC-d world country model confirms the results from the scalar-dummy model for the timing of the break.

4 Alternative measures of diversification gains based on the conditional correlation matrix

In this section we introduce the different diversification measures that will be used to assess the impact of the introduction of the euro on sector vs. country diversification benefits. We propose to use three different types of measures, each one using different type of information. The first set of measures is based directly on our estimates of conditional correlation. The measures are simple averages of conditional correlations and the Goetzmann-Li-Rouwenhorst (GLR), 2001 measure of diversification gains. The second set of measures is constructed for different portfolios and is the portfolio variance $\sigma_t^2 = w_t' H_t w_t$ as a measure for the riskiness of the portfolio strategy. The portfolios are constructed combining the k original indexes according to a weighting scheme described in w_t, a $(k, 1)$ vector showing the proportions of each index that is included in the investment portfolio. We examine three types of portfolios: an equally weighted portfolio, the global minimum variance portfolio and a portfolio that is the optimal portfolio of a power-utility maximising investor. Finally, the third set of measures exploits information from the expected return $E(w_t' r_t)$ of the portfolios and the degree of risk aversion of the investor. The measures are Sharpe ratios and the maximum utility associated which each portfolio. The change in utility can give us a better idea of the economic significance of a change in portfolio allocations, especially when returns are not normal (in which case the Sharpe ratio lead to misleading conclusions).

We begin this section with a short review of the literature on the measures of diversification gains and motivate our choice of measures. Then we present the measures in detail and explain how the estimated conditional correlation matrix is used in each one of them.

4.1 Alternative measures of diversification gains

The literature on international diversification benefits is characterised by the use of different indicators and methods. Simple correlation measures became less popular given their sensitivity to the underlying volatility processes. Goetzmann et al. (2001) use a diversification measure that combines the information from correlations and variances. In the factor analysis approach inspired by Heston and Rouwenhorst (1995), the relative contribution of country and sector shocks to the return process of stocks is estimated. Depending on the relative size of these shocks, it is then concluded whether country or sector strategies would be the dominant strategies. Adjaouté and Danthine (2001) propose to use a measure of dispersion for country and sector indexes in order to evaluate the possible gains from either strategy. Gerard, et al. (2002) use spanning tests and indicate that sectoral indexes can be more easily reproduced by country indexes as vice versa. Bekaert and Urias (1996), Moerman (2004) use Sharpe ratio's to evaluate the relative performance of different investment strategies combining information from covariances and expected returns. Li (2003) compares the utility associated with alternative portfolios to evaluate the diversification benefits. The recent discussion on the impact of monetary unification in the euro area on the relative gains of country and sector diversification offers a good indication of how results are strongly influenced by the different measures of the diversification gains. Therefore, we consider a list of diversification measures to get a more complete picture of how the changes in asset return processes, volatility and correlations, as described by the DCC models have affected the different portfolio outcomes.

To compare different portfolio strategies against each other and through time we concentrate on different types of measures. Each contributes in a different way to point at which strategy is best, and ensures that results are robust to the choice of measure for diversification benefits.

In our applications below, we assume that the conditional correlations are relevant for an active investor with a short term investment horizon who uses information up to t to choose his portfolio, holds it for a fixed period and updates his investment strategy at the end of this period. In contrast, an investor with a long term horizon would choose the optimal portfolio that maximises his unconditional expected utility, i.e. using all the information available over time. In this paper we compute the portfolio weights using the estimate of the conditional correlations at each t, i.e. we use the information up to $t-1$ to compute conditional correlations and these are also used to compute the portfolio weights. The weights change at each t, the investor updates his portfolio weekly. Then, at the end of the holding period, the realised variance of the portfolio is computed and compared to the one predicted by the model. Below we detail each measure for diversification benefits.

4.1.1 Simple average conditional correlation

Simple average correlation is defined as:

$$\frac{1}{n(n-1)/2}\sum_{i}\sum_{j\neq i}\rho_{ij,t}$$

where $\rho_{ij,t}$ are the estimated conditional correlations at each time t. When the average conditional correlation increases, diversification gains decrease. The average conditional correlation disregards any information from the variance of the portfolio.

4.1.2 GLR measure for diversification gain: Weighted average correlation

This measure of diversification benefits , proposed by Goetzman et al. (2001), also uses the information from the estimated conditional correlations between the assets $\rho_{ij,t}$, and their volatilities h_{it} :

$$\begin{aligned}
\frac{var(\frac{1}{n}\sum_{i=1}^{n}x_i)}{\frac{1}{n}\sum_{i=1}^{n}var(x_i)} &= \frac{1}{n}+\frac{2}{n}\frac{\sum_{i=1}^{n}\sum_{j\neq i}cov(x_i,x_j)}{\sum_{i=1}^{n}var(x_i)} \\
&= \frac{1}{n}+\frac{(n-1)}{n}\frac{\overline{cov(x_i,x_j)}}{\overline{var(x_i)}} \\
&= \frac{1}{n}+\frac{(n-1)}{n}\frac{\overline{\rho_{ij,t}h_{it}^{0.5}h_{jt}^{0.5}}}{\overline{h_{it}^{0.5}}}
\end{aligned}$$

where n is the number of assets(indices) included in the portfolio, $\overline{cov(x_i,x_j)}$ is an average of the covariances between the portfolio asset returns and $\overline{var(x_i)}$ is the average of the index variances. The ratio measures the size of the variance reduction that can be achieved by holding a portfolio of assets instead of each asset individually. The variance reduction is scaled by the average variance of all the assets, so that the ratio can be read as a percentage. The ratio varies with t and with n. At each point in time, we can decompose the change in the variance of the portfolio achieved by the introduction of new assets into two terms: the first one reflecting the impact due to the expansion of the opportunity set and the second one reflecting the impact due to the change in the correlation matrix in time. The problem of the average conditional correlation and of the Goetzmann et al. measure is that they focus on risk reduction and ignore the effects on average returns from the expansion of the investment opportunity set. To evaluate the effect on diversification benefits from adding foreign assets to the home assets, we propose to compare the average Sharpe ratios corresponding to different types of portfolios: a minimum-variance portfolio and a power-utility based portfolio.

4.1.3 Variance of global minimum variance (GMV) portfolio

We use the estimates of the conditional correlation R_t and covariance H_t matrix to construct an optimal portfolio weighting scheme that combines the assets in the investment set to construct a portfolio which has the lowest variance that can be achieved through diversification. The weights for this portfolio, $w_t = \{w_{it}\}_{i=1}^{k}$are equal to:

$$\sigma_{GMV}^2 = w_t' H_t w_t \text{ with } w_t = \frac{H_t^{-1}\iota}{\iota' H_t^{-1}\iota}$$

where ι is a $(k,1)$ vector of ones.

A change in the variance of the global minimum variance portfolio associated with a change in the investment opportunity set indicates an horizontal shift in the efficient investment frontier. It combines the information from the correlation structure of the asset returns and the information from their variance. However, this measure remains dependent on the overall variance so it cannot be compared across different periods : higher correlation and higher variance reinforce each other (and the GMV portfolio variance increases) whereas the effect from lower correlation and higher variance is ambiguous.

The objective here is to compare the variance of GMV portfolios from the two main strategies: country vs.sector diversification and investigate whether the global minimum variance of one strategy is lower than the other.

4.1.4 The Sharpe ratio

In order to measure diversification benefits we also consider the Sharpe ratios of the different strategies. This ratio considers the risk/return trade-off that faces any risk-averse investor.

The average Sharpe ratio is the ratio of the mean portfolio return divided by the portfolio standard deviation annualised:

$$\frac{\mu * 52}{\sigma * \sqrt{52}}$$

where μ is the expected return over the entire period and σ the portfolio standard deviation, computed as an average over the entire period. A higher Sharpe ratio indicates a more profitable strategy.

4.1.5 Utility of alternative allocation strategies

One way to test whether the increase in the mean return combined to the reduction of the variance due to the addition of new assets to the investment portfolio increases diversification benefits is to use a regression-based spanning test. This tests whether the mean-variance efficient frontier corresponding to a strategy that consists in investing in all (foreign and home) assets coincides with the one that results from investing in home assets only. However there are several problems with this approach. First, when returns are not normal, the power of the tests is very low. We have shown (Table1) that normality does not hold in the case of weekly index returns. Second, the mean variance frontier is important for a quadratic utility investor with normally distributed returns. However, quadratic utility is not a useful assumption if we need a measure that evaluates the gains from adding new assets to the opportunity set because it implies that utility does not monotonically increase with wealth and because it is independent from the degree of risk aversion of the investor.

An alternative to the spanning test is to use the maximum utility of an investor with power utility and lognormal returns. Li (2003) shows that the optimal portfolio weights in that case are given by:

$$w^* = \frac{1}{\gamma}\Sigma^{-1}\left[\left(\mu + \frac{1}{2}\sigma^2\right) - \left(\frac{i'\Sigma^{-1}\mu + \frac{1}{2}i'\Sigma^{-1}\sigma^2 - \gamma}{i'\Sigma^{-1}i}\right)i\right] \qquad (10)$$

and the corresponding maximum utility is:

$$U(w^*) = U(\overline{\mu}, \Sigma) = \frac{1}{2\gamma}\left[\overline{\mu}'\Sigma^{-1}\overline{\mu} - \frac{1}{i'\Sigma^{-1}i}\left(\overline{\mu}'\Sigma^{-1}i - \gamma\right)^2\right]$$

where $\overline{\mu} = \mu + \frac{1}{2}\sigma^2$. Expected utility combines the expected return and variance information. An increase in utility indicates and increase in diversification benefits. We will also consider the variance of the utility portfolio, i.e. $\sigma_t^2 = w_t' H_t w_t$ with w_t given by (10), and the Sharpe ratio associated with this portfolio.

5 Test of the DCC model predictions for portfolio variances

Before presenting the estimation results for the different diversification measures, we test the DCC model predictions for portfolio variances. In the previous section we have shown that the statistical differences between the alternative DCC models is not always significant. Furthermore, we have seen that returns do not behave as normal variables (Table 1), which should make us especially cautious when we use the likelihood ratio statistics to test one model against the other. For both these reasons it is of particular interest, and common practice as well, to evaluate the performance of the competing models by comparing their ability to estimate correctly the variance of a set of portfolios. The aim of such a test is to find out how well the variance of the portfolio return is predicted by the different DCC models. From this perspective, the minimum variance portfolio is of particular interest as the weights of the assets in the optimal investment strategy are entirely determined by the variance-covariance matrix predicted by the model. In contrast, the utility portfolio reflects the influence of the estimation of the mean of returns and the choice of the degree of risk aversion. Finally, the predicted variance of the equally weighted portfolio.

In this section we test the DCC model specification using a test on the ratio of the standard deviation of portfolio returns standardised by the portfolio standard deviation implied by the estimated variance-covariance matrix, suggested by Engle and Sheppard (2001). We use all portfolios presented previously and test which model fares best in each case. In particular let x_t be the vector of $(k, 1)$ asset returns, $X_t = w_t' \ x_t$ is the portfolio return given by the strategy described by portfolio weights w_t, σ^2 the portfolio unconditional variance,and H_t the estimated variance-covariance matrix of returns. If the model for the conditional correlation is correctly specified, then we expect that the variance of any portfolio with weight w_t would be $w_t' H_t w_t$. Portfolio variances which are too small relative to the predicted variance indicate overestimation of the correlation in H_t, while portfolio variances in excess of the predicted variance are a sign of underestimation of the correlation in H_t. To test the null hypothesis that the predicted variance equals the portfolio variance, i.e. that the ratio is equal to 1, we calculate two-sided confidence intervals for $a = 10\%, 5\%, 1\%$ [9].

