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Energy firms in emerging markets: Systemic risk and diversification opportunities☆

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ABSTRACT

Previous studies in energy stock markets have analyzed market connectedness using aggregate indexes and focusing on developed markets. We depart from the extant literature and we focus our attention on companies listed on emerging stock markets and examine connectedness from the firm's perspective. Using a two-step approach, we remove the common global factors from energy stock returns and estimate the network of global energy stocks in emerging markets. We show that idiosyncratic components are highly relevant for our understanding of risk transmission in energy markets. Moreover, we offer precise diversification alternatives and identify the most systemically important firms and countries.

1. Introduction

The ongoing energy transition to sustainable generation sources has drawn great political and academic attention to the global financial network of energy firms. The connectedness of energy corporations on the world stock market determines not only the market and credit risks to which international investors and banks with share portfolios and loans in the energy sector are exposed, but also the funding opportunities for the operation and innovation of energy firms. Indeed, funding and risk transmission are crucial in a context of change such as that imposed by the energy transition. For instance, a highly integrated market network of energy firms means that there is a considerable degree of risk-sharing across countries enabled by companies listed on a variety of markets, but it also means that there is a high probability of contagion and fewer opportunities for risk diversification in times of crisis and, therefore, a greater likelihood that systemic risk materializes in the global energy sector in times of trouble. For this reason, monitoring the evolution of the global financial network of energy firms and identifying the main actors (both countries and individual firms) in that network are of the utmost importance for global investors and managers of global corporations in the energy sector as well as for policy-makers and

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regulators.

Despite the large body of literature studying the connectedness and spillovers of energy markets, as well as between these markets and traditional financial markets, two major gaps remain that this study seeks to address. First, when estimating the global financial network of energy companies, we opt to focus our attention on companies listed on the emerging stock exchanges, markets that are typically overlooked or, when included, mentioned only in passing. Second, most studies to date rely on market indices to estimate the financial energy network; however, here, we opt to analyze connectedness from the firm's perspective, given that it represents a more informative, more precise alternative. In terms of methodology, our approach is facilitated by the fact that we are able to leverage recent advances in network estimation based on large vector autoregressions (VARs) and factor models. Our estimates, moreover, control for the presence of unobservable common factors that might simultaneously affect the price of energy firms on global stock markets. Specifically, we estimate and remove these unobservable and not diversifiable factors that act as systemic risk components for the portfolios and energy stock prices. In this way, we are able to correct for a common and significant omission in the field, which in our case is fundamental as we deliberately omit developed markets from our network analysis. The approach we adopt allows us to estimate spillovers between individual energy companies listed on the world's emerging stock markets more accurately and to offer more precise policy and portfolio recommendations than previous studies.

Environmental deterioration attributable to the burning of fossil fuels and the transition towards more sustainable forms of production have raised investor awareness and political interest in environmental issues in developed economies and, more recently and with even greater urgency, in emerging economies. Indeed, emerging markets are more frequently and more significantly dependent on the prices of such commodities as oil and coal than are developed markets. In emerging economies, the energy transition directly affects expected government revenues as the latter are frequent shareholders in energy companies. Moreover, energy commodity prices greatly determine domestic current account balances, because emerging economies are more often than not net exporters of these commodities, especially of oil, coal and natural gas, but also of critical materials for the energy transition, including lithium and cobalt. The Global Status Report on Renewables indicates that the participation of emerging economies in total renewable energy investment has grown significantly and consistently in recent years, above all in China, which accounted for 32% of observed investment in 2018 (Renewables 2019 Global Status Report, 2019). In 2020, their renewable energy capacity investment reached USD 153.4 billion, surpassing that of developed countries. This has contributed to a continuing increase in the offsetting of overall investment in fossil fuel-related assets involving investors worth nearly USD 15 trillion (Renewables 2021 Global Status Report, 2021). From the companies' point of view, energy firms in emerging markets have shown higher financial performance than other firms, particularly clean energy producing companies (Schabek, 2020). This fact has been driven by best practices in the corporate governance of these firms, which have shown a greater commitment to social sustainability policies and the energy transition process (Haile and Min, 2022). Naturally, these conditions have obvious repercussions on investment decision-making in the energy stock market, since the higher performance of these firms has affected their degree of exposure to oil price shocks and other conventional energies, as well as their dependence on other firms in the sector. Despite the greater relevance and commitment of emerging market economies to the energy transition, empirical evidence about these factors is scarce. Indeed, to the best of our knowledge, we are the first to focus our research efforts exclusively on energy firms listed on emerging stock markets.

