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Time-Varying Spillover Effects on Sectoral Equity Returns

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ABSTRACT

In this paper, we investigate the integration of the Euro- and US-wide sector equity indices by focusing on the return, volatility, and trend spillover effects of local and global shocks. We explore that unlike volatility spillovers, return spillovers are not significant enough to explain sector equity returns. Moreover, we are able to show that when the trend is incorporated into the volatility spillover analysis, a number of sector equity indices tend to react similarly to local and global shocks. Following this path, we arrive at four major sector groups: production and industry; consumer goods and services; financial; and technology, media, and telecommunication across Euro- and US-wide sector equity indices.

I. INTRODUCTION

A good motive for both investors and consumers to have cross-border assets is the potential for portfolio risk diversification, which can be enhanced if investors possess a good understanding of the origins and drivers of local markets, volatility, and cross-market correlations. Previous research has shown a strong positive relationship between the sensitivity of local market returns to common shocks and the degree of financial integration. For example, studies by Bekaert and Harvey (1997), Stulz and Karolyi (2001), and Hardouvelis et al. (2006) focus on the effect of global risk factors on asset prices across countries, while Adjaoute and Danthine (2003), Baele et al. (2004), Baele (2005), and Bekaert et al. (2005) investigate the cross correlations of equity markets.

At the regional level, financial market integration seems to be strengthened mostly via the formation of free-trade areas or currency unions. It has been shown that the formation of currency unions reduces country-specific risk factors, as exchange rate uncertainty is eliminated and the countries that would become members of the unions boost investors' confidence (Baele 2005). However, the risk premia differences in equity markets depend on the relative degree of integration of the overall markets. In theory, under perfect financial market integration, the equity risk premium is determined solely by the risk factors common to all countries (global or local), and not by a combination of local and global factors, as is the case under partial integration. Using this theoretical framework, Baele (2005) shows that differences in equity returns in the Euro markets are driven by the magnitude of the reaction of these markets to common shocks. Of particular interest is the impact of the integration of the equity markets on returns and the volatility spillover effects arising from local and global shocks. Following Bekaert and Harvey (1997), several studies, including Lin et al. (1994), Ng (2000), Fratzscher (2002), Baele (2005), Kim et al. (2005), Fedorova and Saleem (2010), and Yilmaz (2010) measure the integration between national equity markets, and find significant return and volatility spillover effects resulting from local and global shocks. All these studies suggest that the effect of country-specific factors on the equity returns has declined over time, while the correlation between local and global market returns has increased, substantiating a rise in the degree of national equity market integration. Although the debate between investors and financial analysts as to whether stock market diversification should be sectoral or national is still ongoing, the literature has little to say when it comes to measuring the integration of sectoral stock indices.[1]

Early empirical research on stock market integration has focused on the conditional volatility implied by ARCH/GARCH models introduced by Engle (1982) and Bollerslev (1986). Subsequently, spillover analysis was developed by Engle et al. (1990). Lin et al. (1994) first used this framework to investigate the volatility spillover effects between the US and the Japanese stock markets. Since then, the integration of the equity markets and the effects of return and volatility spillovers on markets have been studied intensely using national stock price indices. These include the works of Fratzscher (2002), Baele (2005) and Balli and Balli (2011) for the European stock markets, Bekaert and Harvey (1997) for emerging stock markets, and Ng (2000) on the volatility spillover effects in various Pacific Basin stock markets from Japan (local effects) and the United States (global effects). Along the same lines, Fedorova and Saleem (2010) look into the linkages between Eastern European emerging equity markets and Russia from the perspective of volatility spillovers. Whereas recently, Yilmaz (2010) documented strong return spillover effects in the Eastern Asian markets.

1 Many of these studies do not offer a consensus as to the 'true effect' of national economy's industrial structure on equity markets. For example, Heston and Rouwenhorst (1994)'s study shows that industrial structure explains little of the cross-sectional difference in a country return's volatility, and the low correlation between countries exists because of country-specific variations. According to Adjaoute and Danthine (2001a, 2001b), the dominance of country effects has diminished, but industry factors are still less important than country factors. On the other hand, Roll (1992) indicates that the industrial structure of the domestic economy is essential in explaining the correlations between sectoral returns. Cavaglia et al. (2000), and Isakov and Sonney (2002) confirm that industry factors closely match country-specific factors and anticipate that industry factors will become even more important in the future. Thus far, the literature has shown that up until the end of the 1990s, country-specific factors were dominant in explaining stock returns; however, more recent studies have shown that industry (sectoral) effects are increasing in importance.

Despite the richness of the strand of research on return and volatility spillover effects at the cross-country level, the literature on spillover effects using sectoral equity indices is quite sparse. It may make sense to believe that the magnitude of the reaction of each sector to local and global shocks is very similar, and that therefore, there is no sensible justification for focusing on the spillover effects on sectoral returns. However, this may not be totally correct: the works of Kraus (2001) and Brooks and Negro (2004) have shown that not all sectors in all equity markets respond similarly to local and common shocks. Therefore, careful attention must be paid to the reactions of sectoral indices' returns when the objective is to investigate equity market integration. These linkages are fundamental in understanding investors' decisions to diversify their portfolios across sectors and countries. Since the Euro and the US regions are home to the most important financial centers and are industrially well diversified, it is quite sensible to scrutinize the integration of the Euro-wide and the US-wide sector equity indices via return and volatility spillovers to get a better appreciation of the mean–variance frontiers that are important to investors.

We use the GARCH (1, 1) process to model the return and volatility of the sector equity indices, and measure the magnitudes of the spillovers of local and global shocks on the volatility of the Euro-wide and US-wide sector equity indices. We compute the return and volatility spillovers following Bekaert and Harvey (1997), Ng (2000), and Bekaert et al. (2005). We use two types of time-varying spillover models. First, to gauge the effects at the inception of the European Monetary Union (EMU), we estimate a Euro spillover model for Euro-wide sector indices. Our findings show that the spillovers of global shocks have declined sharply after the introduction of the Euro. This finding supports Hardouvelis et al. 's (2006) claim that European stock market returns are driven by Euro-wide risk factors instead of global factors.[2] We also find that the aggregate Euro index exerts a variable impact on the sectoral equity indices, and that the aggregate Euro index is increasingly effective in explaining volatility only in financial sector groups such as banking, financial services, and insurance. However, the same could not be argued with respect to volatility in sector equity indices such as automotive and parts, consumer goods, food and beverages, personal goods, health care, and retail services; for these, the aggregate Euro index effect decreases considerably following the state of the Euro.

Second, we use trend spillover modeling to measure the pace of integration among Euro and US-wide sector equity indices. With this approach, we are able to assess not only the magnitude but also the trend and direction of integration of the sectors.[3] Our results show that a number of sector equity indices react similarly to both local and global shocks for both the Euro area and the US markets upon inspecting the signs and magnitudes of these shocks. This finding

2 Balli (2009) used the similar methodology for the European bond markets and found similar results.

3 Christiansen (2007) used a similar model for modeling the volatility spillovers of European bond markets.

suggests that sector indices are likely to form clusters and therefore can be categorized on the basis of their reactions to spillovers. Accordingly, we combine the sectors in relation to production and industry; consumer goods and services; financial; and technology, media, and telecommunication (TMT). We then analyze the response patterns of each group to local and global spillover effects for neither the Euro area nor the US area are the patterns similar. For the Euro-wide financial sectors, local volatility spillover effects display an upward trend and are highly significant statistically over the sample period, while global volatility spillover effects have been declining. By contrast, US financial sector indices have been increasingly perturbed by global shocks, as demonstrated by the upward trend over the same period.

The volatility spillovers of local shocks on Euro-wide production and industry sector groups are statistically significant, and have a downward sloping trend, whereas those of global shocks are also statistically significant but with an upward sloping trend. For the United States, we find the opposite volatility spillover effects of local shocks but similar effects of global shocks on the production and industry sector group, in comparison with the Euro area. However, when we consider impacts on the consumer goods and services sector group's returns instead, we find both the volatility spillover effects and the trend (negative) of local shocks to be statistically significant for both the US- and the Euro-wide sector indices. Global volatility spillovers, by contrast, are not significant for the Euro-wide sector indices but significant for the US-wide sector indices. Overall, these results suggest that equity market integration is not uniform across sectors for the two major economic blocs considered, whether we rely on return/volatility or trend spillover models. The trends are dissimilar where the responses of sector equity indices to local shock spillovers are synchronized. Some sectors are influenced by global shocks while others are not.

II. DATA AND DESCRIPTIVE STATISTICS

We use weekly Euro- and US-wide sector equity indices from DataStream and the Dow Jones STOXX database. The Euro-wide sector equity indices cover Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, and Spain. The data set includes stock prices for 17 leading sectors and over 300 initial public offerings (IPOs) of stocks for the European and the US markets.[4] The sector equity indices' returns span from 1992 to 2009. Aggregate Euro and US equity indices were also extracted from DataStream. Accordingly, the aggregate world equity index, namely 'world,' is a combination of all developed countries' stock market prices from DataStream. The 'world' can be seen as a broad market benchmark that covers 45 countries and represents 93% of the market capitalization of emerging markets, 97% of the market capitalization of Europe, and 93% of the market capitalization of all other developed markets on a country-by-country basis.