Table 7 presents the test results. The ADCC with a break does well in in-sample prediction of the variance of the portfolios for all investment strategies

[9] The confidence intervals (a, b) are constructed so that $\int_0^a f(u)du = \int_b^\infty f(u)du$ where $f(u)$ is the probability density function of a $\chi^2(T-1)$, and so that $b \leq \frac{\sigma^2}{\frac{1}{T}\sum_{t=1}^T w_t' H_t w_t} \leq a$.

considered here except for the minimum variance portfolio. This result is confirmed by Engle and Sheppard (2001)[10]. The ratio lies within the confidence interval across all indices. Even for the minimum variance portfolio the test statistic takes smaller values for the ADCC model with a break than for the other models, across all indexes considered. Although the ratio is significantly different from one at the 1% level, the ADCC model with a break still performs best. As risk aversion increases, the utility portfolio behaves more and more like the minimum variance portfolio. As a result, when the degree of risk aversion is relatively high, for some country/sector models and in particular for the world country and the world sector models, even the best model performs poorly in estimating the portfolio variance

6 Results: country versus sector portfolios

In this section we analyse the gains from cross-country against cross-sector diversification in Europe. We use the conditional correlation estimates from the ADCC model with a break since 1999, the portfolio variances and the Sharpe ratios to shed some light on this question. First, we compare the change in the correlations in sector portfolios with the one in country portfolios and investigate which effect has been larger. Second, given the change in the dynamic correlations, we ask how diversification benefits have changed in Europe. Finally, we evaluate the economic importance of asymmetries in the determination of the most profitable diversification strategy : we look at the impact of asymmetric correlations on the variance of the minimum variance portfolio and the variance of the maximum utility portfolio.

6.1 An increase / positive break in the correlation for country indexes.

(Insert Figure 1 here)

In Figure 1, the different indicators for portfolio diversification based on the world country model are plotted against time.

First, the average conditional correlation between the 24 country index returns has clearly increased since 1999. The average conditional correlation increases from a value around 0.40 to around 0.48. The break in the series in 1999 is clearly the dominant source of fluctuation especially since the correlation in the ADCC model with break is relatively less persistent. The remaining short-run variation in the average conditional correlation appears to be positively related to the peaks in the average standard deviation of the individual country indexes[11] .

[10] Engle and Sheppard (2001) look at how the scalar DCC model performs for different sets of indices, among them the S&P500, and find that, for the minimum variance portfolio, the null is rejected most of the time, whereas for equally weighted portfolios, the DCC estimator produces ratios insignificantly different from one.

[11] These are also conditional volatilities as they are derived from the GARCH estimation.

Second, the Goetzmann-Li-Rouwenhorst (GLR) variance ratio reacts in a slightly different way from the average conditional correlation. This measure also clearly increases since 1999, but there is a second positive break at the end of 2001. In the GLR ratio, contrary to the simple average conditional correlation, correlations are weighted by the index variances. These weights change over time and, as a result, the difference between the volatility of the equally weighted portfolio (the numerator of the ratio) and the average volatility of the country indexes (its denominator) has narrowed since 2001. Furthermore, the GLR ratio is clearly very sensitive to changes in the individual volatility processes. This can be seen at the beginning of 1995, when the ratio decreases abruptly as average volatility increases temporarily. There no impact on the other measures.

Third, the volatility of the minimum variance and the equally weighted portfolios also increases. The increase in the average standard deviations of the individual indexes and the increase in the correlations influences these volatilities in the same direction. The relative influence of each factor is not immediately obvious from Figure 1 but the portfolio volatilities seem to move closely with the average standard deviations indicating a limited role for the correlations: Despite the increase in correlations, portfolio volatility has returned to its level of the beginning of nineties. The timing of the rise in the portfolio volatilities follows closely the timing in the rise in the average standard deviations.

The increase in the volatility of the maximum utility portfolio is much less important than the increase in the volatitlity of the minimum variance portfolio. This result follows from the use of a constant expected returns over the whole period: For constant expected returns, as the expected volatility moves up, investors' preferences move towards less risky portfolios at the cost of a lower portfolio return. This portfolio re-allocation effect will tend to stabilise the variance of the maximum utility portfolio, but only at the cost of increased variation in the expected returns on the portfolio. Since 1997, the maximum utility portfolio volatility has returned to its 1990s level. As a result, the influence of the changing correlations is even smaller for the utility maximising portfolios than for the minimum variance portfolios. Exactly the same trends are obtained if the model is estimated with only the European and the American indexes included (i.e. excluding the Asian markets).

The second part of Figure 1 shows the results for the 11 euro area countries. The correlation during the first sub-period up to 1998 fluctuates around 0.52, while it increases to 0.56 on average from 1999 onwards. The relative increase in the correlation for the euro area countries is lower than the generally observed increase for all 24 countries. The volatility of the minimum variance portfolio remains relatively stable. The higher correlation is not translated into a clear increase in the volatilities of the minimum variance or maximum utility portfolios. As with the full data set, the short run fluctuations in the portfolio volatilities reflect the influence of the average standard deviations of the individual indexes very closely.

(Insert Table 8)

In Table 8 the average correlation of each country index return with the other

23 country index returns is summarised. We consider the entire period but also decompose the sample into two subperiods, $1990-1998$ and $1999-2003$. The table shows which country index returns are on average most correlated with the other country index returns as well as the increase in the correlation for each country after 1999. The table shows that the correlation of the European indexes with the remaining 23 indexes is highest in Germany, France and the Netherlands (exceeding 0.50). Furthermore, the correlation of European non-euro area country indexes with the other indexes is also relative high. The Asian and American indexes have the lowest correlation with the other country indexes and should provide the best diversification opportunities. Over time we see that most countries contribute to the increased correlation. Exceptions are Austria, Japan, Ireland and also Belgium which did not experience an increased correlation. If we concentrate on the European indexes, we see that the main increase in correlation occurred between the core countries of the euro area (France, Germany, Spain and especially Italy). The smaller periphery countries underwent a relative smaller increase in correlation. This is somewhat surprising as one might have thought that integration would have been strongest for periphery countries with a history of relative low correlation. This did not happen and these smaller countries continue to offer more interesting portfolio risk reduction opportunities.

6.2 A negative break in the correlation for the sector indexes

From figure 1, it appears that the correlation between the 10 world sector index returns follows a completely different path over time. The sector correlations clearly decreased strongly since 1999, declining from an average around 0.70 towards values between 0.50 and 0.60. Here the decrease is even more obvious in the GLR risk reduction measure. It is not clear from the graphs whether this break is a persistent decline or whether it is a temporal decline, because both the average correlation and the GLR measures tend to increase again after their lowest values in 2000 and 2001.

The volatility of the minimum variance, the utility maximising and the equally weighted portfolio increases. This implies that the decrease in the correlation was not sufficient to offset the increase in the average standard deviation of the individual indexes. This is clearly reflected on the volatility of the minimum variance portfolio which has increased strongly to return to its high level of the beginning of the nineties. Once again the utility maximising portfolio appears to be characterised by a much more stable volatility.

The correlation between the euro area sector indexes follows a very similar time-path to the correlation between the world sector indexes (second part of Figure 1). The portfolio volatilities however fluctuate more in the short run. This must reflect the relatively high fluctuations in the individual sector correlations at higher frequencies.

Table 8, shows that all sectors contribute to the decrease in the average correlations. The total financials sector contributed somewhat less, but the differences between the sector contributions to the decline is small.

(Insert Figure 2 here)

An alternative approach to understanding the changes in the international correlation structures is to look at the country/sector models. The evolution over the estimation period of the average correlation within each of the 10 country/sector models is summarised in Figure 2. Major positive breaks are observed in the non-cyclical services and the information technology sector. This result reflects the major impact of the world-wide new economy bubble. On the other hand, two sectors have experienced a decline in international correlation: non-cyclical goods and utilities. Note that the average conditional correlation within the sector/country models is lower than the correlations in the country model. Figure 2 shows the volatilities of the maximum utility portfolio for each of the country/sector model. Again the non-cyclical services and the information technology sector appear as the ones with the highest increase in portfolio volatility. Utilities and non-cyclical goods show no particular trend, while the other sectors follow the general country portfolio profile.

6.3 A comparison of sector and country diversification benefits

6.3.1 Correlations and portfolio variances

Up to 1999, the correlation between world sector index returns is higher than the correlation between world country index returns (panel 1, Figure 1). At the same time, the average standard deviation of the individual sector index returns is smaller than the average standard deviation of the country indexes (panel 3, Figure 1). After 1999 both characteristics tend to converge. Correlations between sector indexes declined, while the correlation between country indexes increased but in a weaker way. At the same time, sector and country index return volatility increased, but sector volatility increased by more than country volatility.

In terms of portfolio volatilities, both features compensate each other and no major dominance of one of the two on the portfolio's volatilities is obvious. While, during the first two years of the sample, country portfolio's tended to have a lower volatility, sector portfolios tended to produce lower volatilities between 1993 and 2001. However, since 2001, the graphs show higher variation in the sector portfolios (Panels 4-6, Figure 1).

The picture for correlations for the euro area is very similar as the one relative to the world funds. Country correlations are lower than sector correlations within the Euro area up to 1999, while the two converge after 2002 to an average of 0.50. There is a short period between 1999 and 2002 when the average correlation for the sector funds drops below the country average correlation. The average standard deviation of the sector indexes is lower than the average standard deviation of the country indexes, but the difference is much smaller than for the world model, and this trend seems to have been reversed during the recent period. In terms of portfolio volatilities, the differences are even smaller.

However the periods in which sector portfolios produce lower volatilities are rare. Even during the 2000, when correlations are very low, portfolio variances remain unchanged.

6.3.2 Sharpe ratios and maximum utility

(Insert Table 9 here)

To evaluate the diversification gains resulting from each strategy we consider Sharpe ratios and utility outcomes for country and sector portfolios. Table 9 shows Sharpe ratios computed for the minimum variance and the maximum utility portfolio, with a low and high degree of risk aversion. Sharpe ratios are computed using the average return over the whole period and the conditional covariance matrix from the ADCC model with break. On average diversification across countries pays off slightly more than diversification across sectors, especially in the case of the world model. For example the average Sharpe ratio associated with the maximum utility portfolio with low risk aversion takes the value of 1.30 against 1.10 for a cross-country vs a cross sector strategy. When we look at the euro area case, results are slightly different: cross-sector diversification seems to pay off more and the values of the corresponding Sharpe ratios are 1.02 against 0.75 . We cannot tell if these differences are significant, but they are confirmed across different portfolios (minimum variance, and maximum utility with high risk aversion).

(Insert Figure 4 here)

Figure 4 shows the evolution of Sharpe ratios over time. The ratios for the world country vs. the world sector model are plotted. Once again, the Sharpe ratio corresponding to diversification across country indexes is higher than the Sharpe ratio corresponding to diversification across sectors. This advantage is encountered with all portfolios, from minimum risk to very risky portfolios and is an indication that a diversification strategy across countries yields higher benefits than a diversification strategy across sectors. However, when we look at the Sharpe ratio associated with the euro area model (Figure 4, part 2), we find that the Sharpe ratio is higher for cross-sector portfolio than for the cross-country portfolio. For the risk averse portfolios this result is valid over the whole period, and has become stronger during the recent years. For the low risk portfolios, this advantage of the sector indexes has disappeared recently.

(Insert Figure 5 and 6 here)

A comparison of utility outcomes for the two strategies leads to the same conclusions (Figure 5). Cross-country diversification in general pays off more than cross-sector diversification but the gain is very small. In Figure 6, we compare the expected utility outcomes from international diversification within a sector (using the country/sector models) with the utility outcome from international diversification across markets (using the world country model) . The results prove that international diversification across markets, in most cases is more efficient than international diversification within one particular sector. The observed lower average correlation in the country/sector models is outweighed by the higher volatilities within sectors or by lower average returns. Technology and non-cyclical services are again the clearest examples. However, during specific periods country/sector models outperform general country portfolio's: utilities and non-cyclical goods did well in the second half of the sample. Financials and cyclical services have also been relatively interesting portfolio's.

6.3.3 Discussion

We have shown that market return correlations have exhibited a break since 1999. Country correlations increase, while the correlation between world sector returns decreases. The decrease in sector return correlations is more pronounced than the increase in market correlations.