We study connectedness in a large firm-level system comprising 219 energy companies listed on 27 emerging markets. Our analysis is based on weekly data for the period between January 13, 2010 and March 24, 2021. In line with the approach recently developed by Fan et al. (2021) for analyzing large panels of data, we combine sparse VARs and factor models, estimated using principal component analysis (PCA), to estimate connectedness and spillover statistics across energy firms at the global scale. We follow a two-step approach. First, we estimate the common factors in the returns of our large set of energy firms by means of PCA, in keeping with a traditional factor model in econometrics, and, second, we fit the network model proposed by Demirer et al. (2018) to the series of idiosyncratic components of the system (i.e. the residuals of the regression of each stock return on the common factors). This methodology allows us to calculate the spillover statistics proposed by Diebold and Yilmaz (2012, 2014) when the curse of dimensionality is a concern, by reducing the parameter space of the VAR system through the least absolute shrinkage and selection operator (LASSO). We contrast our results at the firm level with results at the country level, the latter being built upon equally weighted index portfolios for each country. In this way, we can assess robust and complementary characteristics of the energy stock network and, all in all, we manage to capture firm heterogeneity in terms of connectedness and evaluate the idiosyncratic relevance of each firm and country in our sample.

A vast empirical literature has studied the link between stocks in developed markets and energy commodity markets (Kumar et al., 2012; Reboredo and Ugolini, 2016, 2018; Lundgren et al., 2018; Ferrer et al., 2018; Xia et al., 2019; Kocaarslan and Soytas, 2019; Reboredo et al., 2019; Nasreen et al., 2020; Naeem et al., 2020; Hanif et al., 2021; Geng et al., 2021a, 2021b; Saeed et al., 2021; Gomez-Gonzalez et al., 2022), and although a few studies have analyzed the relationship between stocks in emerging markets and energy commodities (Li and Wei, 2018; Evrim et al., 2020; Demirer et al., 2020), evidence on the latter remains scarce. Moreover, the literature exclusively concerned with energy market connectedness is very recent and is not exempt from methodological limitations. For example, Singh et al. (2019) employ Diebold and Yilmaz's (2012) methodology to model the MSCI energy equity indices of 21 countries in Europe, North and Latin America and Asia-Pacific and find that the energy stock markets of developed countries (mainly North America and Europe) are net transmitters of shocks and have a dominant role in the energy market network. The authors also show that after the global financial crisis, emerging countries, and particularly China, have experienced an increase in their share of total system spillovers. More recently, Tiwari et al. (2021) analyzed connectedness between energy stock markets, using indices from 20 regional blocks. This study used Diebold and Yilmaz's (2014) approach exploiting a time-varying parameter (TVP)-VAR and the LASSO model. Their findings lend support to the conclusions drawn by Singh et al. (2019) by indicating that the energy stock markets of developed countries (i.e. those belonging to the G7 and G12) are the main net transmitters of volatility, while the markets of

Southeast Asia, Scandinavia, the Far East and the Americas are net receivers.

Despite the relevance of these findings from a methodological point of view, earlier studies have omitted the fact that the connectedness between energy stock markets is determined by both idiosyncratic and systematic factors (i.e. oil, coal, and gas prices, but also global activity, global funding liquidity, etc.). In our case, we use dynamic factor models through PCA to estimate the systemic component of energy returns, both for individual firms and markets. Two points of view support our proposal. From the methodological point of view, we draw inspiration from Fan et al. (2023) who show that through sparse regression, systemic components can be structured as a function of highly correlated common factors in any given system and, such components simultaneously affect all series, while the idiosyncratic component only considers less correlated signals, which in our case correspond to diversifiable risks of the energy stocks. From traditional portfolio theory we have that common multi-factors act as a proxy for systematic non-diversifiable risks in the market which are unobservable (Cochrane, 2005; Campbell, 2018), while the residual risk is fully diversifiable. For these reasons, we remove the systemic component from the returns and we construct the connectedness measures using only the idiosyncratic component. This separation is fundamental for investment decisions and for identifying real diversification opportunities for international investments. Our analysis provides a description of precise diversification opportunities, as well as the transmission of non-systematic abnormal shocks that certain markets or companies can propagate within the global financial network.