4 The names of the sectors are listed in Table 1.

Table 1 The list of sector equity indices

Production and industry sectors	
	Automotive and parts (AUT)
	Basic resources (BSRS)
	Industrial goods (IDS)
	Oil and gas (OIL)
	Utilities (UTI)
Consumer goods and services sectors	
	Consumer goods (CNS)
	Food and beverages (FOOD)
	Health care (HTH)
	Personal goods (PRHGD)
	Retail services (RTL)
Financial sectors	
	Banking (BNK)
	Financial institutions (FIN)
	Financial services (FNSR)
	Insurance (INSR)
TMT	
	Technology (TECH)
	Media (MED)
	Telecommunications (TEL)

Table 2 presents the statistics for the returns of the Euro- and US-wide sector equity indices. The average weekly returns of the Euro-wide sector indices range from 0.07% (automotive and parts) to 0.18% (retail services); for the US sectors, the range is between 0.02% (automotive and parts) and 0.21% (technology). The variability in the returns is much more dispersed across sectors; the standard deviation of the weekly returns of the Euro-wide sector indices falls between 1.44% (consumer goods) and 4.26% (technology). For the US, the same measure lies between 2.14% (food and beverages) and 4.38% (basic resources).

Generally, as the average return increases, the sectoral equity return tends to become more variable. The return distributions of both the Euro- and US-wide equity indices are skewed to the left (except for the automotive and parts sector in the Euro-wide region), while all the distributions show excess kurtosis. Accordingly, the Jarque and Bera (1980) test rejects normality for all the series. The last two columns of the Table 2 report the Ljung and Box (1978) portmanteau test statistics Q and Q^2 (for the squared data) to test for first- and second-moment dependencies in the distribution of the sector equity indices.[5] For most

5 Ljung and Box (1978) examines if any of a group of autocorrelations within a time series is different from zero. The Ljung–Box test is based on the autocorrelation plot. However, instead of testing randomness at each distinct lag, it tests the 'overall' randomness based on a number of lags. The null hypothesis is that there is no serial correlation among the series.

Table 2 Descriptive statistics for sector equity indices

	Mean	SD	Skew	Kurt	Q(1)	Q(4)	$Q^2(1)$	$Q^2(4)$
Euro-wide sector equity indices								
AUT	0.07	3.98	0.08	26.68	0.14‡	0.03	0.52‡	0.21‡
BSRS	0.13	3.61	–0.81	10.93	0.04‡	0.04‡	0.35‡	0.17‡
IDS	0.12	2.95	–0.69	6.87	0.03†	0.02‡	0.34‡	0.07‡
OIL	0.15	2.92	–0.80	6.92	–0.01	0.01*	0.42‡	0.16‡
UTI	0.17	2.43	–1.01	10.83	0.07‡	0.03‡	0.25‡	0.11‡
CNS	0.11	2.52	–0.61	6.73	0.08‡	0.03‡	0.36‡	0.11‡
FOOD	0.16	2.16	–0.56	6.48	0.06	0.03	0.26‡	0.12‡
HTH	0.16	2.22	–0.46	6.35	–0.03	–0.06‡	0.16‡	0.06‡
PRHGD	0.08	1.44	–0.29	5.35	0.01	–0.02	0.20‡	0.14‡
RTL	0.18	2.59	–0.57	7.49	0.05†	–0.02‡	0.37‡	0.12‡
BNK	0.08	3.29	–0.72	10.15	0.03‡	0.04‡	0.51‡	0.23‡
FIN	0.08	3.00	–0.63	8.49	0.05†	0.04‡	0.44‡	0.21‡
FNSR	0.08	2.37	–0.75	6.93	0.07†	0.01‡	0.36‡	0.10‡
INSR	0.07	3.33	–0.45	8.02	0.06†	0.07‡	0.29‡	0.21‡
TECH	0.17	4.26	–0.32	5.60	–0.03‡	0.01*	0.15‡	0.28‡
MED	0.10	3.02	–0.25	7.55	0.05‡	–0.03‡	0.26‡	0.21‡
TEL	0.16	3.33	–0.19	5.23	0.05‡	0.05‡	0.13‡	0.20‡
US-wide sector equity indices								
AUT	0.02	3.83	–0.44	11.32	0.02	0.07‡	0.25‡	0.11‡
BSRS	0.09	4.38	–0.72	20.48	0.14‡	0.06‡	0.51‡	0.27‡
IDS	0.15	2.82	–0.89	11.11	–0.05†	0.02‡	0.28‡	0.14‡
OIL	0.16	3.20	–0.67	10.62	0.16‡	0.04*	0.50‡	0.11‡
UTI	0.06	2.40	–1.12	11.19	0.03‡	0.05‡	0.25‡	0.09‡
CNS	0.08	2.64	–0.74	9.50	–0.01	0.01‡	0.09‡	0.08‡
FOOD	0.13	2.14	–0.76	9.66	–0.04	0.01	0.10‡	0.06‡
HTH	0.14	2.18	–1.13	11.04	0.07‡	–0.02‡	0.18‡	0.02‡
PRHGD	0.14	2.33	–1.40	14.16	0.08‡	0.01‡	0.13‡	0.11‡
RTL	0.16	3.14	–0.29	6.80	–0.06†	0.05‡	0.18‡	0.17‡
BNK	0.09	4.19	–1.33	21.41	0.21‡	0.11‡	0.43‡	0.10‡
FIN	0.12	3.48	–1.30	25.08	0.18†	0.06‡	0.33‡	0.05‡
FNSR	0.16	3.70	–0.72	16.59	0.18†	–0.05‡	0.35‡	0.05‡
INSR	0.13	3.09	–0.97	25.82	0.11‡	0.01‡	0.32‡	0.01‡
TECH	0.21	3.86	–0.61	5.46	0.07‡	0.01†	0.21‡	0.12‡
MED	0.10	2.90	–0.51	11.48	–0.03‡	0.04‡	0.35‡	0.08‡
TEL	0.04	3.07	–0.71	20.44	0.10‡	0.06‡	0.24‡	0.16‡

Notes: The table reports the summary statistics for the weekly returns (in %) of the Euro- and US-wide sector equity indices. The following statistics are reported: mean, standard deviation (SD), skewness (Skew), kurtosis (Kurt), autocorrelations of orders 1 and 4 ($Q(1)$-$Q(4)$), and autocorrelations of the squared time series of orders 1 and 4 ($Q^2(1)$ and $Q^2(4)$). *, †, and ‡indicate that the Ljung and Box (1978) test statistic is significant at the 10%, 5%, and 1% level, respectively.

of the sector equity indices, the Q statistic is significant, suggesting that sector equity indices are serially correlated. The Q^2 statistic is significant for all sectors, providing evidence of strong second-moment dependencies (conditional heteroskedasticity) in the distribution of the sector equity indices.

III. THE GARCH MODEL

We compute the return and volatility spillovers following Bekaert and Harvey (1997), Ng (2000), and Bekaert et al. (2005). We consider both the mean and the volatility spillover effects of the aggregate Euro and aggregate world index in building the empirical model for the sector equity indices. First, we present a univariate AR-GARCH model for the returns of the aggregate Euro and world equity indices. The conditional return of the aggregate Euro equity index (R_{eu}) and the aggregate world equity index (R_w) are assumed to follow an AR(1) process as follows:

$$R_{eu,t} = a_{eu} + b_{eu}R_{eu,t-1} + \epsilon_{eu,t} \tag{1}$$

$$R_{w,t} = a_w + b_w R_{w,t-1} + \epsilon_{w,t}. \tag{2}$$

Since it is quite possible for common news to drive both the aggregate Euro and the aggregate world equity indices, innovations from these two variables are modeled as being independent from each other. We constrain the innovations from equations (1) and (2) as being driven by their own idiosyncratic shocks by orthogonalizing their variance–covariance matrix. Following Ng (2000), the orthogonalized innovations, $\varepsilon_{eu,t}$ and $\varepsilon_{w,t}$ can be obtained using $\epsilon_{eu,t} = \varepsilon_{eu,t} + K_{t-1}{*}\varepsilon_{w,t}$ and $\epsilon_{w,t} = \varepsilon_{w,t}$. K_{t-1} is computed by Cholesky decomposition such that $H_t = K_{t-1}\Sigma_t K'_{t-1}$ and $\Sigma_t = \begin{pmatrix} \sigma^2_{eu,t} & 0 \\ 0 & \sigma^2{}_{w,t} \end{pmatrix}$. Based on this specification, the aggregate Euro index shock ($\varepsilon_{eu,t}$) represents a shock that is isolated from the global shocks.

Second, we use a multivariate AR-GARCH to model the returns of the Euro-wide sector equity indices by considering both the mean and the volatility spillover effects of the aggregate world equity index and the aggregate Euro equity index as explanatory variables. Accordingly, the conditional return of the Euro sector equity index (R_s) is assumed to follow an AR(1) process described by

$$R_{s,t} = a_s + b_s R_{s,t-1} + \eta_{eu,t-1}R_{eu,t-1} + \eta_{w,t-1}R_{w,t-1} + \phi_{eu,t-1}\varepsilon_{eu,t} + \phi_{w,t-1}\varepsilon_{w,t} + \varepsilon_{s,t} \tag{3}$$

where $\eta_{eu,t-1}$ and $\eta_{w,t-1}$ are, respectively, the return spillover effects of the aggregate Euro index and the aggregate world index on the return of each Euro sector equity index, and $\phi_{eu,t-1}$ and $\phi_{w,t-1}$ are their corresponding coefficients of the volatility spillover effects. Algebraically, equation (3) states that the conditional return of the Euro sector equity index is a linear combination of its own lagged return, and the lagged return and volatility spillover effects of the aggregate Euro and the aggregate world equity indices.