At a more disaggregated level, country/sector return correlations exhibit a break, which is significant most of the time but the timing of the break varies across sectors and countries. This is confirmed in the literature (see e.g. Berben and Jensen, 2003) which shows that the length of the transition periods from one regime to the other vary strongly across countries and sectors. The same general features hold for sector correlations within the euro area but the break is less pronounced than in world sector correlations. One reason for this can be that some European markets tend to follow the US market very closely while other appear to move in a more disconnected way. In fact, bigger European markets (UK, France, Germany) move more independently than smaller and newer European markets (Greece, Finland). This can be evidence that the origin of the break in euro area sector correlations may be different from the break in world sector correlations. It might indicate for example, that the idiosyncratic behaviour of the US technology sector is responsible for the decrease in correlations between world sector returns, whereas within euro area a higher degree of real and financial integration increased comovement between euro area markets returns which tuned down the sector-specific effect of the global technology shock. With our correlation model we have no way of distinguishing between the two possible origins of the change. In a way this is the price we pay for including a larger set of assets in our analysis. When the cross-section dimension is smaller it is possible to estimate a structural model for dynamic correlations and identify the shocks, as for example in Bonfignioli and Favero (2000). In a study of US and European stock markets, they find that long run interdependence between the two stock markets is driven by fundamentals. They also find evidence of short run interdependence between stock markets: during high volatility periods, short run fluctuations in the US stock market have an effect on European stock markets, but not the reverse.

What is the impact of these correlation changes on the two alternative investment strategies considered in this paper? We looked at how the change in dynamic correlations impacted on the volatility of portfolios created according to a country or a sector diversification strategy. The main conclusion was that both the sector and the country portfolio volatilities have increased over time. This comes as a surprise since, as we saw previously, correlations between the assets that constitute these portfolios have behaved in opposite ways. It implies that the increase in the individual sector volatilities must be bigger than the change in the individual country volatilities. Looking at averaged individual volatility we showed that this is indeed what happens. We also found confirmation in the literature that sector volatility has been increasing over the last decade (e.g. Campbell et al. (2003)).

In terms of choosing the strategy that pays off more either in terms of risk reduction (lowest portfolio volatility) or in terms of risk/return trade-off (best Sharpe ratio) our main conclusions is that the relative benefits from following one strategy against the other have remained stable over time, even though correlations have exhibite significant breaks and time-variation. It also appears that although some European markets behave in different ways than the rest of the world in that they do not follow closely the US markets, the benefits from one investment strategy against the other have remained stable over time. This trend is observed in both the euro area and the world-wide portfolios and is therefore not specific to the European integration process. At the same time, the volatility in the sector indexes has increased remarkably and in a relatively stronger way compared to the volatility in the country indexes. Both trends tend to cancel out in the calculations of optimal portfolio variance: lower sector correlation is offset by higher sector volatility and higher country correlation is neutralised by the relative lower volatility in country indexes. Therefore no clear trend appears from comparing the relative conditional variances of sector and country portfolios. After taking into account the effect of average returns, it turns out that country diversification is still the dominant strategy for world portfolios, whereas sector diversification is more interesting for euro area portfolios.

In the next section we investigate the role of asymmetries and downside risk.

6.4 Impact of asymmetry/downside risk on the different measures

In this section we compare the estimation outcome for correlation and portfolio variances in a model with and without asymmetries. The presence of asymmetries in the reaction of conditional correlation to negative return shocks with respect to positive ones is important as it implies that gains from diversification could be absent at moments when they would have been most useful. Furthermore we have seen in the table presenting descriptive statistics that our data seem to display some form of asymmetric behaviour in what correlations are concerned.

(Insert Figure 7 here)

Figure 7 shows the difference between the measures computed on the basis of the ADDC model vs the DCC model (with a break) in order to illustrate the link between volatilities and asymmetric effects. The impact of asymmetry is limited for the correlation measures: the largest difference between the two models is 0.015. The major differences in the correlations are positive: the model with asymmetry delivers higher correlations and this especially during periods of higher volatility. So indeed, diversification is less available at moments when it is needed most, but the impact is small. The impact on the volatility of the portfolios is also limited. The maximum impact on the portfolios is of the order of a 0.40 increase in the annualised standard deviation of the maximum utility portfolio: this represents a 5 percent increase in the portfolio standard deviation at most. The impact is not larger when we consider the models without the break.

Our main conclusion is that although asymmetries are present, in the sense that the ADCC model performs best interms of the LR test and the variance predictive power test in section 2, their size is not very important. As a result, the direction of the previous results on portfolio variances is not altered by their presence, at least when we look at the country and sector indexes. However there could be two further issues that could complicate this interpretation. Let us re-write equation (7) :

$$\begin{aligned} Q_t &= \left(\overline{Q} - d\widetilde{Q} - A'\overline{Q}A + dA'\widetilde{Q}A - B'\overline{Q}B + dB'\widetilde{Q}B - G'\overline{N}G + dG'\widetilde{N}G\right) \\ &\quad + A'\varepsilon_{t-1}\varepsilon'_{t-1}A + B'Q_{t-1}B + G'n_{t-1}n'_{t-1}G \end{aligned}$$

First, it is possible that, at a more disaggregated level (country/sector returns), asymmetries become important for some sectors which have had large bull or bear experiences. Investigating further down this path however is left for future work especially in light of a further issue: Even though the diagonal ADCC model is flexible enough to include asymmetric reactions of correlations to negative return shocks in a computationally feasible way, it is still quite restrictive in two directions. First, in the way asymmetries are defined, i.e. both standardised residuals ($\varepsilon_{i,t-1}\varepsilon_{j,t-1}$) are negative at the same t. At that point in time we do not take into consideration how all the other markets, or at least a few important markets behave (like the US market or in crisis times, markets where the crisis originates from) , to define the presence of the asymmetry. To do that we would need to extend the ADCC model in its definition of n_t. Second, in being diagonal the ADCC model restricts the dynamics of Q_t in ways that probably do not allow to capture the dynamics reflected in the descriptive statistics table. Generalising the matrices A, B and G to be full matrices is not possible since the model is not identified (too many parameters to estimate) in that case.

7 Summary and Conclusion

The Asymmetric diagonal Dynamic Conditional Correlation (ADCC) model turns out to offer a relatively flexible instrument to describe the dynamic process of correlations among a large set of stock indices. The two-step estimation approach and the restrictions on the structure of the correlation dynamics (diagonality of A, B and G matrices) reduce the computational effort needed to estimate the model but nevertheless provide a sufficiently general dynamic specification. Other techniques, such as the multivariate GARCH models, are computationally too complex to be applied to the estimation of the dynamic covariance structure of large portfolio's. This makes the ADCC model the natural candidate for investigating issues like the diversification gains from different portfolio strategies. At the same time, further statistical tests through, for instance, out-of-sample prediction exercises, are necessary to evaluate the power of the model.

When the ADCC model is applied to country and sector portfolios, we find that the correlation between countries have increased strongly during the last 2 years, while the correlation between sector indexes has shown a remarkable decrease. The increase in the correlation between countries was however not a typical European or euro area phenomenon. The contribution of monetary and financial integration to this change in the correlation structure is therefore far from clear from this evidence. Possibly, the factors that have been causing the higher correlations in the world portfolios have been different from those responsible for the increase in the euro area portfolios. One important source behind the correlation shifts could be the world-wide technology bubble. We leave it for future research to identify the relative contribution of particular sectors to these outcomes.

While the correlations between country and sector indexes have moved in opposite directions, for both type of indexes we observe a strong increase in conditional volatility. However, the increase is stronger for sector indexes than for country indexes, and this trend tends to offset the implication of the shifts in correlation for the portfolio strategies. Relatively higher sector volatility has increased the need for diversification for sector portfolio's and the lower sector correlation has helped to achieve this objective. Higher country correlation was less of a problem because the increase in country volatility was relatively smaller. The combined effect on the portfolio variances was therefore more or less neutral and no clear trend in the relative benefits from the two portfolio's strategies, country or sector diversification, appear from our analysis, at least in terms of risk alone. A comparison of alternative strategies using information from both the variance and the expected return of the portfolios can be achieved with the portfolio Sharpe ratio or the expected maximum utility. After taking into account the effect of average returns, it turns out that country diversification is still the dominant strategy for world portfolio's, whereas sector diversification is more interesting for euro area portfolio's. All in all, the results indicate that one must be careful in drawing strong conclusions for the relative performance of country or sector strategies from partial analysis.

The shifts in correlations that result clearly from the estimation of the ADCC models with break, raises the question of whether these shifts are permanent or transitory. A definite answer to that question can be achieved only by analysing the underlying drivers. The literature suggests that the main forces behind this evolution are fluctuations in volatility, the business cycle and market tendencies (bear and bull markets). Including these variables in the dynamic specification of the correlation model is one approach for testing these hypothesis. The relative minor contribution of the asymmetric component in our model over the last cycle does not point towards an important role for business cycle effects and market tendencies, at least as far as one expects these processes to contribute asymmetrically to the correlation structure.

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Table 1: descriptive statistics on stock market indexes

	mean	std	skew	kurt	min	max	corr	bear	normal	bull
Countries										
Austria	0.49	19.02	-0.40	7.67	-0.17	0.15	0.40	0.42	0.32	0.39
Belgium	3.06	16.91	-0.15	4.90	-0.10	0.11	0.48	0.42	0.29	0.35
Denmark	7.32	17.81	-0.47	6.01	-0.14	0.10	0.45	0.41	0.30	0.35
France	5.14	18.21	-0.15	4.09	-0.10	0.10	0.56	0.38	0.20	0.31
Germany	2.92	19.64	-0.34	4.85	-0.11	0.11	0.57	0.37	0.18	0.29
Ireland	6.66	18.78	-0.40	5.37	-0.13	0.12	0.46	0.41	0.30	0.35
Italy	0.93	22.98	0.05	5.48	-0.13	0.17	0.44	0.40	0.31	0.35
Netherlands	6.24	17.12	-0.44	6.37	-0.10	0.14	0.57	0.36	0.19	0.29
Spain	4.72	19.77	-0.12	4.09	-0.11	0.13	0.53	0.39	0.24	0.27
Greece	8.58	31.54	0.31	5.35	-0.17	0.21	0.33	0.46	0.35	0.40
Portugal	0.67	18.56	-0.02	4.67	-0.12	0.13	0.43	0.42	0.32	0.37
Finland	9.67	31.79	-0.46	5.64	-0.23	0.19	0.41	0.38	0.33	0.37
Sweden	5.14	25.80	-0.11	6.00	-0.17	0.22	0.52	0.38	0.26	0.30
Switzerland	8.90	17.17	-0.10	5.10	-0.11	0.11	0.52	0.40	0.27	0.31
Norway	3.64	21.70	-0.33	5.35	-0.13	0.13	0.45	0.42	0.28	0.33
United Kingdom	4.59	15.81	0.08	4.95	-0.09	0.11	0.52	0.38	0.26	0.31
Australia	4.75	16.45	-0.18	3.97	-0.11	0.09	0.40	0.40	0.34	0.35
Hong Kong	9.91	25.89	-0.49	6.00	-0.20	0.14	0.39	0.41	0.32	0.39
Japan	-4.89	23.89	0.26	4.32	-0.13	0.12	0.32	0.44	0.36	0.38
New Zealand	1.69	19.84	-0.38	5.00	-0.13	0.11	0.36	0.42	0.36	0.38
Singapore	1.27	22.35	-0.54	9.19	-0.23	0.16	0.40	0.42	0.33	0.38
Canada	6.12	16.50	-0.55	6.34	-0.12	0.09	0.43	0.41	0.34	0.38
Mexico	9.72	30.32	-0.60	6.84	-0.28	0.19	0.33	0.44	0.35	0.37
United States	8.65	16.21	-0.59	7.25	-0.14	0.09	0.44	0.40	0.36	0.37
sectors. world level										
Basic industries	-0.46	15.52	-0.21	5.07	-0.10	0.08	0.71	0.57	0.38	0.48
Cyclical goods	1.60	16.73	-0.37	7.35	-0.15	0.11	0.70	0.55	0.42	0.51
Cyclical services	2.96	15.17	-0.34	5.87	-0.12	0.08	0.76	0.50	0.28	0.45
General industries	3.93	16.58	-0.41	6.48	-0.15	0.09	0.77	0.49	0.26	0.42
Total financials	9.71	26.92	-0.59	6.57	-0.24	0.16	0.57	0.56	0.54	0.54
Non-cyclical goods	7.88	13.14	-0.15	5.04	-0.08	0.07	0.60	0.57	0.48	0.53
Non-cyclical services	2.81	16.31	-0.25	5.00	-0.10	0.11	0.63	0.51	0.43	0.55
Inform. technology	5.47	15.65	-0.45	5.20	-0.11	0.08	0.52	0.60	0.54	0.53
Ressources	2.60	16.75	-0.05	5.45	-0.11	0.11	0.74	0.52	0.34	0.48
Utilities	0.95	11.36	0.12	5.62	-0.08	0.08	0.58	0.60	0.52	0.52
sectors. euro area										
Basic industries	2.52	17.60	-0.43	5.42	-0.11	0.11	0.73	0.55	0.38	0.45
Cyclical goods	1.00	20.75	-0.69	7.00	-0.18	0.12	0.70	0.56	0.44	0.47
Cyclical services	3.59	17.73	-0.41	7.45	-0.16	0.11	0.73	0.53	0.36	0.44
General industries	3.08	19.27	-0.41	4.42	-0.11	0.10	0.75	0.51	0.33	0.45
Total financials	3.13	18.75	-0.16	7.98	-0.12	0.16	0.74	0.54	0.37	0.47
Non-cyclical goods	7.71	15.21	-0.20	4.10	-0.08	0.09	0.65	0.57	0.43	0.50
Non-cyclical services	8.13	22.30	0.06	5.38	-0.14	0.16	0.62	0.54	0.49	0.54
Inform. technology	11.69	32.00	-0.52	5.47	-0.20	0.18	0.60	0.55	0.51	0.52
Ressources	7.48	19.20	-0.28	5.84	-0.16	0.15	0.54	0.61	0.52	0.51
Utilities	6.20	14.99	-0.20	3.92	-0.08	0.08	0.62	0.60	0.48	0.56