Another methodological limitation of these earlier studies, which we seek to address here, concerns their use of aggregate country or regional indices as their unit of analysis. This level of aggregation does not permit the full incorporation of key heterogeneities at the firm level, critical for understanding risk transmission within a country or between firms listed on different markets (Pham, 2019). Only a few studies have sought to overcome this limitation but they focus primarily on energy markets in developed countries. Restrepo et al. (2018) was one of the first to advocate the use of firm-level data to estimate spillovers in the financial energy network – focusing on 20 oil companies with the largest market capitalization in the US – to construct a network in line with the approach developed by Diebold and Yilmaz (2012). Fuentes and Herrera (2020) study the connectedness between the stock prices of 16 renewable energy companies from the United States, Canada, Brazil, Denmark and China, and various volatility indicators of oil, stocks and gold markets. Exploiting Diebold and Yilmaz's (2014) methodology, the authors conclude that significant and heterogeneous spillovers occur both within and between sectors and renewable energy companies, which are mainly affected by stock market volatility. Foglia and Angelini (2020), in an analysis of 24 renewable energy companies listed on the NASDAQ and MSCI Global Energy Efficiency indices, show that total spillover in the system varied from 21.36% pre-Covid-19 to 61.23% following the onset of the pandemic. Geng et al. (2021a) corroborate the strong connectedness between oil and stock prices for eight renewable energy companies in Europe. All these studies are, nevertheless, limited in terms of the number of firms on which they base their conclusions. For this reason, it proves impossible to assess the systemic relevance to the global stock market of the vast majority of firms in the energy sector (even those with a relatively large market capitalization in their respective domestic markets), which means potentially relevant network nodes are omitted ad hoc without any theoretical or empirical justification. Here, in our calculations, we specifically address this shortcoming by incorporating a total of 219 energy firms.

This study provides three main sets of results. First, we show that emerging energy stock markets are closely integrated even after controlling for global systematic factors. Moreover, we are able to establish the contributions of both systematic and idiosyncratic factors. Second, we provide precise diversification alternatives at both the country and firm levels, related to those countries or firms that are less sensitive to shocks from the rest of the system, or which are located on the periphery of the global energy network. Third, we identify idiosyncratically important countries and firms, that is, the actors that generate the largest shocks to the rest of the system or which are more authoritative and central within the emerging market energy network that we estimate.

More specifically, as regards our first set of results, when energy stock returns include the common systematic factors, we show that the system's total connectedness at the country level reaches 61.43%, falling to 24.45% when the effect of these factors is removed and the stock returns are fully idiosyncratic. The corresponding levels of network connectedness when using firm-level data are 82.97 and 39.92%, respectively. This first result is relevant as it highlights two specific characteristics of the global energy network: *i*) when common factors are not taken into account, energy market spillover estimates are biased upwards, and individual markets and individual firms are identified as being more systemically important than they actually are, because much of the system's variation comes from global factors that affect all markets and firms simultaneously; and, *ii*) after considering the common factors, idiosyncratic components of energy stock returns continue to be highly relevant for our understanding of risk transmission in energy markets. For this reason, energy markets can be considered vulnerable to episodes of financial spillovers in times of distress.

In the case of our second set of results, if we consider the network from which we have factored out the effects of global energy factors, the countries in its periphery are those that interact less with the rest of the system and which, therefore, offer potentially greater diversification opportunities. This set of countries includes Peru, Bosnia-Herzegovina, South Korea, Thailand, Argentina, Malaysia, Colombia, Chile, Brazil, Indonesia and Russia. At the firm level, greater heterogeneity can be seen between firms from different countries. Companies such as Kohinoor Energy Ltd. (Pakistan), Can Don Hydro Power and Vinh Son Song Hinh Hydropower (Vietnam), Sahacogen Chonburi Public Company Ltd. (Thailand) and Ultrapar Participacoes (Brazil) stand out as investment alternatives that favor portfolio diversification within the energy markets because they receive the lowest spillovers from other firms.