The idiosyncratic shock of the sector indices ($\varepsilon_{s,t}$) is assumed to be normally distributed with a zero mean and conditional variance, and evolves according to a GARCH (1,1) process:

$$\sigma^2_{s,t} = \omega_s + \alpha_s\varepsilon_{s,t-1} + \beta_s\sigma^2_{s,t-1} + \mu_s\theta^2_{s,t-1} \tag{4}$$

where ω_s, α_s, and β_s are positive, and $\alpha_s + \beta_s$ is strictly less than 1 to satisfy the necessary condition for stationarity. θ_s captures the effects of negative shocks on the returns. Following Bekaert *et al.* (2005), we set $\theta_{s,t}$ as min(0, $\varepsilon_{s,t}$).

Finally, the unexpected returns of the Euro sector equity indices are given by

$$\epsilon_{s,t} = \phi_{eu,t-1}\varepsilon_{eu,t} + \phi_{w,t-1}\varepsilon_{w,t} + \varepsilon_{s,t}. \tag{5}$$

The ensuing conditional variance of the unexpected return of each Euro sector equity index based on the information available at time t–1 (I_{t-1}) is given by

$$h_{s,t} = E\left(\epsilon_{s,t}^2 \middle| I_{t-1}\right) = (\phi_{eu,t-1})^2 \sigma_{eu,t}^2 + (\phi_{w,t-1})^2 \sigma_{w,t}^2 + \sigma_{s,t}^2. \tag{6}$$

Equation (6) affirms that the conditional variance of the unexpected return of each sector equity index (s) depends on the variance of the contemporary aggregate Euro equity index, the aggregate world equity index, and its own idiosyncratic shocks. ϕ_i captures the volatility spillovers of local and global shocks on the Euro sector equity indices. A positive and statistically significant value of, say, ϕ_i is indicative of the dominance of the sector's unexpected return volatility. In other words, the sign and significance of the parameters $\phi_{eu,t-1}$ and $\phi_{w,t-1}$, determine whether volatility spillover effects from the aggregate Euro index or the aggregate world index are able to explain the conditional variance of the sector equity indices.

We build upon the Euro sector equity indices model to assess the US sector equity indices using the same methodology. Similarly, we assume that local shocks originate from the aggregate US equity index (R_{us}) and the global shocks emanate from the aggregate world equity (R_w) index. Accordingly, the return of the US sector equity index ($R_{us(s)}$) is specified as

$$R_{us(s),t} = a_{us(s)} + b_{us(s)}R_{us(s),t-1} + \eta_{us,t-1}R_{us,t-1} + \eta_{w,t-1}R_{w,t-1} + \phi_{us,t-1}\varepsilon_{us,t} + \phi_{w,t-1}\varepsilon_{w,t} + \varepsilon_{us(s),t}. \tag{7}$$

The conditional variance of the unexpected return of each sector equity index, based on information available at time t–1 (I_{t-1}), is given by

$$h_{us(s),t} = E\left(\epsilon_{us(s),t}^2 \middle| I_{t-1}\right) = (\phi_{us,t-1})^2 \sigma_{us,t}^2 + (\phi_{w,t-1})^2 \sigma_{w,t}^2 + \sigma_{us(s),t}^2. \tag{8}$$

It is quite likely that for some countries' sector indices, the spillover effects are best captured with time-varying models and other sets of exogenous factors. We address this issue by introducing such models in the next subsection. The exposition that follows applies to both the Euro and the US markets, but we use the Euro parameters for ease of explanation.

A. Time-varying spillover model

Once we relax the assumption of constant parameters, two variants of the methodology follow naturally. First, we use a bloc time dummy to determine whether the pre-EMU and post-EMU periods make a difference to the spillover parameter estimates. This is equivalent to assuming that the formation of the EMU created a structural break in the data. Second, we estimate time-varying models to determine which of the parameters have changed through time by incorporating trends into the analysis.

The spillover parameters, when we assume a structural break in the data, can be expressed as

$$\eta_{eu,t} = \eta_{eu_0,t} + \eta_{eu_1,t} * D_{EMU} \tag{9}$$

$$\eta_{w,t} = \eta_{w_0,t} + \eta_{w_1,t} * D_{EMU} \tag{10}$$

$$\phi_{eu,t} = \phi_{eu_0,t} + \phi_{eu_1,t} * D_{EMU} \tag{11}$$

$$\phi_{w,t} = \phi_{w_0,t} + \phi_{w_1,t} * D_{EMU}. \tag{12}$$

The dummy variable, D_{EMU}, equals 0 before the start of the EMU (i.e., before January 1, 1999) and 1 thereafter. Accordingly, the return of the sector indices is given by

$$\begin{aligned} R_{s,t} = a_s &+ b_s R_{s,t-1} + \eta_{eu_0,t-1} R_{eu,t-1} + \eta_{eu_1,t-1} R_{eu,t-1} * D_{EMU} + \eta_{w_0,t-1} R_{w,t-1} \\ &+ \eta_{w_1,t-1} R_{w,t-1} * D_{EMU} + \phi_{eu_0,t-1} \varepsilon_{eu,t} + \phi_{eu_1,t-1} \varepsilon_{eu,t} * D_{EMU} + \phi_{w_0,t-1} \varepsilon_{w,t} \\ &+ \phi_{w_1,t-1} \varepsilon_{w,t} * D_{EMU} + \varepsilon_{s,t}. \end{aligned} \tag{13}$$

We measure the integration of the sector indices with the aggregate indices by allowing the spillover parameters to undergo a gradual transition, taking on a different value for every year of the sample:

$$\eta_{eu,t} = \eta_{eu_0,t} + \eta_{eu_1,t} * TREND \tag{14}$$

$$\eta_{w,t} = \eta_{w_0,t} + \eta_{w_1,t} * TREND \tag{15}$$

$$\phi_{eu,t} = \phi_{eu_0,t} + \phi_{eu_1,t} * TREND \tag{16}$$

$$\phi_{w,t} = \phi_{w_0,t} + \phi_{w_1,t} * TREND. \tag{17}$$

TREND is a variable that takes 1 for the year 1992 and increases by 1 for each year until the end of the sample. Accordingly

$$\begin{aligned} R_{s,t} = a_s &+ b_s R_{s,t-1} + \eta_{eu_0,t-1} R_{eu,t-1} + \eta_{eu_1,t-1} R_{eu,t-1} * TREND + \eta_{w_0,t-1} R_{w,t-1} \\ &+ \eta_{w_1,t-1} R_{w,t-1} * TREND + \phi_{eu_0,t-1} \varepsilon_{eu,t} + \phi_{eu_1,t-1} \varepsilon_{eu,t} * TREND + \phi_{w_0,t-1} \varepsilon_{w,t} \\ &\phi_{w_1,t-1} \varepsilon_{w,t} * TREND + \varepsilon_{s,t}. \end{aligned} \tag{18}$$

B. Variance ratio

To measure the magnitude of the local and global shocks on the volatility of the unexpected return of each Euro (or US) sector equity index, we compute the following variance ratios:

$$VR_{s,t}^{eu} = \frac{(\phi_{eu_0,t-1} + \phi_{eu_1,t-1} * TREND)^2 * \sigma_{eu,t}^2}{(\phi_{eu_0,t-1} + \phi_{eu_1,t-1} * TREND)^2 * \sigma_{eu,t}^2 + (\phi_{w_0,t-1} + \phi_{w_1,t-1} * TREND)^2 * \sigma_{w,t}^2 + \sigma_{s,t}^2} \tag{19}$$

$$VR_{s,t}^{w} = \frac{(\phi_{w0,t-1} + \phi_{w1,t-1} * TREND)^2 * \sigma_{w,t}^2}{(\phi_{eu0,t-1} + \phi_{eu1,t-1} * TREND)^2 * \sigma_{eu,t}^2 + (\phi_{w0,t-1} + \phi_{w1,t-1} * TREND)^2 * \sigma_{w,t}^2 + \sigma_{s,t}^2} \quad (20)$$

$$VR_{us(s),t}^{us} = \frac{(\phi_{us0,t-1} + \phi_{us1,t-1} * TREND)^2 * \sigma_{us,t}^2}{(\phi_{us0,t-1} + \phi_{us1,t-1} * TREND)^2 * \sigma_{us,t}^2 + (\phi_{w0,t-1} + \phi_{w1,t-1} * TREND)^2 * \sigma_{w,t}^2 + \sigma_{us(s),t}^2} \quad (21)$$

$$VR_{us(s),t}^{w} = \frac{(\phi_{w0,t-1} + \phi_{w1,t-1} * TREND)^2 * \sigma_{w,t}^2}{(\phi_{us0,t-1} + \phi_{us1,t-1} * TREND)^2 * \sigma_{us,t}^2 + (\phi_{w0,t-1} + \phi_{w1,t-1} * TREND)^2 * \sigma_{w,t}^2 + \sigma_{us(s),t}^2}. \quad (22)$$

$VR_{s,t}^{eu}$ (or $VR_{us(s),t}^{us}$) measures the proportion of variance of the unexpected return of the Euro (or US) sector equity index (s) that is caused by the aggregate Euro (or US) equity index.[6] Similarly, $VR_{s,t}^{w}$ (or $VR_{us(s),t}^{w}$) measures the proportion of variance of the unexpected return of the Euro (or US) sector equity index that is caused by the aggregate world index. The variance ratios are helpful in gauging how powerful the spillovers effects are in explaining the unexpected return of each sector's equity index. Simple mean comparisons of these measures enable us to evaluate the relative importance of local and global shocks for each sector.