skew stands for skewness. kurt for kurtosis. std for standard deviation. min for minimum. max for maximum
corr represents the average unconditional correlation of each country/sector with all other countries/sectors over all periods
bear represents the average correlation of the index with the other indexes. in periods of bear markets.
normal represents the average correlation of the index with the other indexes. in normal periods.
bull represents the average correlation of the index with the other indexes. in periods of bull markets.

Table 2: Garch and ADCC parameters for the world country model

	Garch parameters			Asymmetric DCC with dummy		
	ω	α	β	a	b	g
Austria	0.212	0.081	0.882	0.004	0.862	0.008
	0.051	*0.013*	*0.009*	*0.002*	*0.099*	*0.015*
Belgium	0.846	0.183	0.669	0.042	0.709	0.017
	0.217	*0.041*	*0.050*	*0.019*	*0.105*	*0.016*
Denmark	0.029	0.059	0.940	0.008	0.851	0.002
	0.025	*0.008*	*0.003*	*0.006*	*0.103*	*0.001*
France	0.573	0.099	0.812	0.025	0.797	0.006
	0.144	*0.024*	*0.022*	*0.008*	*0.061*	*0.006*
Germany	0.191	0.111	0.868	0.019	0.723	0.004
	0.069	*0.018*	*0.011*	*0.009*	*0.093*	*0.004*
Ireland	0.059	0.052	0.941	0.003	0.849	0.002
	0.032	*0.007*	*0.002*	*0.001*	*0.127*	*0.002*
Italy	2.392	0.158	0.604	0.017	0.767	0.003
	0.744	*0.039*	*0.085*	*0.009*	*0.105*	*0.002*
Netherlands	0.451	0.193	0.728	0.027	0.826	0.003
	0.121	*0.035*	*0.034*	*0.009*	*0.051*	*0.002*
Spain	0.398	0.104	0.844	0.008	0.762	0.045
	0.107	*0.020*	*0.014*	*0.005*	*0.079*	*0.022*
Greece	0.278	0.072	0.913	0.005	0.684	0.006
	0.089	*0.010*	*0.005*	*0.004*	*0.186*	*0.009*
Portugal	1.254	0.149	0.662	0.011	0.568	0.040
	0.353	*0.039*	*0.062*	*0.010*	*0.143*	*0.024*
Finland	0.480	0.119	0.861	0.007	0.980	0.004
	0.165	*0.019*	*0.012*	*0.005*	*0.011*	*0.005*
Sweden	0.676	0.139	0.814	0.006	0.923	0.004
	0.175	*0.023*	*0.018*	*0.004*	*0.031*	*0.003*
Switzerland	1.308	0.142	0.625	0.026	0.653	0.012
	0.357	*0.037*	*0.073*	*0.012*	*0.145*	*0.009*
Norway	0.629	0.077	0.852	0.009	0.562	0.003
	0.133	*0.017*	*0.014*	*0.008*	*0.227*	*0.002*
United Kingdom	1.394	0.110	0.597	0.031	0.781	0.002
	0.407	*0.035*	*0.086*	*0.015*	*0.080*	*0.001*
Australia	0.230	0.048	0.907	0.004	0.931	0.004
	0.060	*0.013*	*0.006*	*0.002*	*0.046*	*0.003*
Hong Kong	0.299	0.093	0.888	0.008	0.731	0.003
	0.109	*0.015*	*0.008*	*0.006*	*0.113*	*0.002*
Japan	0.620	0.095	0.849	0.004	0.824	0.010
	0.170	*0.020*	*0.014*	*0.002*	*0.092*	*0.027*
New Zealand	0.340	0.083	0.871	0.003	0.542	0.003
	0.078	*0.015*	*0.010*	*0.002*	*0.192*	*0.003*
Singapore	0.179	0.103	0.884	0.004	0.581	0.003
	0.057	*0.015*	*0.008*	*0.003*	*0.272*	*0.002*
Canada	0.130	0.103	0.874	0.005	0.611	0.037
	0.041	*0.016*	*0.010*	*0.004*	*0.173*	*0.024*
Mexico	0.772	0.107	0.852	0.004	0.731	0.010
	0.242	*0.022*	*0.013*	*0.003*	*0.146*	*0.020*
United States	0.016	0.052	0.946	0.004	0.942	0.003
	0.012	*0.006*	*0.002*	*0.002*	*0.030*	*0.002*

The GARCH parameters are the univariate Garch estimates used to standarize the return data.
The ADCC parameters correspond to the asymmetric DCC model with a dummy break in the intercept from the first week of 1999 onwards.
Standard errors are reported below the coefficients

Table 3: Garch and ADCC parameters for the world sector model

	Garch parameters			Asymmetric DCC with dummy		
	ω	α	β	a	b	g
Basic industries	0.188	0.123	0.839	0.031	0.887	0.010
	0.056	*0.021*	*0.016*	*0.006*	*0.017*	*0.008*
Cyclical goods	0.503	0.155	0.749	0.022	0.914	0.006
	0.123	*0.028*	*0.031*	*0.006*	*0.021*	*0.004*
Cyclical services	0.041	0.076	0.915	0.025	0.927	0.006
	0.019	*0.010*	*0.005*	*0.005*	*0.016*	*0.004*
General industries	0.105	0.109	0.875	0.028	0.923	0.004
	0.038	*0.016*	*0.010*	*0.005*	*0.013*	*0.003*
Total financials	0.055	0.064	0.934	0.020	0.974	0.002
	0.034	*0.007*	*0.003*	*0.005*	*0.007*	*0.001*
Non-cyclical goods	0.012	0.027	0.973	0.020	0.927	0.005
	0.011	*0.005*	*0.001*	*0.007*	*0.017*	*0.003*
Non-cyclical services	0.034	0.059	0.934	0.007	0.972	0.019
	0.019	*0.007*	*0.003*	*0.002*	*0.012*	*0.009*
Information technology	0.022	0.043	0.953	0.012	0.865	0.002
	0.015	*0.005*	*0.002*	*0.008*	*0.073*	*0.001*
Ressources	0.290	0.128	0.820	0.021	0.937	0.002
	0.081	*0.022*	*0.018*	*0.006*	*0.018*	*0.001*
Utilities	0.081	0.064	0.903	0.014	0.824	0.030
	0.022	*0.012*	*0.007*	*0.008*	*0.057*	*0.015*

The GARCH parameters are the univariate Garch estimates used to standarize the return data
The ADCC parameters correspond to the asymmetric DCC model with a dummy break in the intercept from the first week of 1999 onwards.
Standard errors are reported below the coefficients

Table 4: Likelihood ratio tests of alternative DCC models

	Log Likelihood	H_0	LR test	p-value
World country model				
(1) CDCC	-36266			
(2) SDCC	-36187	(2) vs (1)	157.48	0.00
(3) SDCC-d	-35834	(3) vs (2)	706.70	0.00
(4) SDCC-t	-36170	(4) vs (2)	34.84	0.00
(5) DDCC	-36105	(5) vs (1)	164.24	0.00
(6) DDCC-d	-35796	(6) vs (3)	75.89	0.00
(7) ADCC	-36088	(7) vs (5)	33.77	0.09
(8) ADCC-d	-35779	(8) vs (6)	32.98	0.10
World sector model				
(1) CDCC	-11737			
(2) SDCC	-11487	(2) vs (1)	500.51	0.00
(3) SDCC-d	-11380	(3) vs (2)	212.79	0.00
(4) SDCC-t	-11468	(4) vs (2)	37.82	0.00
(5) DDCC	-11459	(5) vs (1)	54.19	0.00
(6) DDCC-d	-11352	(6) vs (3)	56.03	0.00
(7) ADCC	-11449	(7) vs (5)	21.03	0.02
(8) ADCC-d	-11342	(8) vs (6)	19.82	0.03
Euro area country model				
(1) CDCC	-16777			
(2) SDCC	-16666	(2) vs (1)	222.00	0.00
(3) SDCC-d	-16553	(3) vs (2)	226.81	0.00
(4) SDCC-t	-16657	(4) vs (2)	19.16	0.00
(5) DDCC	-16622	(5) vs (1)	88.45	0.00
(6) DDCC-d	-16531	(6) vs (3)	43.40	0.00
(7) ADCC	-16616	(7) vs (5)	12.28	0.34
(8) ADCC-d	-16521	(8) vs (6)	21.25	0.03
Euro area sector model				
(1) CDCC	-13356			
(2) SDCC	-13085	(2) vs (1)	540.85	0.00
(3) SDCC-d	-12957	(3) vs (2)	255.61	0.00
(4) SDCC-t	-13060	(4) vs (2)	49.66	0.00
(5) DDCC	-13067	(5) vs (1)	35.37	0.01
(6) DDCC-d	-12943	(6) vs (3)	27.76	0.00
(7) ADCC	-13061	(7) vs (5)	13.23	0.21
(8) ADCC-d	-12936	(8) vs (6)	14.96	0.13

CDCC stands for the constant CC model
SDCC stands for the scalar DCC model
SDCC-d stands for the scalar DCC model with break in intercept from 1999 onwards
SDCC-t stands for the scalar DCC model with determistic trend in intercept
DDCC stands for the diagonal DCC model
DDCC-d stands for the diagonal DCC model with break in intercept from 1999 onwards
ADCC stands for the asymmetric diagonal DCC model
ADCC-d stands for the asymmetric diagonal DCC model with break in intercept from 1999 onwards