In the third set of results, we find that the main transmitters of shocks at the market level are Romania, India, Vietnam, Pakistan, Mongolia, Philippines, Hong Kong, Turkey, Montenegro, Sri Lanka and Taiwan. In addition, Chinese (Huadian Power International Corporation, Huaneng Power International, China Petroleum & Chemical Corporation) and Brazilian firms (Centrais Eletricas Brasileiras, Petroleo Brasileiro, Centrais Eletricas Brasileiras, Companhia Energetica de Minas Gerais) stand out as the main spreaders of idiosyncratic risks. This means that these markets and firms, located in the core of the network, can induce additional volatility pressures in the system, which are largely unrelated to the global energy factors that affect all stocks simultaneously and which merit special monitoring on the part of corporate risk managers.

The remainder of the paper is structured as follows. Section 2 presents our data and Section 3 provides details of our methodological approach. Section 4 shows our main results and, finally, Section 5 reports the conclusions and implications of our study.

2. Data

Stock prices for energy firms (expressed in US dollars) were obtained from Bloomberg for a sample period that runs from January 13, 2010 to March 24, 2021. The sample comprises 219 firms from the energy sector listed in 27 emerging countries, predominantly in Asia. Firms with incomplete records were eliminated from the sample. Appendix 1 provides further details of the firms sampled.

The weekly returns of the energy firms were calculated from Wednesday to Wednesday to mitigate non-synchronous trading issues and weekend anomalies. For the country-level analysis, we constructed equally weighted index portfolios for each country. Table 1 summarizes the descriptive statistics of the weekly portfolio returns at the country level. According to the mean and median values, weekly portfolio returns oscillate around 0 and most are left-skewed. In addition, there is significant heterogeneity between countries in terms of return and risk. In general, the Asian energy stock markets present the lowest risk. Shapiro-Wilk test statistics reject the null hypothesis of normality in all cases and ADF test results indicate that all return series are stationary. Appendix 2 shows the descriptive statistics for the data at the firm level.

3. Methodology

We combine sparse VARs and factor models and adopt a two-step approach. First, in line with Fan et al. (2021), Barigozzi and Brownlees (2019) and other recent studies, we factor out an energy firm's stock returns using PCA. We, then, estimate the network model proposed by Demirer et al. (2018) on the idiosyncratic components of the returns. This approach allows us to calculate the spillover statistics proposed by Diebold and Yilmaz (2012, 2014) for a wide system of stock returns by reducing the parameter space of the VAR system through the LASSO.

We, first, estimate the common factors in the returns of our large set of energy firms via PCA in order to isolate the idiosyncratic components of the system. We estimate the following regression:

$$\boldsymbol{r}_t = \boldsymbol{\Lambda} \boldsymbol{F}_t + \boldsymbol{U}_t \tag{1}$$

Table 1
Descriptive statistics by country.