IV. EMPIRICAL ANALYSIS

A. Euro spillover model

We estimate the spillover models using quasi-maximum likelihood methods with (univariate) Gaussian likelihood functions. In line with the theoretical framework of GARCH developed by Engle (1982) and Bollerslev (1986), the estimation was conducted using the numerical optimization algorithm of Berndt et al. (1974). The parameters are estimated by maximizing a univariate log likelihood function. Table 3 reports the results of estimating the coefficients of the Euro spillover model for the Euro-wide sector equity indices. It shows that the sum of α^s and β^s is more than 0.9 but less than 1 in each case, indicating that the volatility process is highly persistent and stationary. We find the AR(1) coefficients of each sector's equity index to be small, mostly positive but not significant. With respect to the spillover effects, for six of the sector equity indices, the means of the aggregate Euro index (η_{eu0}) are significant for the period prior to the EMU, where, for the aggregate world index (η_{w0}), only the consumer goods sector's index is significant. There is also evidence that

6 The variance ratio for Euro-wide sector indices using Euro spillovers is

$$VR_{s,t}^{eu} = \frac{(\phi_{eu0,t-1} + \phi_{eu1,t-1} * D_{EMU})^2 * \sigma_{eu,t}^2}{(\phi_{eu0,t-1} + \phi_{eu1,t-1} * D_{EMU})^2 * \sigma_{eu,t}^2 + (\phi_{w0,t-1} + \phi_{w1,t-1} * D_{EMU})^2 * \sigma_{w,t}^2 + \sigma_{s,t}^2}$$

Table 3 Euro spillover model. GARCH estimates for the Euro-wide sector equity indices

	b_s	η_{eu_0}	η_{eu_1}	η_{w_0}	η_{w_1}	ϕ_{eu_0}	ϕ_{eu_1}	ϕ_{w_0}	ϕ_{w_1}	α_s	β_s	μ_s
AUT	–0.01	–0.09	–0.02	–0.08	0.10*	0.93‡	–0.43‡	0.16‡	0.02†	0.15‡	0.84‡	0.01
BSRS	0.05*	–0.14*	0.04	0.08	–0.01	0.43‡	0.03†	0.10	0.07†	0.08‡	0.90‡	0.01
IDS	–0.03	–0.11†	0.01	0.01	0.03	1.08‡	–0.08†	–0.01	0.18†	0.11‡	0.84‡	0.02
OIL	0.01	–0.10	0.17†	–0.03	0.24‡	0.72‡	0.02	0.24†	–0.06†	0.08‡	0.90‡	0.01
UTI	0.05*	–0.15†	0.04	–0.01	0.09	0.96‡	–0.05	–0.18†	0.02*	0.10‡	0.87‡	–0.01
CNS	0.03	–0.05	–0.08	–0.07*	0.07	0.96‡	–0.36‡	0.13	–0.08*	0.16‡	0.81‡	0.01
FOOD	0.03	–0.14‡	0.10*	–0.03	–0.03	0.84‡	–0.08‡	–0.03	–0.14†	0.11‡	0.83‡	0.01
HTH	–0.03	–0.14‡	0.11*	–0.01	–0.02	0.96‡	–0.15‡	–0.06	–0.17†	0.11‡	0.85‡	0.03*
PRHGD	–0.03	–0.04	–0.09*	–0.01	0.07	0.93‡	–0.08*	–0.01	–0.05†	0.09‡	0.84‡	0.04†
RTL	0.04	–0.10	0.08	0.03	–0.17‡	0.94‡	–0.06*	–0.08	–0.10†	0.02†	0.88‡	0.09
BNK	0.05	–0.08*	–0.04	0.01	–0.01	1.02‡	0.08‡	–0.03	–0.03†	0.12‡	0.80‡	0.07‡
FIN	0.11‡	–0.12	–0.03	0.01	–0.04	0.98‡	0.08‡	–0.01	–0.02†	0.08‡	0.78‡	0.10‡
FNSR	0.02	–0.07*	0.08	0.04	–0.08	0.93‡	0.05‡	–0.06	–0.03†	0.08‡	0.878‡	0.10‡
INSR	0.10‡	0.12‡	–0.03	0.01	–0.05	0.96‡	0.04†	–0.04	0.02	0.06‡	0.84‡	0.07‡
TECH	–0.04	–0.08	–0.16	0.04	0.04	1.01‡	–0.34‡	–0.02‡	0.07†	0.07†	0.90‡	0.01
MED	0.01	–0.06	0.02	0.01	0.01	0.85‡	0.04‡	–0.06	0.08†	0.17‡	0.80‡	0.01
TEL	0.07†	–0.13†	0.12	–0.02	–0.10	0.92‡	0.11‡	–0.07	0.13†	0.07†	0.90‡	0.01

Notes: The GARCH model for sector equity indices is defined as follows:

$$R_{s,t} = a_s + b_s R_{s,t-1} + \eta_{eu_0,t-1} R_{eu,t-1} + \eta_{eu_1,t-1} R_{eu,t-1} * D_{EMU} + \eta_{w_0,t-1} R_{w,t-1} + \eta_{w,t-1} R_{w,t-1} * D_{EMU}$$
$$+ \phi_{eu_0,t-1}\varepsilon_{eu,t} + \phi_{eu_1,t-1}\varepsilon_{eu,t} * D_{EMU} + \phi_{w_0,t-1}\varepsilon_{w,t} + \phi_{w_1,t-1}\varepsilon_{w,t} * D_{EMU} + \varepsilon_{s,t}.$$

$R_{s,t}$ is the weekly return of the Euro-wide sector equity indices (s). η_{eu} and η_w are the return spillover effects of the returns of the aggregate Euro index and the aggregate world index, respectively. ϕ_{eu} and ϕ_w are the volatility spillover effects of the returns of the aggregate Euro index, the aggregate world index, respectively. The dummy variable D_{EMU} takes 1 when the observation occurred in January 1999 or later; otherwise, it takes 0. $\varepsilon_{s,t}$ has a mean of zero and a conditional variance of $\sigma^2_{s,t} = \omega_s + \alpha_s \varepsilon^2_{s,t-1} + \beta_s \sigma^2_{s,t-1} + \mu_s \theta_{s,t-1}$, where $\theta_{s,t} = min(0, \varepsilon_{s,t})$. The constants of each variance equation and mean equation are not reported for the sake of brevity. *,†, and‡indicate that the relevant coefficient is significant at the 10%, 5%, and 1% level, respectively.

the consumer goods and services sector group (food and beverage, health care, and personal goods) is the only sector group for which the return spillover effects of the aggregate Euro index are significant for the post-EMU era, as per the values of η_{eu_1}. The return spillover effects of the aggregate world index (η_{w_1}) are significant for the automobile, oil and gas, and retail services sectors for the same period. Further perusal of Table 3 indicates that ϕ_{eu_0}, the European volatility spillover effect, is highly significant for all sectors as expected, and ϕ_{w_0}, the world volatility spillover effect, is only significant for the production and industry sector group (automobile, oil and gas, and utilities) and the technology sector. Some important patterns do emerge for the post-EMU period: both ϕ_{eu_1} and ϕ_{w_1} are significant but negative for the consumption goods and services sectors, thereby indicating a decline in the effect of global and local shocks on the volatility of these sectors. For the production and industry sectors, local volatility spillover effects are negative and significant, but the world spillover effects are positive and significant (except for oil and gas), confirming that global shocks are important for these sectors. For the financial sector group, local volatility spillover effects display positive and significant effect, whereas the world volatility spillover effects decline over the same period. For the TMT sector group, we see that both local and global volatility spillover effects are positive and significant.

B. Trend spillover model

The trend spillover model allows the spillover parameters to change with a constant value each year (equations (14)–(17)). Thus, the spillover parameters may change gradually during the sample period. Tables 4 and 5 show the results arising from estimating the trend spillover models for the Euro-wide and US-wide sector equity indices, respectively. Tables 4 and 5 are structured in a similar way to Table 3, except that we modeled the spillovers to vary across time. Since the estimated time-varying models produced results that are similar in nature to Table 3, we do not need to repeat the explanations provided earlier, but we focus on interpreting the return and volatility spillovers.

We find the return spillover effect of local shocks (η_{eu_1}) for the time-varying models to be significant for the Euro-wide production and industry, consumer goods and services, and TMT sector groups (specifically, oil and gas, consumer goods, and technology), whereas the return spillover effect of global shocks (η_{w_1}) is mostly nonsignificant across the Euro-wide sectors, except for the oil and gas, and retail services indices. We came across similar results for the US-wide sector indices. The return spillover effect of local shocks is time-varying and significant (η_{us_1}) for the US-wide production and industry, financial, and TMT sector groups. We find only significant time-varying global spillover effects (η_{w_1}) for the US-wide automotive and parts, utilities, health care, and technology sectors, but all these coefficient estimates are negative, thereby suggesting a declining effect of global shocks on the US-wide sector equity returns.