Table 5: Likelihood ratio tests of alternative DCC models

	Log Likelihood	H_0	LR test	p-value
Basic industries				
(1) CDCC	-38855			
(2) SDCC	-38841	(2) vs (1)	27.64	0.00
(3) SDCC-d	-38596	(3) vs (2)	489.99	0.00
(4) SDCC-t	-38836	(4) vs (2)	11.29	0.00
(5) DDCC	-38794	(5) vs (1)	94.88	0.00
(6) DDCC-d	-38568	(6) vs (3)	55.97	0.00
(7) ADCC	-38780	(7) vs (5)	28.22	0.21
(8) ADCC-d	-38548	(8) vs (6)	41.18	0.01
Cyclical goods				
(1) CDCC	-30203			
(2) SDCC	-30191	(2) vs (1)	24.03	0.00
(3) SDCC-d	-30100	(3) vs (2)	181.05	0.00
(4) SDCC-t	-30190	(4) vs (2)	0.66	0.41
(5) DDCC	-30156	(5) vs (1)	70.02	0.00
(6) DDCC-d	-30073	(6) vs (3)	53.44	0.00
(7) ADCC	-30145	(7) vs (5)	22.01	0.14
(8) ADCC-d	-30059	(8) vs (6)	29.62	0.02
Cyclical services				
(1) CDCC	-38540			
(2) SDCC	-38524	(2) vs (1)	32.74	0.00
(3) SDCC-d	-38335	(3) vs (2)	377.74	0.00
(4) SDCC-t	-38520	(4) vs (2)	8.41	0.00
(5) DDCC	-38483	(5) vs (1)	81.92	0.00
(6) DDCC-d	-38309	(6) vs (3)	51.59	0.00
(7) ADCC	-38469	(7) vs (5)	26.94	0.26
(8) ADCC-d	-38293	(8) vs (6)	33.26	0.08
General industries				
(1) CDCC	-38516			
(2) SDCC	-38499	(2) vs (1)	33.54	0.00
(3) SDCC-d	-38275	(3) vs (2)	447.31	0.00
(4) SDCC-t	-38499	(4) vs (2)	0.28	0.60
(5) DDCC	-38457	(5) vs (1)	85.03	0.00
(6) DDCC-d	-38253	(6) vs (3)	45.32	0.00
(7) ADCC	-38442	(7) vs (5)	29.26	0.14
(8) ADCC-d	-38240	(8) vs (6)	25.04	0.30
Total financials				
(1) CDCC	-40159			
(2) SDCC	-40111	(2) vs (1)	95.85	0.00
(3) SDCC-d	-39856	(3) vs (2)	510.40	0.00
(4) SDCC-t	-40105	(4) vs (2)	13.80	0.00
(5) DDCC	-40031	(5) vs (1)	161.75	0.00
(6) DDCC-d	-39810	(6) vs (3)	93.29	0.00
(7) ADCC	-40007	(7) vs (5)	48.17	0.00
(8) ADCC-d	-39791	(8) vs (6)	37.73	0.04

CDCC stands for the constant CC model
SDCC stands for the scalar DCC model
SDCC-d stands for the scalar DCC model with break in intercept from 1999 onwards
SDCC-t stands for the scalar DCC model with determistic trend in intercept
DDCC stands for the diagonal DCC model
DDCC-d stands for the diagonal DCC model with break in intercept from 1999 onwards
ADCC stands for the asymmetric diagonal DCC model
ADCC-d stands for the asymmetric diagonal DCC model with break in intercept from 1999 onwards

Table 5 (continued): Likelihood ratio tests of alternative DCC models

	Log Likelihood	H_0	LR test	p-value
Non-cyclical goods				
(1) CDCC	-37222			
(2) SDCC	-37214	(2) vs (1)	14.06	0.00
(3) SDCC-d	-37027	(3) vs (2)	374.55	0.00
(4) SDCC-t	-37214	(4) vs (2)	1.36	0.24
(5) DDCC	-37182	(5) vs (1)	65.78	0.01
(6) DDCC-d	-37012	(6) vs (3)	31.31	0.09
(7) ADCC	-37160	(7) vs (5)	42.57	0.01
(8) ADCC-d	-36995	(8) vs (6)	33.34	0.06
Non-cyclical services				
(1) CDCC	-31498			
(2) SDCC	-31473	(2) vs (1)	49.03	0.00
(3) SDCC-d	-31331	(3) vs (2)	284.72	0.00
(4) SDCC-t	-31469	(4) vs (2)	7.64	0.01
(5) DDCC	-31448	(5) vs (1)	49.31	0.03
(6) DDCC-d	-31317	(6) vs (3)	27.74	0.05
(7) ADCC	-31437	(7) vs (5)	23.78	0.13
(8) ADCC-d	-31308	(8) vs (6)	17.57	0.42
Information technology				
(1) CDCC	-26681			
(2) SDCC	-26648	(2) vs (1)	65.65	0.00
(3) SDCC-d	-26525	(3) vs (2)	245.29	0.00
(4) SDCC-t	-26638	(4) vs (2)	20.83	0.00
(5) DDCC	-26607	(5) vs (1)	81.27	0.00
(6) DDCC-d	-26506	(6) vs (3)	39.46	0.00
(7) ADCC	-26598	(7) vs (5)	18.33	0.15
(8) ADCC-d	-26498	(8) vs (6)	14.75	0.32
Resources				
(1) CDCC	-26958			
(2) SDCC	-26946	(2) vs (1)	25.69	0.00
(3) SDCC-d	-26833	(3) vs (2)	224.43	0.00
(4) SDCC-t	-26944	(4) vs (2)	2.81	0.09
(5) DDCC	-26891	(5) vs (1)	108.24	0.00
(6) DDCC-d	-26812	(6) vs (3)	42.85	0.00
(7) ADCC	-26890	(7) vs (5)	2.97	1.00
(8) ADCC-d	-26803	(8) vs (6)	17.30	0.30
Utilities				
(1) CDCC	-23017			
(2) SDCC	-23014	(2) vs (1)	5.36	0.07
(3) SDCC-d	-22959	(3) vs (2)	110.35	0.00
(4) SDCC-t	-23014	(4) vs (2)	0.28	0.60
(5) DDCC	-22998	(5) vs (1)	32.41	0.12
(6) DDCC-d	-22950	(6) vs (3)	17.99	0.16
(7) ADCC	-22991	(7) vs (5)	14.15	0.36
(8) ADCC-d	-22941	(8) vs (6)	18.05	0.16

CDCC stands for the constant CC model
SDCC stands for the scalar DCC model
SDCC-d stands for the scalar DCC model with break in intercept from 1999 onwards
SDCC-t stands for the scalar DCC model with determistic trend in intercept
DDCC stands for the diagonal DCC model
DDCC-d stands for the diagonal DCC model with break in intercept from 1999 onwards
ADCC stands for the asymmetric diagonal DCC model
ADCC-d stands for the asymmetric diagonal DCC model with break in intercept from 1999 onwards

Table 6: Comparison of the log likelihoods for different breakpoints between 1995 to 2002 for the scalar-dummy model

	1995	1996	1997	1998	1999	2000	2001	2002
World country model	-35930	-35881	-35883	-35869	**-35833**	-35860	-35834	-35915
World sector model	-11421	-11409	-11400	-11386	**-11381**	-11447	-11470	-11477
Euro area country model	-16614	-16592	-16587	-16568	**-16553**	-16556	-16576	-16611
Euro area sector model	-12997	-12965	-12960	-12958	**-12958**	-13035	-13075	-13082
Country/sector models								
Basic industries	-38633	-38616	-38624	-38631	**-38596**	-38613	-38603	-38645
Cyclical goods	-30088	-30082	-30095	-30106	-30101	-30085	-30087	**-30076**
Cyclical services	-38328	-38314	-38339	-38349	-38335	-38302	**-38273**	-38327
General industries	-38293	-38280	-38302	-38291	**-38275**	-38290	-38293	-38315
Total financials	-39910	-39885	-39889	-39864	-39857	-39850	**-39848**	-39884
Non-cyclical goods	-37034	**-36998**	-37010	-37010	-37027	-37033	-37007	-37043
Non-cyclical services	-31365	-31357	-31356	-31358	-31330	**-31311**	-31366	-31395
Information technology	-26580	-26572	-26569	-26559	-26524	-26490	**-26482**	-26549
Ressources	-26841	-26822	-26828	-26835	-26832	-26831	**-26819**	-26846
Utilities	-22963	-22957	-22957	-22952	-22959	-22961	**-22951**	-22958

Bold figures give the minimum Likelihood for each model

Table 7: X^2 tests of the DCC model prediction for portfolio variance

	CDCC	SDCC	SDCC-d	DDCC	DDCC-d	ADCC	ADCC-d
Equal weights portfolio							
World country model	1.07	1.04	1.04	1.04	1.04	1.04	1.03
World sector model	1.01	0.99	1.00	0.99	1.00	0.98	1.00
Euro area country model	1.08	1.07	1.04	1.04	1.04	1.03	1.04
Euro area sector model	1.01	1.00	1.00	1.00	1.00	0.99	1.00
Country/sector models							
Basic industries	1.05	1.03	1.03	1.03	1.02	1.03	1.02
Cyclical goods	1.11 **	1.03	1.03	1.04	1.03	1.02	1.01
Cyclical services	1.11 *	1.06	1.06	1.06	1.06	1.06	1.05
General industries	1.07	1.03	1.03	1.03	1.02	1.02	1.02
Total financials	1.12 **	1.06	1.06	1.06	1.06	1.05	1.05
Non-cyclical goods	1.08	1.04	1.04	1.04	1.03	1.02	1.02
Non-cyclical services	1.15 ***	1.10 *	1.06	1.10 *	1.06	1.07	1.05
Information technology	1.22 ***	1.12 **	1.07	1.12 **	1.06	1.10 *	1.05
Ressources	1.02	1.00	1.00	1.00	1.00	1.00	0.99
Utilities	1.05	0.99	0.99	0.99	0.99	0.97	0.97
Minimum variance portfolio							
World country model	1.40 ***	1.38 ***	1.37 ***	1.36 ***	1.35 ***	1.37 ***	1.36 ***
World sector model	1.31 ***	1.28 ***	1.25 ***	1.26 ***	1.25 ***	1.26 ***	1.25 ***
Euro area country model	1.47 ***	1.44 ***	1.28 ***	1.26 ***	1.26 ***	1.26 ***	1.26 ***
Euro area sector model	1.50 ***	1.39 ***	1.34 ***	1.38 ***	1.32 ***	1.37 ***	1.33 ***
Country/sector models							
Basic industries	1.21 ***	1.20 ***	1.16 ***	1.19 ***	1.16 ***	1.19 ***	1.15 ***
Cyclical goods	1.34 ***	1.28 ***	1.26 ***	1.25 ***	1.24 ***	1.24 ***	1.22 ***
Cyclical services	1.30 ***	1.29 ***	1.24 ***	1.25 ***	1.21 ***	1.24 ***	1.21 ***
General industries	1.29 ***	1.26 ***	1.22 ***	1.25 ***	1.21 ***	1.24 ***	1.21 ***
Total financials	1.40 ***	1.39 ***	1.37 ***	1.37 ***	1.33 ***	1.35 ***	1.32 ***
Non-cyclical goods	1.14 **	1.11 **	1.11 **	1.11 **	1.12 **	1.11 **	1.11 **
Non-cyclical services	1.23 ***	1.21 ***	1.21 ***	1.20 ***	1.21 ***	1.19 ***	1.20 ***
Information technology	1.42 ***	1.37 ***	1.35 ***	1.39 ***	1.35 ***	1.35 ***	1.33 ***
Ressources	1.11 **	1.06	1.04	1.06	1.05	1.06	1.04
Utilities	1.04	1.00	0.99	1.00	0.98	0.99	0.98
Maximum utility portfolio low risk aversion							
World country model	1.01	1.02	1.04	1.04	1.05	1.04	1.06
World sector model	1.09 *	1.00	0.98	1.00	0.98	1.01	0.99
Euro area country model	0.96	0.97	0.97	0.98	0.99	0.99	1.00
Euro area sector model	1.01	1.04	0.99	1.05	1.00	1.06	1.01
Country/sector models							
Basic industries	1.01	1.00	1.00	0.99	1.01	1.01	1.01
Cyclical goods	1.05	1.00	1.01	0.98	1.01	1.01	1.03
Cyclical services	1.00	0.99	0.99	1.00	0.99	0.99	0.99
General industries	1.03	1.02	1.02	1.02	1.02	1.03	1.04
Total financials	1.05	1.04	1.06	1.04	1.06	1.04	1.06
Non-cyclical goods	1.06	1.04	1.04	1.04	1.04	1.06	1.05
Non-cyclical services	1.09	1.05	1.01	1.05	1.01	1.07	1.02
Information technology	1.15 ***	1.01	0.99	1.03	0.98	1.06	1.00
Ressources	1.04	0.99	1.00	0.99	1.00	0.99	1.01
Utilities	1.35 ***	0.99	1.00	0.99	1.00	0.99	1.01

See the legend below.