Table 4 Trend spillover model. GARCH estimates for the Euro-wide sector equity indices

	b_s	η_{eu_0}	η_{eu_1}	η_{w_0}	η_{w_1}	ϕ_{eu_0}	ϕ_{eu_1}	ϕ_{w_0}	ϕ_{w_1}	α_s	β_s	μ_s
AUT	–0.01	0.05	0.04	0.05	–0.01*	0.91‡	–0.04‡	0.14‡	0.04†	0.22‡	0.70‡	0.01
BSRS	0.04*	–0.14*	0.10	0.20†	–0.01	0.90‡	–0.04‡	0.30	0.06†	0.08‡	0.90‡	0.01
IDS	–0.01	–0.08†	0.01	0.04	–0.01	0.95‡	–0.03†	0.04	0.18‡	0.09‡	0.80‡	0.02†
OIL	–0.11	–0.09	0.10†	–0.02	0.02†	0.63‡	0.01*	0.19†	–0.04†	0.06‡	0.91‡	0.00
UTI	0.04*	0.10†	0.07*	0.01	–0.01	0.96‡	–0.03†	–0.12†	0.01†	0.08‡	0.87‡	0.01
CNS	0.01	–0.03	0.06†	0.06*	–0.02*	0.98‡	–0.01‡	0.01	–0.01	0.06†	0.81‡	0.08†
FOOD	0.01	–0.10‡	0.07	–0.09	–0.01	0.98‡	–0.12‡	0.19†	–0.04†	0.08‡	0.84‡	0.04*
HTH	–0.04	–0.021‡	0.11*	0.09	–0.01	0.88‡	–0.01‡	–0.03	–0.29‡	0.10†	0.81‡	0.06‡
PRHGD	–0.03	–0.04	–0.04	0.02	0.01	0.96‡	0.01	0.06	0.04†	0.06‡	0.84‡	0.03†
RTL	0.01	–0.04	0.05	0.06	–0.06‡	0.97‡	–0.01*	–0.07	–0.01	0.01	0.90‡	0.08‡
BNK	0.04	–0.06	–0.01	0.01	–0.02	0.98‡	0.11‡	–0.04	0.01	0.10‡	0.73‡	0.10‡
FIN	0.11‡	–0.07†	–0.07†	0.02	–0.01	0.99‡	0.10‡	–0.03	–0.01	0.09†	0.80‡	0.09‡
FNSR	–0.01	–0.07*	0.01	0.02	–0.01	0.84‡	0.13‡	–0.02	–0.15‡	0.04‡	0.92‡	0.02
INSR	0.11†	–0.08	–0.02	0.02	–0.01	1.16‡	0.03†	–0.14	0.01	0.05‡	0.90‡	0.03†
TECH	–0.03	0.04	–0.22†	0.01	0.01	0.98‡	–0.06‡	0.35‡	–0.01†	0.06†	0.91‡	0.01*
MED	0.01	–0.01	–0.01	0.01	0.01	0.95‡	–0.02‡	–0.02	–0.01†	0.15‡	0.80‡	0.03
TEL	0.07†	–0.05	0.07*	–0.04	–0.01	0.95‡	–0.01	0.16†	–0.04‡	0.06‡	0.91‡	0.02†

Notes: The GARCH model for sector equity indices is defined as follows:

$$R_{s,t} = a_s + b_s R_{s,t-1} + \eta_{eu_0,t-1} R_{eu,t-1} + \eta_{eu_1,t-1} R_{eu,t-1} * TREND + \eta_{w_0,t-1} R_{w,t-1} + \eta_{w,t-1} R_{w,t-1} * TREND + \phi_{eu_0,t-1}\varepsilon_{eu,t} + \phi_{eu_1,t-1}\varepsilon_{eu,t} * TREND + \phi_{w_0,t-1}\varepsilon_{w,t} + \phi_{w_1,t-1}\varepsilon_{w,t} * TREND + \varepsilon_{s,t}.$$

$R_{s,t}$ is the weekly return of the Euro-wide sector equity indices (s). η_{eu} and η_w are the return spillover effects of the returns of the aggregate Euro index, and the aggregate world index, respectively. ϕ_{eu} and ϕ_w are the volatility spillover effects of the returns of the aggregate Euro index and the aggregate world index, respectively. The variable TREND takes 1 for the year 1992 and increases by 1 for each year until the end of the sample. $\varepsilon_{s,t}$ has a mean of zero and a conditional variance of $\sigma^2_{s,t} = \omega_s + \alpha_s \varepsilon^2_{s,t-1} + \beta_s \sigma^2_{s,t-1} + \mu_s \theta_{s,t-1}$, where $\theta_{s,t} = min(0, \varepsilon_{s,t})$. The constants of each variance equation and mean equation are not reported for the sake of brevity. *, †, and ‡indicate that the relevant coefficient is significant at the 10%, 5% and 1% level, respectively.

Table 5 Trend spillover model. GARCH estimates for the US-wide sector equity indices

	$b_{us(s)}$	η_{us_0}	η_{us_1}	η_{w_0}	η_{w_1}	ϕ_{us_0}	ϕ_{us_1}	ϕ_{w_0}	ϕ_{w_1}	$\alpha_{us(s)}$	$\beta_{us(s)}$	$\mu_{us(s)}$
AUT	0.01	–0.14*	0.09	0.19†	–0.01†	0.49‡	0.04‡	0.16*	–0.01	0.10‡	0.88‡	0.01
BSRS	–0.05*	–0.01	–0.15†	0.02	–0.02	0.56‡	–0.04‡	–0.06	0.08‡	0.05‡	0.91‡	0.03‡
OIL	–0.10	0.01	–0.03	–0.03	–0.01	0.75‡	0.03*	0.12*	0.02†	0.05‡	0.88‡	0.06‡
IDS	–0.03	–0.06	–0.01	0.09†	–0.04	0.95‡	0.06†	0.11†	–0.01†	0.02‡	0.90‡	0.05‡
UTI	0.04	–0.15‡	0.25†	0.07	–0.01†	0.43‡	0.01†	–0.03	0.03	0.10‡	0.81‡	0.04†
CNS	–0.02	–0.08	0.03	0.06	–0.01	0.96‡	–0.08‡	0.29†	–0.01†	0.06‡	0.92‡	0.01
FOOD	–0.06†	0.10†	–0.03	–0.01	–0.01	1.14‡	–0.05‡	0.09†	0.02†	0.10‡	0.81‡	0.01
HTH	0.01	–0.08‡	0.01	0.15‡	–0.01†	0.98‡	–0.08‡	0.05	0.01†	0.10†	0.87‡	0.01
PRHGD	–0.10†	0.08	–0.03	–0.19†	0.01	0.90‡	–0.01*	0.30†	–0.01†	0.08‡	0.75‡	0.08‡
RTL	–0.03	0.03	–0.01	–0.30†	–0.01	0.99‡	–0.12†	–0.06	–0.01	0.096‡	0.88‡	0.01
BNK	0.01	–0.12†	–0.11*	0.02	0.00	0.98‡	0.02†	0.14*	0.01†	0.14‡	0.82‡	0.01
FIN	–0.06‡	–0.01	–0.10†	0.20‡	0.01	1.10‡	0.07‡	–0.06	–0.01	0.03†	0.83‡	0.05‡
FNSR	–0.11‡	0.01	–0.01	–0.04	0.01	1.15‡	0.09‡	–0.08	0.01	0.04	0.81‡	0.09‡
INSR	–0.11*	–0.08	–0.07	–0.03	0.01	0.91‡	0.02‡	–0.04	0.01†	0.03	0.82‡	0.09‡
TECH	–0.03	–0.10	–0.09	0.19†	–0.01*	0.91‡	0.03‡	0.05	–0.01	0.07†	0.92‡	0.01
MED	–0.11‡	–0.01	–0.06	–0.04	0.01	0.98‡	0.07‡	–0.08	0.01†	0.04‡	0.85‡	0.08‡
TEL	–0.03	0.01	0.11*	–0.08	–0.01	0.67‡	0.03†	0.10	–0.01	0.01	0.90‡	0.06‡

Notes: The GARCH model for sector equity indices is defined as follows:

$$R_{us(s),t} = a_{us(s)} + b_{us(s)}R_{us(s),t-1} + \eta_{us_0,t-1}R_{us,t-1} + \eta_{us_1,t-1}R_{us,t-1} * TREND + \eta_{w_0,t-1}R_{w,t-1} \\ + \eta_{w,t-1}R_{w,t-1} * TREND + \phi_{us_0,t-1}\varepsilon_{us,t} + \phi_{us_1,t-1}\varepsilon_{us,t} * TREND + \phi_{w_0,t-1}\varepsilon_{w,t} + \phi_{w_1,t-1}\varepsilon_{w,t} * TREND + \varepsilon_{us(s),t}.$$

$R_{us(s),t}$ is the weekly return of the US-wide sector equity index ($us(s)$). η_{us} and η_w are the return spillover effects of the returns of the US aggregate equity index and the aggregate world equity index, respectively. ϕ_{us} and ϕ_w are the volatility spillover effects of the returns of the US aggregate index and the aggregate world index, respectively. The variable TREND takes 1 for the year 1992 and increases by 1 for each year until the end of the sample. $\varepsilon_{us(s),t}$ has a zero mean and a conditional variance of $\sigma^2_{us(s),t} = \omega_{us(s)} + \alpha_{us(s)}\varepsilon^2_{us(s),t-1} + \beta_{us(s)}\sigma^2_{us(s),t-1} + \mu_{us(s)}\theta_{us(s),t-1}$, where $\theta_{us(s),t} = min(0, \varepsilon_{us(s),t})$. The constants of each variance equation and mean equation are not reported for the sake of brevity. *, †, and ‡ indicate that the relevant coefficient is significant at the 10%, 5%, and 1% level, respectively.

Strong volatility spillover effects are at play for both the Euro- and the US-wide sector equity indices when we consider the estimated volatility spillover coefficients (ϕ) in Tables 4 and 5. For the local volatility spillovers to affect the Euro- and the US-wide sector equity indices significantly, these two coefficients must be statistically significant for each market. A positive value of ϕ_{eu_0} or ϕ_{us_0} confirms the importance of local spillover effects, and a positive (negative) and significant value of ϕ_{eu_1} or ϕ_{us_1} indicates whether the local spillover effects have increased (decreased) over the specific time.

For the Euro area, similar to our findings in Table 3, we find significant volatility spillover effects of local shocks on the volatility of Euro-wide sector equity indices, as demonstrated by the positive and statistically significant values of ϕ_{eu_0}. We reject the null hypothesis that the volatility parameter of the spillover effects of local shocks (ϕ_{eu_1}) is constant for almost all the Euro-wide sector indices. Notably, the volatility spillover effects of local shocks declined for the production and industry, consumer goods and services, and TMT sector groups, but gradually increased over time for the financial sector group. For the US-wide sector equity indices, similar to the Euro-wide sector indices, the volatility spillover of the local shocks (ϕ_{us_0}) is significant and positive for all sector indices. However, throughout the whole period, these effects have declined significantly for the consumer goods and services sector group (as ϕ_{us_1} is negative and significant) while, for the other clusters i.e. production and industry, financial, and TMT, there has been an increase (as ϕ_{us_1} is positive and significant) in the volatility spillover effects of local shocks.

It is also important to note that both the Euro- and the US-wide sector equity indices are subjected to the volatility spillovers of global shocks. We capture this relationship via the estimated coefficients of ϕ_{w_0} and ϕ_{w_1} in Tables 4 and 5. Arguably, for the world volatility spillovers to affect the Euro- and US-wide sector equity indices significantly, these two coefficients must be statistically significant for each sector. A positive value of ϕ_{w_0} confirms the importance of world spillover effects, and a positive (negative) and significant value of ϕ_{w_1} indicates whether the effects have increased (decreased) over time. We find statistically significant increasing world spillover effects on the production and industry sector group; decreasing effects on the consumer goods and services, and TMT sector groups; and no significant effects on the financial sector group for the Euro-wide sector equity indices. For the US market, we could not find any clear pattern of world spillover effects on the clusters. The results differ from those of the Euro-wide counterpart, save for the production and industry sector group. Banking and insurance sectors are increasingly affected by world spillover effects, while the TMT sector groups do not respond at all to these effects.

C. Variance ratios

In Tables 6–8, we present the percentage variability in the sector returns that can be accounted for by local (the aggregate Euro or US index) or global (the aggregate world index) shocks. For the mean, volatility, and trend spillover

Table 6 Variance ratio for the Euro-wide sector equity indices with the Euro spillover model

	VR^{eu}		VR^{w}	
	Mean	SD	Mean	SD
AUT	0.38	0.18	0.01	0.01
BSRS	0.23	0.12	0.06	0.03
IDS	0.65	0.21	0.01	0.02
OIL	0.28	0.15	0.02	0.03
UTI	0.55	0.23	0.03	0.03
CNS	0.49	0.21	0.01	0.01
FOOD	0.38	0.19	0.01	0.02
HTH	0.44	0.20	0.02	0.03
PRHGD	0.38	0.21	0.02	0.02
RTL	0.43	0.20	0.01	0.02
BNK	0.63	0.21	0.00	0.00
FIN	0.67	0.21	0.00	0.00
FNSR	0.69	0.15	0.00	0.01
INSR	0.57	0.21	0.00	0.00
TECH	0.43	0.19	0.05	0.05
MED	0.42	0.20	0.05	0.02
TEL	0.43	0.15	0.11	0.05

Notes: The table reports the mean and the standard deviation (SD) of the Euro sector equity indices' variance ratios for the Euro spillover model. The variance of the unexpected return of the Euro sector index (s) caused by the aggregate Euro index (local) and the aggregate world index (global) is formulated as

$$VR^{eu}_{s,t} = \frac{(\phi_{eu_0,t-1} + \phi_{eu_1,t-1} * D_{EMU})^2 * \sigma^2_{eu,t}}{h_{s,t}} \text{ and } VR^{w}_{s,t} = \frac{(\phi_{w0,t-1} + \phi_{w_1,t-1} * D_{EMU})^2 * \sigma^2_{w,t}}{h_{s,t}}$$

where $h_{s,t} = (\phi_{eu_0,t-1} + \phi_{eu_1,t-1} * D_{EMU})^2 * \sigma^2_{eu,t} + (\phi_{w0,t-1} + \phi_{w_1,t-1} * D_{EMU})^2 * \sigma^2_{w,t} + \sigma^2_{s,t}$.

models, local shocks clearly dominate global shocks, which are considerably weak, irrespective of the sector equity indices. We find the production and industry, consumer goods and services, and TMT sector groups to be more or less equally sensitive to the local shocks, whereas the financial sector group seems to be most responsive to local shocks, regardless of the models estimated or whether we look at the Euro or US markets. The mean variance ratios of local shocks for production and industry, consumer goods and services, financial, and TMT sector groups, respectively, are 0.42, 0.42, 0.64, and 0.43 for the Euro-wide sectors with the Euro spillover model; 0.40, 0.42, 0.54, and 0.39 for the Euro-wide sectors with the trend spillover model; and 0.40, 0.40, 0.53, and 0.40 for the US-wide sectors with trend spillover models. Accordingly, it is apparent that the financial sector group is the most sensitive to local shocks in both Euro and US markets. In terms of single sector, the industrial goods sector is the most sensitive in both markets. The trend spillover models also show that the basic resource sector, with a variance ratio of 0.11 for the Euro and 0.06 for the US, is the most sensitive of all sectors to global shocks, while the Euro

Table 7 Variance ratio for the Euro-wide sector equity indices with the trend spillover model

	VR^{eu}		VR^{w}	
	Mean	SD	Mean	SD
AUT	0.36	0.09	0.02	0.04
BSRS	0.21	0.10	0.11	0.03
IDS	0.61	0.21	0.00	0.01
OIL	0.28	0.15	0.03	0.02
UTI	0.55	0.23	0.03	0.03
CNS	0.47	0.11	0.02	0.02
FOOD	0.41	0.09	0.01	0.02
HTH	0.45	0.20	0.02	0.02
PRHGD	0.38	0.21	0.02	0.02
RTL	0.42	0.18	0.03	0.03
BNK	0.62	0.21	0.00	0.01
FIN	0.47	0.13	0.01	0.02
FNSR	0.54	0.11	0.00	0.02
INSR	0.54	0.14	0.02	0.04
TECH	0.32	0.14	0.03	0.03
MED	0.41	0.21	0.00	0.01
TEL	0.43	0.15	0.04	0.05

Notes: The table reports the mean and the standard deviation of (SD) the Euro sector equity indices' variance ratios for the Euro spillover model. The variance of the unexpected return of the Euro sector index (s) caused by the aggregate Euro index (local) and the aggregate world index (global) is formulated as

$$VR_{s,t}^{eu} = \frac{(\phi_{eu_0,t-1} + \phi_{eu_1,t-1} * TREND)^2 * \sigma_{eu,t}^2}{h_{s,t}} \text{ and } VR_{s,t}^{w} = \frac{(\phi_{w0,t-1} + \phi_{w1,t-1} * TREND)^2 * \sigma_{w,t}^2}{h_{s,t}}$$

where $h_{s,t} = (\phi_{eu_0,t-1} + \phi_{eu_1,t-1} * TREND)^2 * \sigma_{eu,t}^2 + (\phi_{w0,t-1} + \phi_{w1,t-1} * TREND)^2 * \sigma_{w,t}^2 + \sigma_{s,t}^2$.

volatility spillover model shows the telecommunication sector to be the most sensitive, with a variance ratio of 0.11.

To convey a better understanding of the variance decomposition analysis of the sector indices, in Figures 1–4, we present the variance ratios as time series plots for the period 1992–2009. We eliminated the spikes in the data by using 6-month moving average intervals. There are three pieces of information in each panel containing the three channels through which shocks can perturb a sector or a cluster of sectors: local (aggregate Euro or aggregate US), sectoral (own or specific), and global (world). Since the sectors respond in a fairly similar way to these shocks within groups, as shown in Table 6–8, we only focus our attention on a single sector for each group. Figures 1 and 2 display the variance ratios of the Euro-wide sector indices.

The first graph in Figure 1 suggests that the basic resource sector is the least vulnerable to local shocks, although it has been increasingly exposed to global shocks. The second graph shows that world spillover effects are on the decline for the food and beverage sector. The first graph in Figure 2 shows that global

Table 8 Variance ratio for the US-wide sector equity indices with the trend spillover model

	VR^{us}		VR^{w}	
	Mean	SD	Mean	SD
AUT	0.29	0.11	0.02	0.02
BSRS	0.25	0.15	0.06	0.06
IDS	0.63	0.21	0.00	0.00
OIL	0.44	0.24	0.04	0.04
UTI	0.41	0.14	0.01	0.13
CNS	0.39	0.19	0.02	0.02
FOOD	0.32	0.16	0.01	0.01
HTH	0.47	0.19	0.03	0.04
PRHGD	0.40	0.15	0.03	0.04
RTL	0.42	0.29	0.01	0.02
BNK	0.50	0.20	0.00	0.01
FIN	0.57	0.21	0.01	0.01
FNSR	0.56	0.20	0.00	0.00
INSR	0.48	0.19	0.01	0.02
TECH	0.42	0.19	0.00	0.00
MED	0.48	0.09	0.01	0.01
TEL	0.30	0.16	0.00	0.00

Notes: The table reports the mean and the standard deviation (SD) of the US sector equity indices' variance ratios for the trend spillover model. The variance of the unexpected return of the US sector index (US(*s*)) caused by the aggregate US index (local) and the aggregate world index (global) is formulated as

$$VR^{us}_{us(s),t} = \frac{(\phi_{us0,t-1} + \phi_{us1,t-1} * TREND)^2 * \sigma^2_{us,t}}{h_{us(s),t}} \text{ and } VR^{w}_{us(s),t} = \frac{(\phi_{w0,t-1} + \phi_{w1,t-1} * TREND)^2 * \sigma^2_{w,t}}{h_{s,t}}$$

where $h_{us(s),t} = (\phi_{us0,t-1} + \phi_{us1,t-1} * TREND)^2 * \sigma^2_{us,t} + (\phi_{w0,t-1} + \phi_{w1,t-1} * TREND)^2 * \sigma^2_{w,t} + \sigma^2_{us(s),t}$.

shocks have become less important while local shocks have become more important for the financial services sector. The second graph in Figure 2 shows that local disturbances have the least impact on the TMT sectors. All these results are in line with the findings reported in Tables 4 and 7.