Table 7 (continued): X² tests of the DCC model prediction for portfolio variance

	CDCC	SDCC	SDCC-d	DDCC	DDCC-d	ADCC	ADCC-d
Maximum utility portfolio medium risk aversion							
World country model	1.07	1.08	1.10 *	1.10 *	1.10 *	1.10 *	1.12 **
World sector model	1.12 **	1.00	0.99	1.01	0.99	1.02	1.00
Euro area country model	1.19 ***	1.18 ***	1.14 **	1.12 **	1.15 ***	1.12 **	1.13 **
Euro area sector model	1.14 ***	1.11 **	1.06	1.12 **	1.05	1.13 **	1.06
Country/sector models							
Basic industries	1.04	1.02	1.01	1.00	1.01	1.02	1.02
Cyclical goods	1.10 *	1.06	1.06	1.05	1.05	1.05	1.06
Cyclical services	1.01	1.01	1.00	1.01	1.00	1.01	1.01
General industries	1.07	1.05	1.06	1.05	1.05	1.06	1.07
Total financials	1.08	1.07	1.08	1.07	1.07	1.06	1.07
Non-cyclical goods	1.08	1.06	1.04	1.06	1.05	1.07	1.05
Non-cyclical services	1.12 **	1.09 *	1.07	1.09	1.07	1.10 *	1.07
Information technology	1.20 ***	1.10 *	1.09	1.12 **	1.08	1.14 **	1.09 *
Ressources	1.07	1.01	1.01	1.01	1.02	1.01	1.02
Utilities	1.35 ***	0.99	1.00	1.00	1.00	1.00	1.01
Maximum utility portfolio high risk aversion							
World country model	1.31 ***	1.30 **	1.30 **	1.30 **	1.28 **	1.31 **	1.30 **
World sector model	1.25 ***	1.15 **	1.14 **	1.15 **	1.14 **	1.15 **	1.14 *
Euro area country model	1.47 ***	1.45 ***	1.28 ***	1.25 ***	1.25 ***	1.25 ***	1.26 ***
Euro area sector model	1.43 ***	1.32 ***	1.26 ***	1.31 ***	1.25 ***	1.31 ***	1.25 ***
Country/sector models							
Basic industries	1.15 ***	1.14	1.10	1.12	1.09	1.12	1.10
Cyclical goods	1.28 ***	1.23	1.21	1.21	1.19	1.19	1.18
Cyclical services	1.16 ***	1.16 **	1.13 *	1.14 **	1.11 *	1.13 *	1.11
General industries	1.23 ***	1.20	1.17	1.19	1.17	1.18	1.17
Total financials	1.26 ***	1.25 **	1.25 **	1.24 *	1.20 *	1.22 *	1.20 *
Non-cyclical goods	1.13 **	1.10	1.08	1.10	1.09 *	1.10	1.09
Non-cyclical services	1.21 ***	1.18	1.18	1.18	1.18	1.17	1.17
Information technology	1.37 ***	1.31 ***	1.31 ***	1.33 ***	1.30 ***	1.31 ***	1.30 ***
Ressources	1.11 **	1.05	1.04	1.05	1.05	1.05	1.04
Utilities	1.20 ***	1.00	0.99	1.00	0.99	1.00	1.00

CDCC stands for the constant CC model
SDCC stands for the scalar DCC model
SDCC-d stands for the scalar DCC model with break in intercept from 1999 onwards
DDCC stands for the diagonal DCC model
DDCC-d stands for the diagonal DCC model with break in intercept from 1999 onwards
ADCC stands for the asymmetric diagonal DCC model
ADCC-d stands for the asymmetric diagonal DCC model with break in intercept from 1999 onwards

* indicates significantlly different from 1 at the 10% level. ** indicates significantlly different from 1 at the 5% level. *** indicates significantlly different from 1 at the 1% level.

Table 8: Average conditional correlation of each country/sector with all other countries/sectors

	1990-2003	1990-1998	1999-2003	change
World country model				
Austria	0.37	0.41	0.31	-0.10
Belgium	0.45	0.45	0.46	0.01
Denmark	0.42	0.41	0.44	0.04
France	0.52	0.47	0.61	0.13
Germany	0.53	0.49	0.61	0.12
Ireland	0.43	0.42	0.44	0.02
Italy	0.40	0.32	0.56	0.24
Netherlands	0.54	0.52	0.58	0.06
Spain	0.49	0.46	0.55	0.09
Greece	0.28	0.26	0.32	0.06
Portugal	0.39	0.37	0.42	0.06
Finland	0.39	0.37	0.43	0.07
Sweden	0.49	0.45	0.56	0.11
Switzerland	0.48	0.47	0.50	0.03
Norway	0.43	0.39	0.50	0.10
United Kingdom	0.49	0.46	0.56	0.10
Australia	0.37	0.32	0.47	0.15
Hong Kong	0.35	0.31	0.42	0.12
Japan	0.29	0.30	0.28	-0.01
New Zealand	0.33	0.33	0.33	0.01
Singapore	0.36	0.34	0.40	0.07
Canada	0.38	0.33	0.49	0.16
Mexico	0.31	0.27	0.39	0.12
United States	0.37	0.32	0.46	0.14
World sector model				
Basic industries	0.71	0.77	0.59	-0.18
Cyclical goods	0.69	0.74	0.58	-0.16
Cyclical services	0.76	0.80	0.67	-0.13
General industries	0.76	0.80	0.68	-0.12
Total financials	0.56	0.60	0.49	-0.10
Non-cyclical goods	0.59	0.66	0.46	-0.20
Non-cyclical services	0.65	0.73	0.50	-0.23
Information technology	0.52	0.57	0.43	-0.14
Ressources	0.73	0.76	0.66	-0.10
Utilities	0.57	0.64	0.43	-0.21

Conditional correlations estimated using the ADCC-d model with break in the intercept from 1999 onwards

Table 8 (continued): Average conditional correlation of each country/sector with all other countries/sectors.

	1990-2003	1990-1998	1999-2003	change
Euro area country model				
Austria	0.44	0.48	0.35	-0.13
Belgium	0.54	0.54	0.52	-0.02
France	0.58	0.54	0.65	0.11
Germany	0.60	0.57	0.66	0.08
Ireland	0.46	0.46	0.46	0.00
Italy	0.46	0.37	0.62	0.24
Netherlands	0.59	0.57	0.63	0.06
Spain	0.55	0.52	0.62	0.10
Greece	0.34	0.33	0.36	0.03
Portugal	0.47	0.45	0.50	0.05
Finland	0.41	0.40	0.42	0.02
Euro area sector model				
Basic industries	0.73	0.79	0.61	-0.18
Cyclical goods	0.69	0.75	0.59	-0.16
Cyclical services	0.74	0.80	0.63	-0.16
General industries	0.75	0.81	0.65	-0.15
Total financials	0.74	0.78	0.66	-0.12
Non-cyclical goods	0.68	0.79	0.48	-0.31
Non-cyclical services	0.66	0.75	0.48	-0.27
Information technology	0.60	0.67	0.47	-0.19
Ressources	0.54	0.62	0.39	-0.23
Utilities	0.62	0.69	0.49	-0.20

Conditional correlations estimated using the ADCC-d model with break in the intercept from 1999 onwards

Table 9: Sharpe ratios associated with alternative portfolios

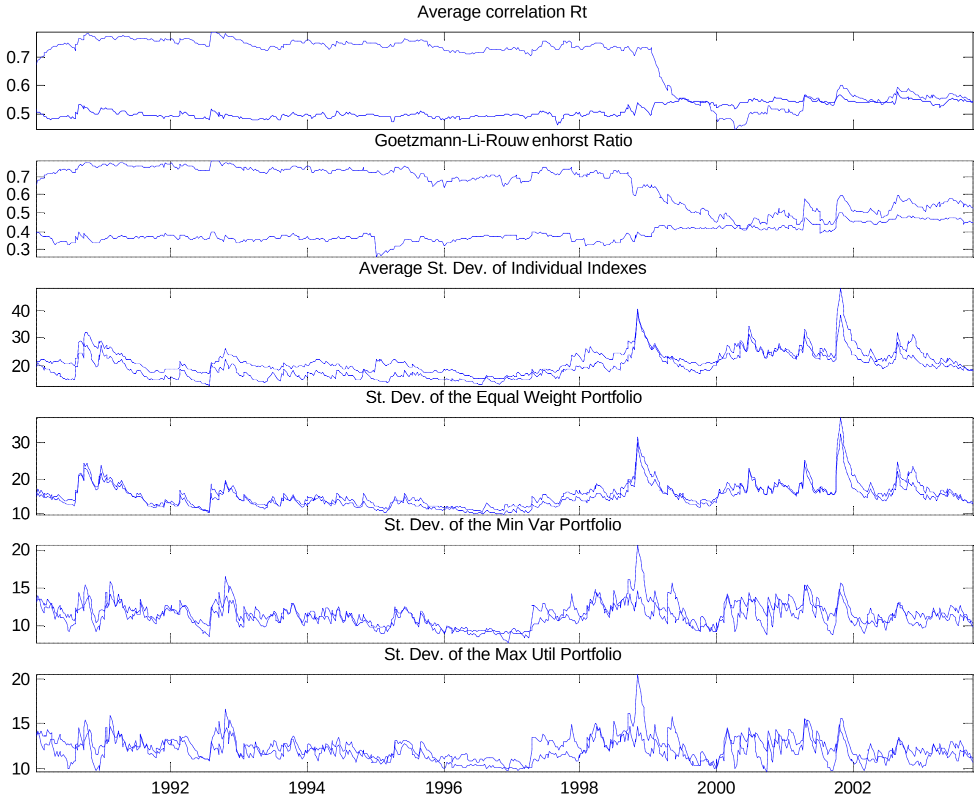
	minimum variance	max utility (high ra)	max utility (low ra)	equal weighted
World country model	0.56	0.90	1.30	0.36
World sector model	0.34	0.58	1.10	0.29
Euro area country model	0.35	0.43	0.75	0.30
Euro area sector model	0.50	0.64	1.02	0.35
Country/sector models				
Basic industries	0.26	0.46	1.03	0.18
Cyclical goods	0.28	0.47	1.13	0.20
Cyclical services	0.31	0.76	1.56	0.27
General industries	0.18	0.44	1.19	0.07
Total financials	0.51	0.92	1.48	0.31
Non-cyclical goods	0.63	0.93	1.28	0.49
Non-cyclical services	0.40	0.54	0.93	0.32
Information technology	0.06	0.35	1.51	0.28
Ressources	0.54	0.71	1.01	0.31
Utilities	0.61	0.84	1.08	0.59

minimum variance stands for minimum variance portfolio
max utility (high ra) stands for maximum utility portfolio for a highly risk-averse investor
max utility (low ra) stands for maximum utility portfolio for a low risk-averse investor
equal weighted stands for equal weighted portfolio