Figures 3 and 4 present similar information for the US-wide sector indices. In Figure 3, we observe that global volatility spillover effects are stronger for the production and industry sector group. The second graph shows that the food and beverage sector, a member of the consumer goods and services cluster, has been increasingly influenced by global shocks. In Figure 4, the first graph suggests that the financial sector group has been increasingly affected over time by both global and local shocks. The second graph in Figure 4 confirms that local effects (US-wide shocks) explain little of the variation in the technology sector, a member of the TMT sector group.

Although there are similarities between the Euro- and the US-wide sector equity indices, when we consider the vulnerability of the production and

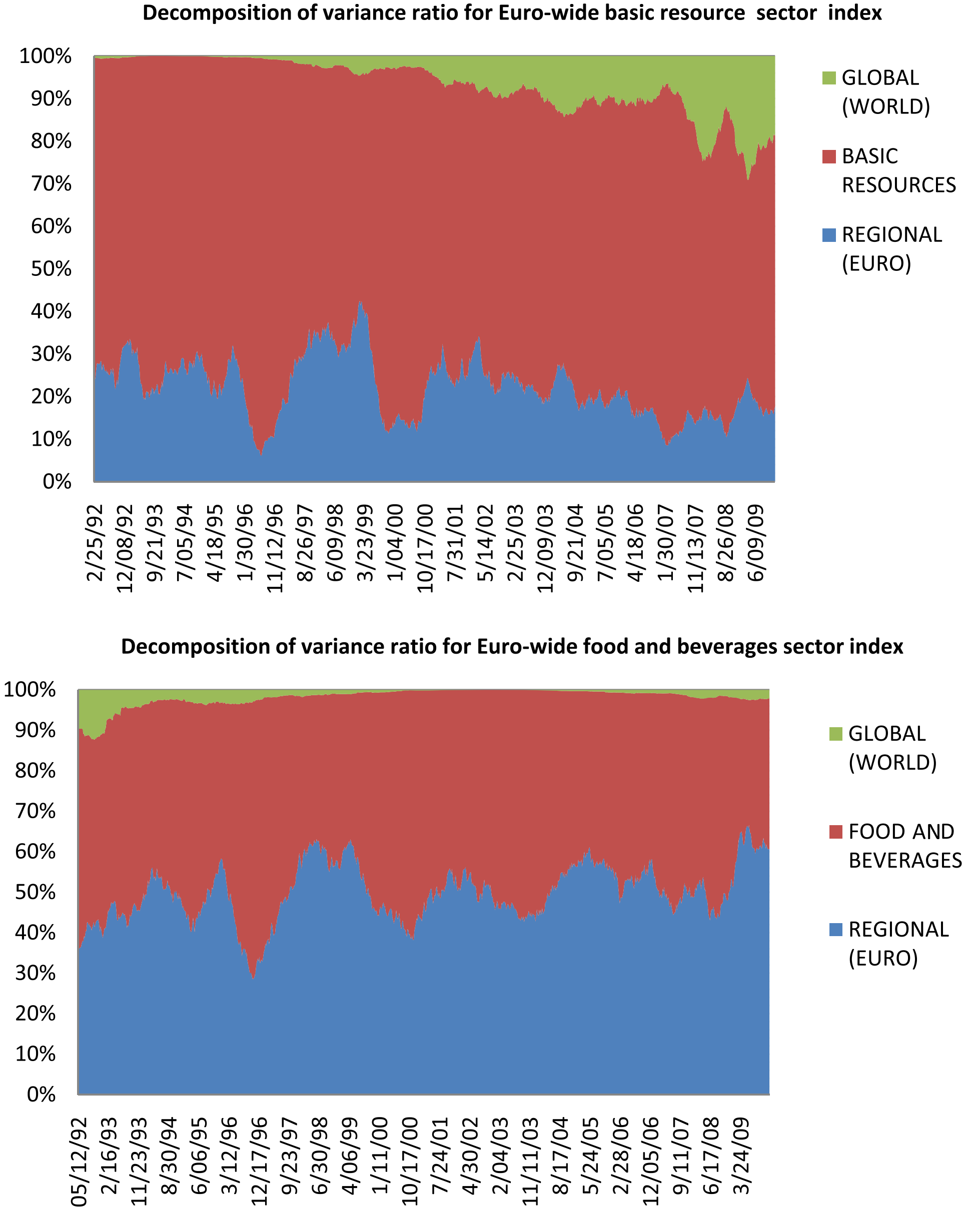
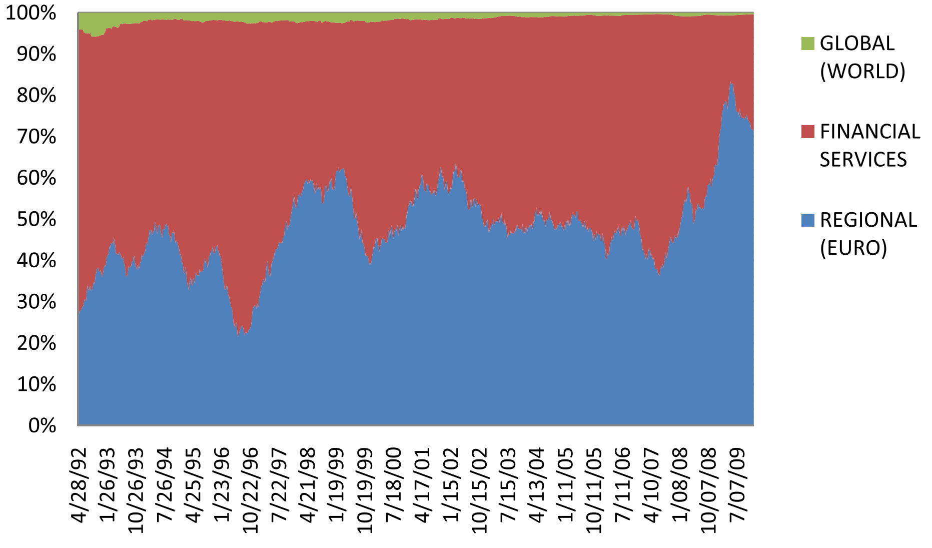


Figure 1 Variance Ratios for Euro-Wide Sector Indices.
Variance ratios are calculated using equations (19) and (20) in the text. We used 6 months moving average intervals. Global represents the ratio of global shocks on the volatility of the sector indices. Regional (Euro) represents the ratio of regional shocks on the volatility of the sector indices. The middle region is the idiosyncratic (own) shocks of the sector indices on its volatility.

Decomposition of variance ratio for Euro-wide financial services sector equity index



Decomposition of variance ratio for Euro-wide technology sector index

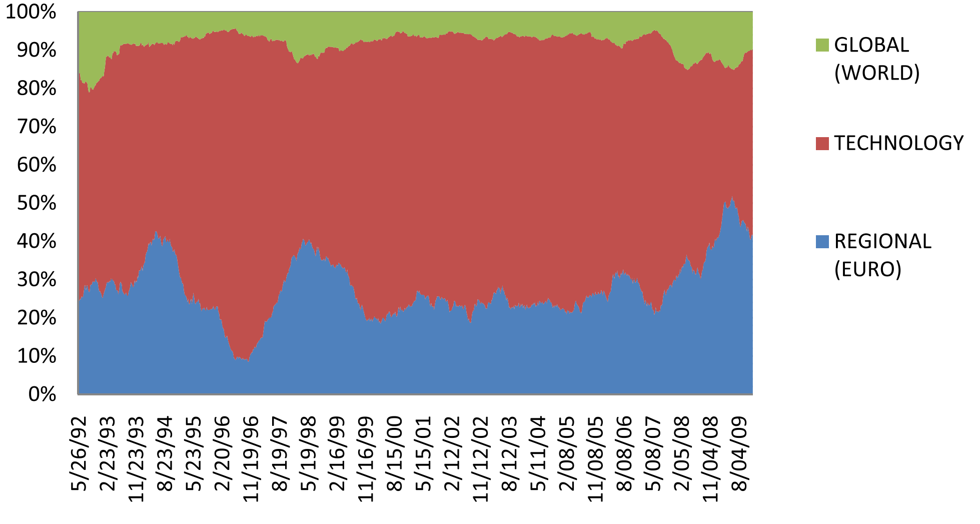
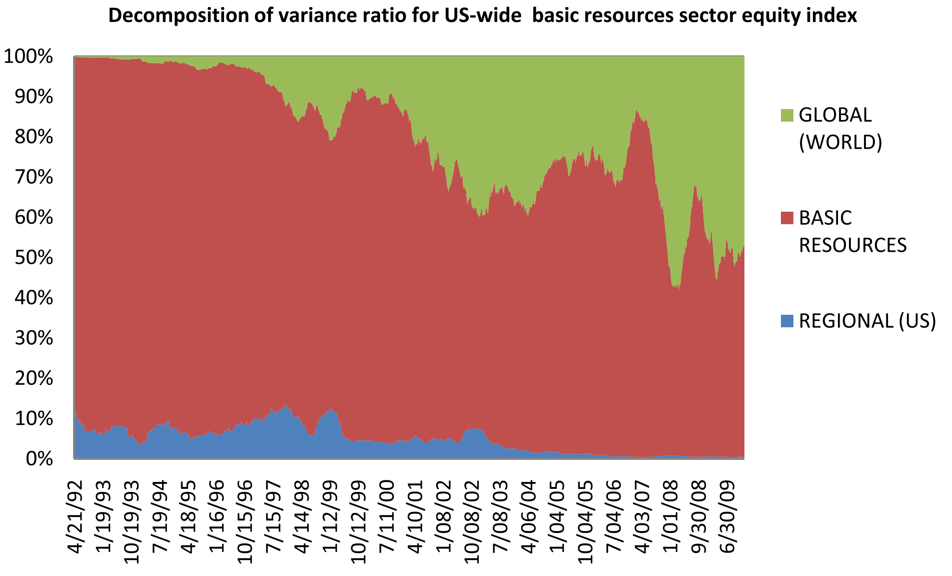


Figure 2 Variance Ratios for Euro-Wide Sector Indices.
Variance ratios are calculated using equations (19) and (20) in the text. We used 6 months moving average intervals. Global represents the ratio of global shocks on the volatility of the sector indices. Regional (Euro) represents the ratio of regional shocks on the volatility of the sector indices. The middle region is the idiosyncratic (own) shocks of the sector indices on its volatility.