Figure 1: Diversification measures for world country and world sector models

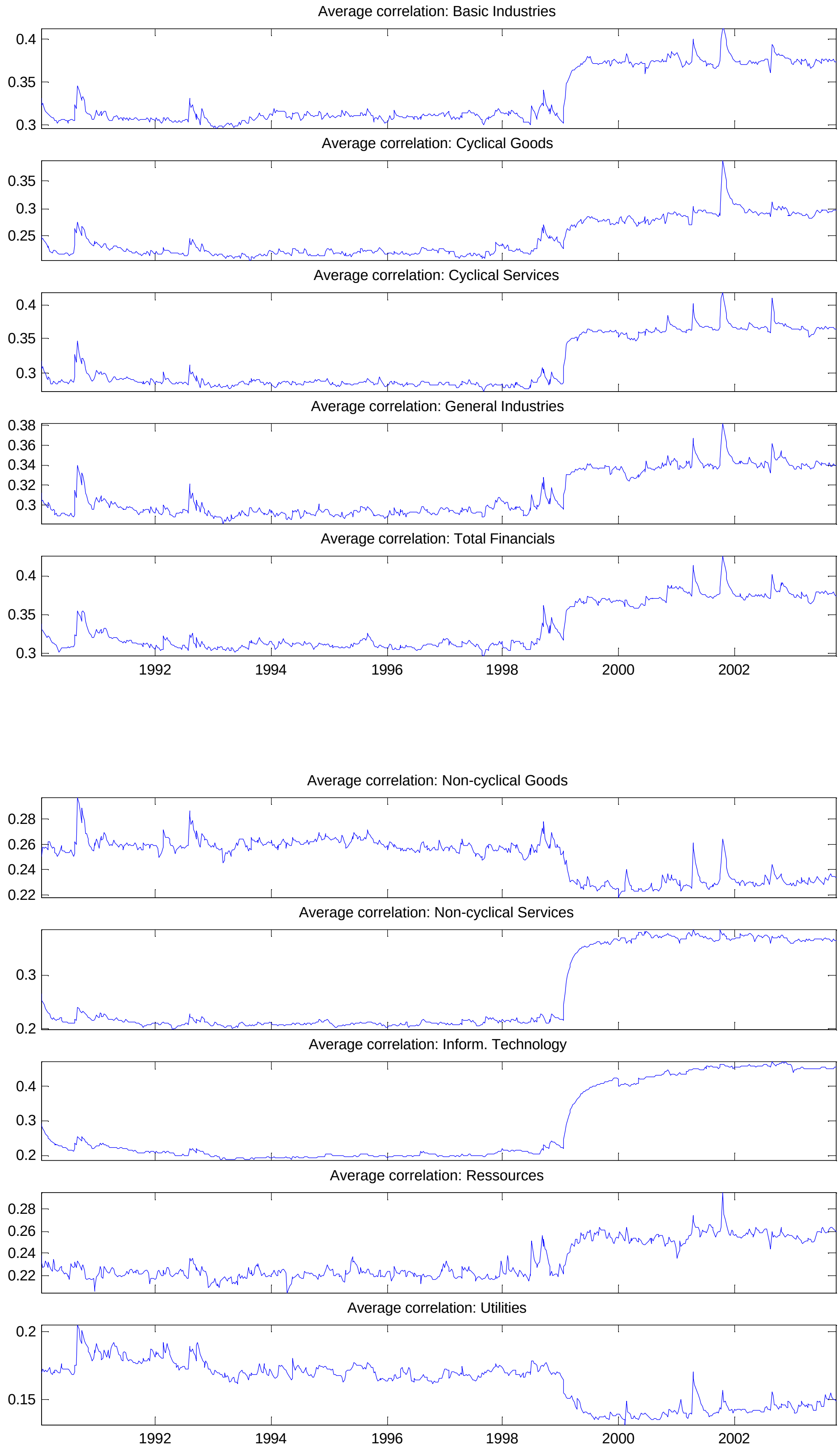
Conditional correlations estimated from the asymmetric DCC model with a dummy break since 1999 onwards. Goetzmann-Li-Rouwenhorst variance ratio measure of diversification benefits. Anualized standard deviations of the weekly portfolio returns. Straight lines represent the results for the country model, dashed lines respresent the result for the sector model. The maximum uitlity portfolio is evaluated at the medium risk aversion.

Figure 1 (continued): Diversification measures for euro area country and euro area sector models



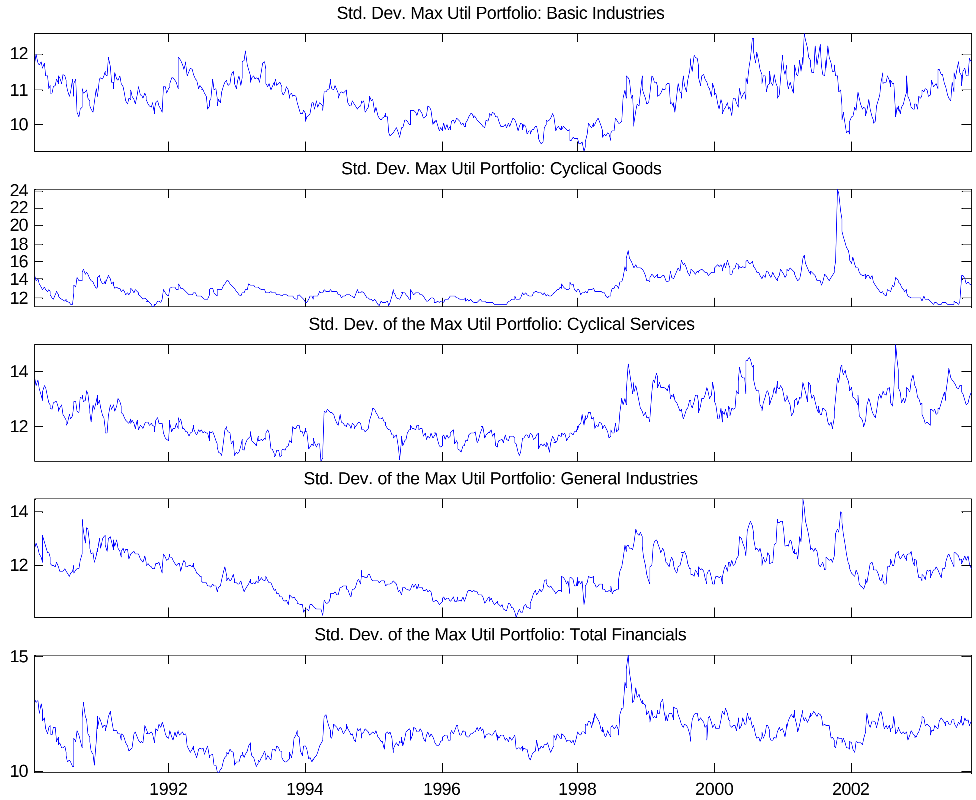
Conditional correlations estimated from the asymmetric DCC model with a dummy break since 1999 onwards. Goetzmann-Li-Rouwenhorst variance ratio measure of diversification benefits. Anualized standard deviations of the weekly portfolio returns. Straight lines represent the results for the country model, dashed lines respresent the result for the sector model. The maximum uitlity portfolio is evaluated at the medium risk aversion.

Figure 2: International conditional correlation for the country/sector models



Conditional correlations estimated from the asymmetric DCC model with a dummy break since 1999 onwards.

Figure 3: Volatility of the maximum utility portfolio for the country/sector models



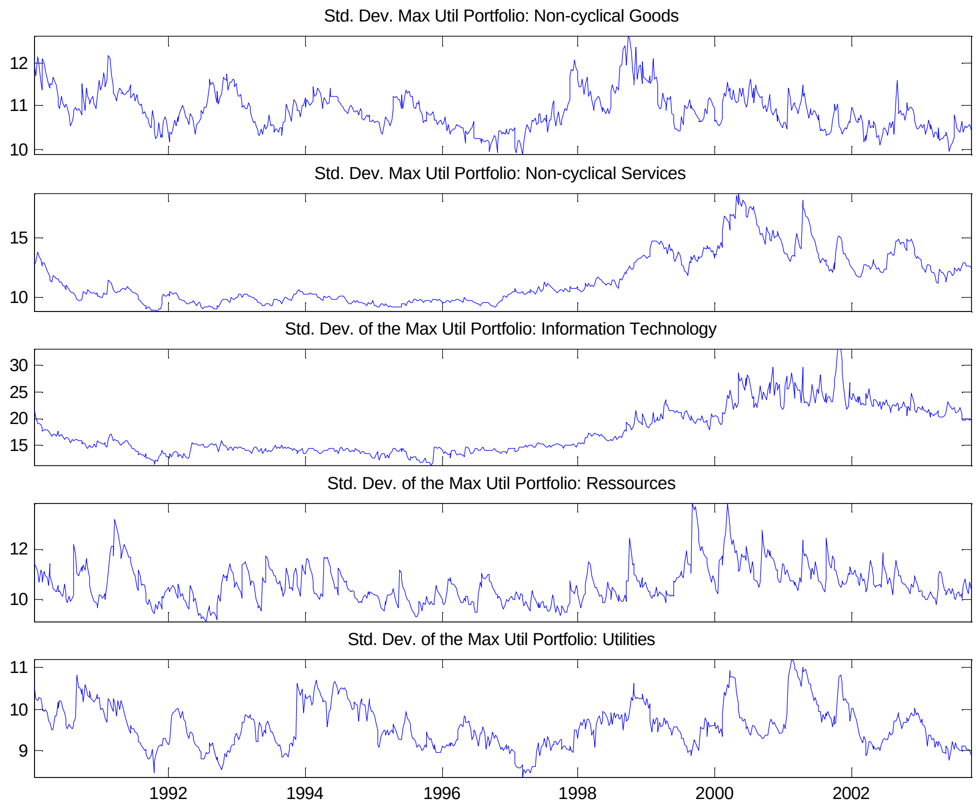


Figure 4: Sharpe ratio for world country and world sector model

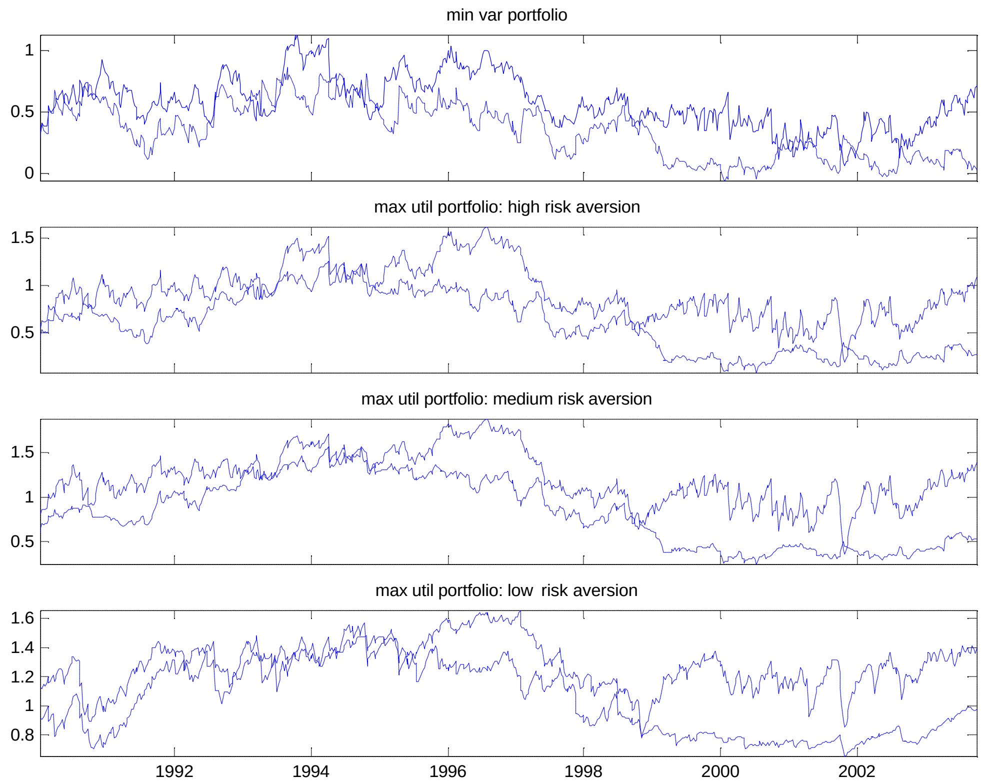
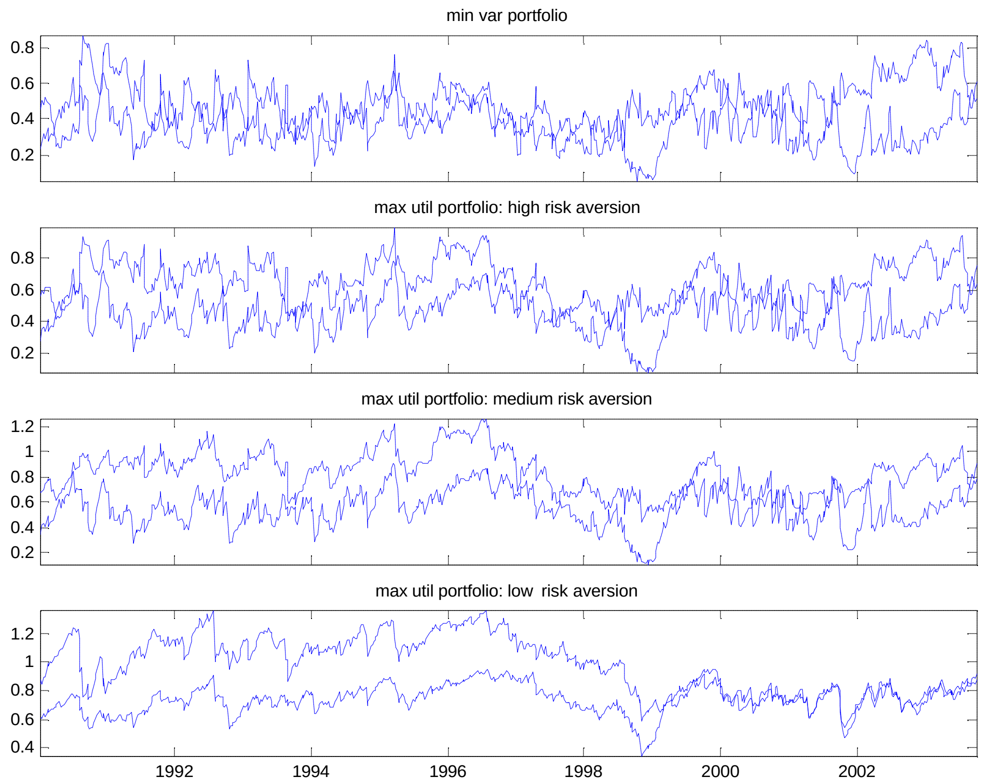


Figure 4 (continued): Sharpe ratio for euro area country and euro area sector model



Straight lines represent the results for the country model, dashed lines respresent the result for the sector model.