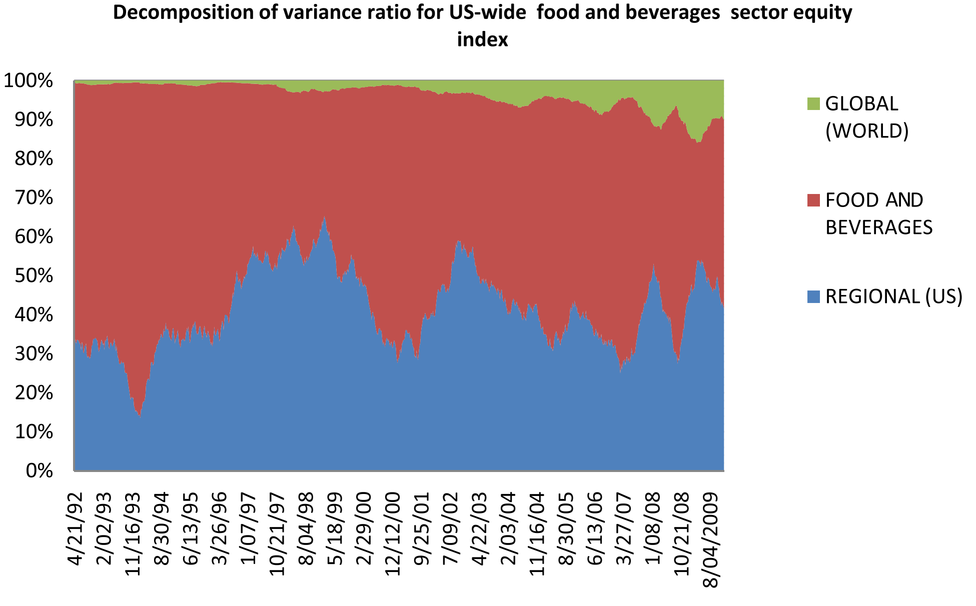
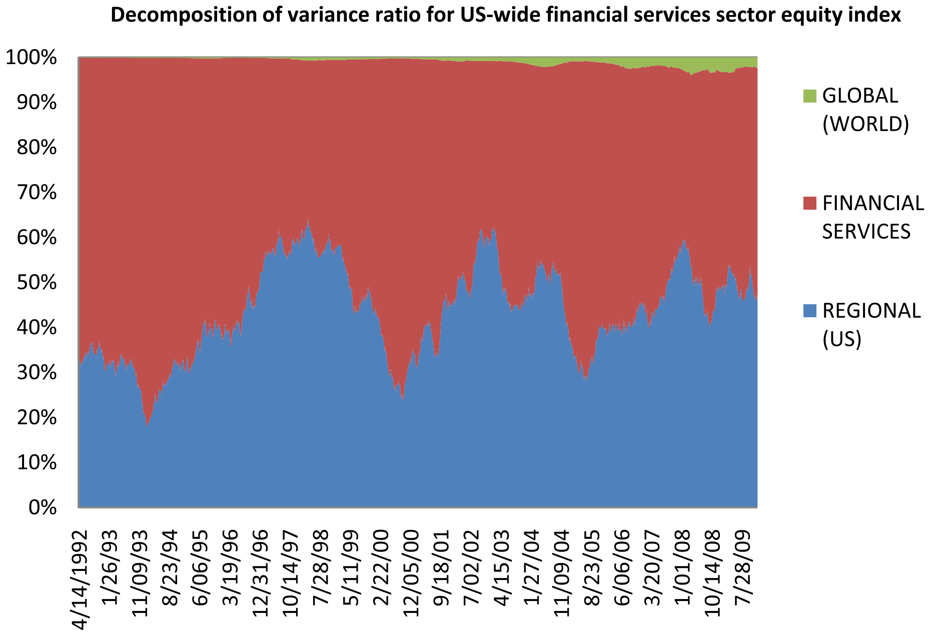


Figure 3 Variance Ratios for US-Wide Sector Indices.
Variance ratios are calculated using equations (21) and (22) in the text. We used 6 months moving average intervals. Global represents the ratio of global shocks on the volatility of the sector indices. Regional (US) represent the ratio of regional shocks on the volatility of the sector indices. The middle region is the idiosyncratic (own) shocks of the sector indices on its volatility.



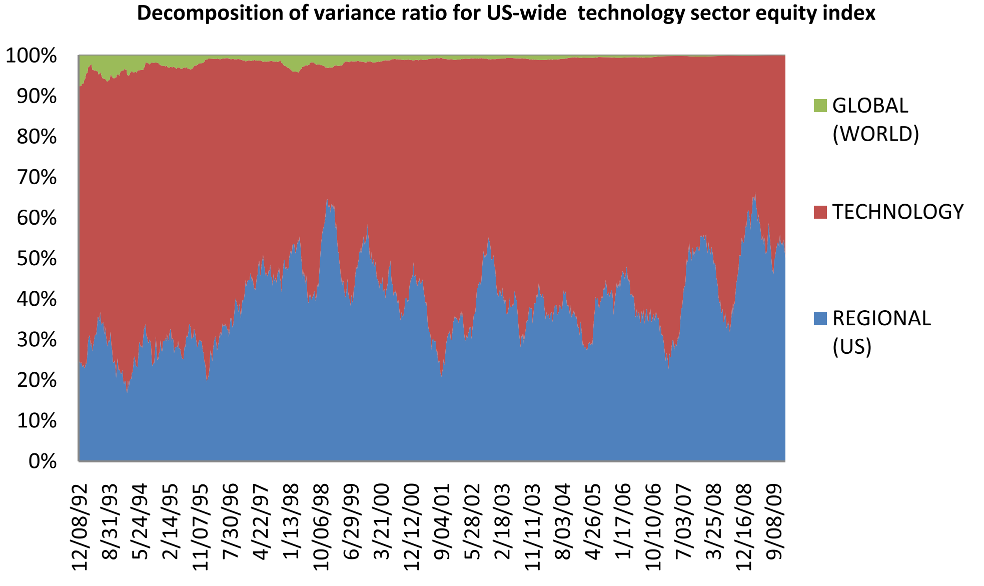


Figure 4 Variance Ratios for US-Wide Sector Indices.
Variance ratios are calculated using equations (21) and (22) in the text. We used 6 months moving average intervals. Global represents the ratio of global shocks on the volatility of the sector indices. Regional (US) represent the ratio of regional shocks on the volatility of the sector indices. The middle region is the idiosyncratic (own) shocks of the sector indices on its volatility.

industry sector group to global volatility spillovers, sharp contrasts also appear when we scrutinize the dynamics of the financial sector group.

V. CONCLUDING REMARKS

In this paper, we investigate the integration of the Euro- and US-wide sector equity indices by focusing on the return, volatility, and the trend spillover effects of local and global shocks. We compute the return and volatility spillover effects using Euro and time-varying spillover models. Using the spillover models, we have shown that sector indices have been integrated within the region, and the start of Euro has accelerated this process. We are also able to show that when trends are incorporated into the spillover analysis, a number of sector equity indices tend to react similarly to local and global shocks; it is therefore possible to organize them in clusters (or groups) for a richer and more meaningful analysis. We follow this path for both the Euro and US markets, and arrive at four major sector groups: production and industry, consumer goods and services, financial, and TMT using 17 sector equity indices that we gathered from DataStream and other sources. We then analyze the response patterns of each group to local and global spillover effects. Overall, these results suggest that equity market integration is not uniform across sector groups for the two major economic blocs, considering that we rely on the trend spillover model. The trends are dissimilar where the responses of sector equity indices to local shock spillovers are synchronized. Some sectors are influenced by global shocks while others are not. Further analysis of the data leads us to consider the variance decomposition of the sector returns. The findings are unambiguous: the production and industry, consumer goods and services, and TMT sector groups are equally responsive to local shocks, but the financial sector group is the most sensitive of all. These results hold irrespective of the model used or whether the US or the Euro area is under consideration. Local shocks stochastically dominate global shocks in terms of their relative effects on the sector returns.

Finally, the results of our paper are most useful for investors in their quest for minimizing risk. We therefore emphasize that risks can be further reduced through portfolio diversification across sector groups. The portfolio risk allocation literature clearly postulates that in the presence of asymmetric shocks, an investor's portfolio diversification can be seen as insurance against bad times when economic cycles are asynchronous across regions. Our paper also finds a place in this strand of the literature.

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