Figure 5: Expected utility from country portfolio minus expected utility from sector portfolio (for the world and euro area models)

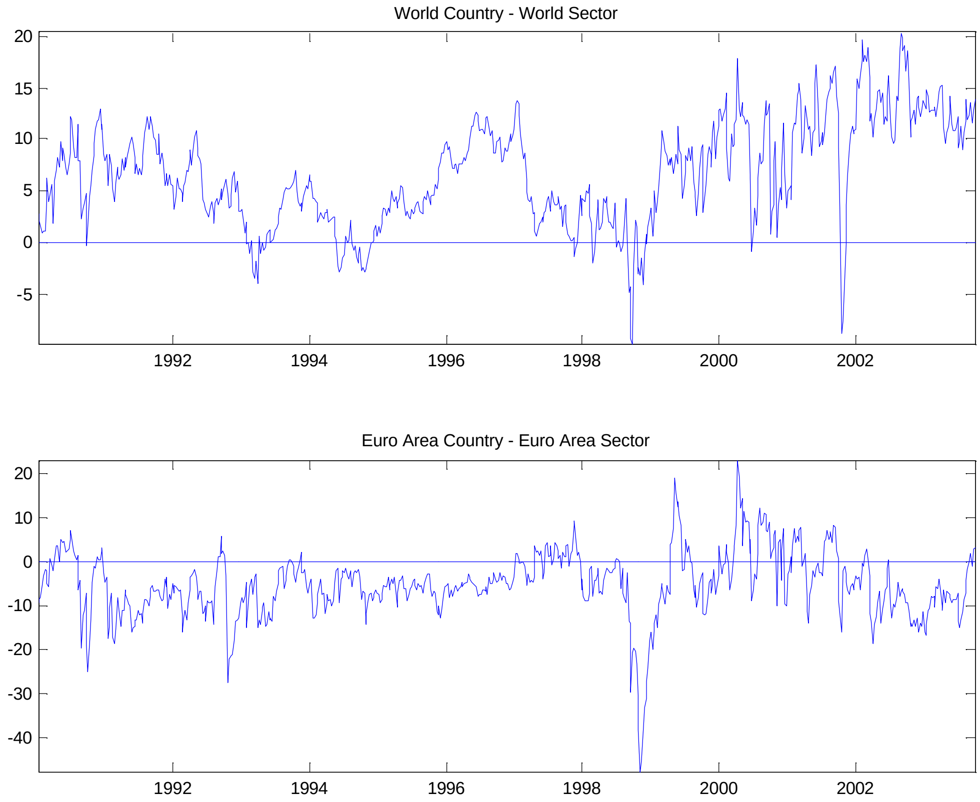
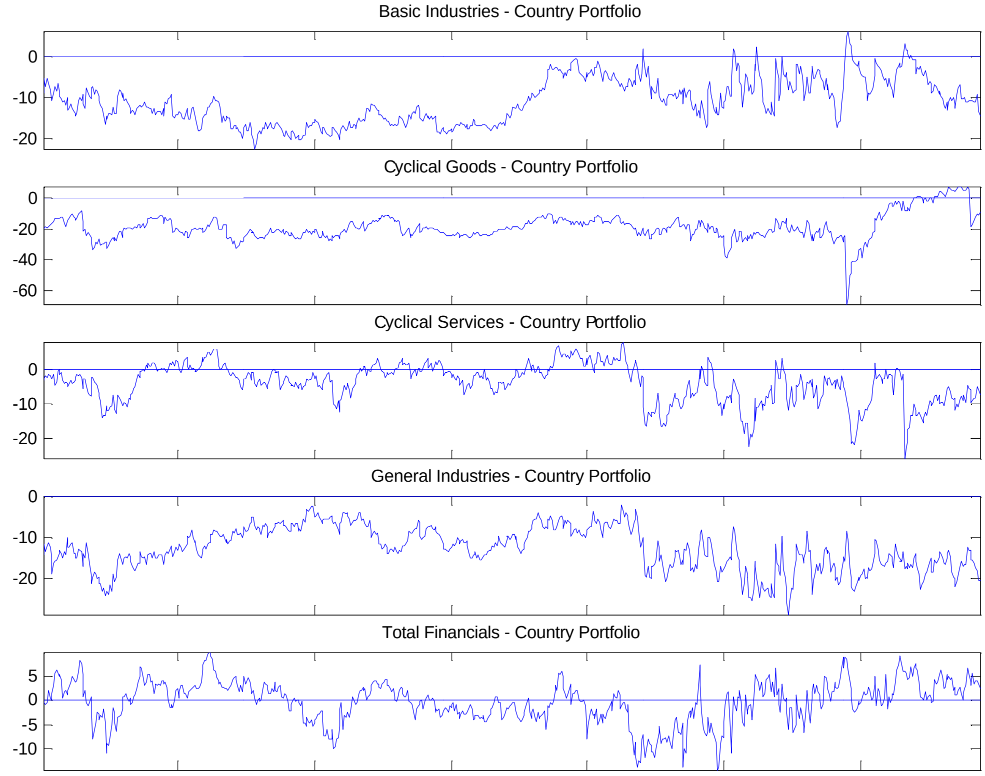


Figure 6: Expected utility from international diversification for country/sector models minus world country Model



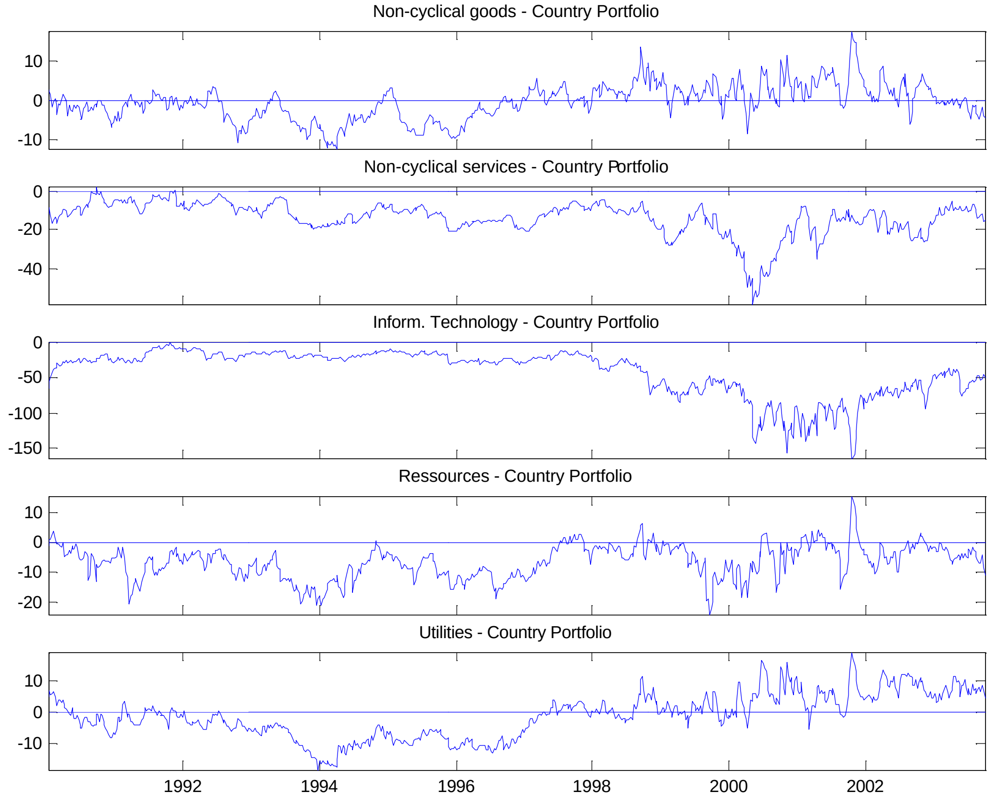
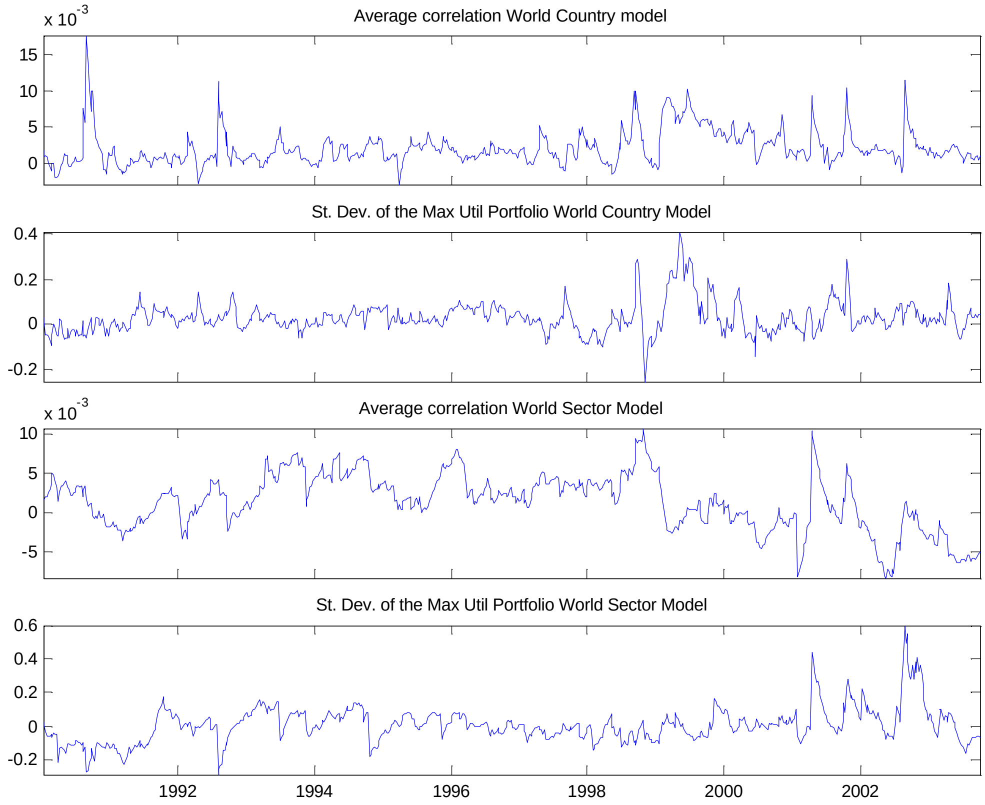


Figure 7: Impact of asymmetry on the average conditional correlation and portfolio volatility for the world country model and the world sector model



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