Region/Countries	Firms	Mean	Median	Std. Dev.	Min	Max	Skewness	Kurtosis	Shapiro-Wilk	ADF test
Asia & Oceania										
Hong Kong (HK)	6	0.0259	0.0670	2.4557	−11.6964	11.1737	−0.0588	4.9541	4.660***	−23.834***
China (CH)	32	0.1463	0.1678	3.4605	−26.1921	14.7383	−1.3201	14.8563	9.281***	−22.546***
Taiwan (TW)	11	0.1198	0.0700	2.1446	−13.9927	6.6731	−0.4873	6.8530	6.304***	−23.164***
South Korea (KS)	22	0.1762	0.2624	2.8607	−19.8321	13.4420	−0.6843	8.8084	7.251***	−23.364***
Pakistan (PK)	16	0.1420	0.0771	3.2730	−20.2799	11.7565	−0.5107	6.5090	6.024***	−20.254***
Sri Lanka (SL)	4	0.0809	−0.0909	3.0770	−11.6644	23.1816	1.3373	11.1483	8.537***	−24.403***
Thailand (TH)	18	0.2614	0.4581	3.2601	−20.4069	14.8670	−0.6874	7.9521	7.606***	−22.292***
Indonesia (IJ)	7	0.1801	0.2309	4.6934	−25.9236	24.5668	−0.0149	6.8352	6.931***	−20.492***
India (IN)	6	0.0175	0.1869	3.6570	−16.1070	13.5693	−0.1299	4.5649	4.439***	−21.872***
Singapore (SP)	2	−0.1390	−0.1295	3.8213	−20.9685	16.9669	0.0229	7.0587	7.289***	−22.360***
Malaysia (MK)	6	0.0805	0.0719	2.3148	−12.9017	9.4651	−0.3152	5.7736	5.679***	−24.339***
Philippines (PM)	8	0.1749	0.0551	2.7143	−12.3376	10.9881	−0.0833	5.0278	5.315***	−22.770***
Vietnam (VM)	11	0.0738	0.1664	2.5681	−12.0504	12.7383	−0.0498	6.1950	6.612***	−23.512***
Mongolia (MG)	5	0.1666	−0.4369	5.4444	−19.1571	39.0368	2.4328	16.1103	10.295***	−19.928***
Latin America										
Argentina (AR)	9	0.3051	0.4460	6.3224	−49.6263	30.1107	−0.8577	11.2159	7.926***	−23.283***
Brazil (BR)	18	0.0458	0.0188	4.3215	−28.4373	20.4246	−0.4570	7.9603	7.002***	−21.481***
Chile (CL)	6	−0.0287	−0.0226	3.2640	−24.4674	13.4432	−0.3595	9.0507	7.064***	−24.261***
Peru (PE)	5	0.1001	−0.0395	2.7103	−19.1099	20.0205	0.3859	13.1668	8.603***	−21.800***
Colombia (CO)	4	0.0539	0.2573	3.8687	−30.2266	24.1598	−0.6451	14.4056	8.945***	−23.728***
Europe										
Romania (RM)	2	0.1762	0.1374	3.4622	−13.9996	15.0427	0.1153	5.2180	6.061***	−23.556***
Montenegro (MN)	2	0.0819	−0.0632	3.9675	−18.0413	23.7765	0.4487	7.5878	7.866***	−28.787***
Czech Republic (CR)	1	−0.0587	0.0712	3.5207	−20.5877	16.9211	−0.1008	6.7200	6.361***	−26.208***
Russia (RU)	11	0.1227	0.1938	4.4541	−27.9081	29.6397	−0.2121	11.0673	8.450***	−24.440***
Slovenia (SV)	1	0.0382	0.0398	3.0347	−16.0297	15.6794	0.1009	6.4210	6.325***	−24.139***
Turkey (TK)	2	0.0250	0.2169	4.7959	−26.3367	19.5193	−0.3914	6.0378	5.927***	−26.092***
Bosnia-Herzegovina (BH)	3	−0.0099	−0.3059	5.5317	−16.4906	62.3759	4.4211	46.0979	11.400***	−18.849***
Hungary (HG)	1	0.0139	−0.0523	4.7626	−28.4656	27.6560	−0.0977	8.6828	7.614***	−26.263***

Note: Statistics are reported as percentage points. Data correspond to equally weighted index portfolio returns for each country. Sample period extends from January 13, 2010 to March 24, 2021. Shapiro-Wilk refers to the Shapiro-Wilk test for the null of normality. ADF corresponds to the Augmented Dickey-Fuller unit root test, which only considers the random walk specification. Superscripts ***, **, * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

where $\boldsymbol{r}_t$ are the stock returns in time t, $\boldsymbol{F}_t$ is a vector of latent common factors, and $\boldsymbol{U}_t$ is an idiosyncratic component described as residual stock returns. Eq. (1) estimates the vector containing the factor loadings, $\boldsymbol{\Lambda}$, and $\boldsymbol{F}_t$ for $t = 1, \ldots, T$ by means of PCA.

Once the stock returns have been filtered from their systematic components, we use the methodological framework developed by Demirer et al. (2018) to study the connectedness between countries or energy firms. Demirer et al. (2018) extend Diebold and Yilmaz's approach (2012, 2014) using LASSO methods, which facilitates the handling of large data sets, selecting and shrinking in optimal ways. Consider a covariance stationary N-variable sparse VAR(p) model for the vector of (filtered) energy stock returns $\boldsymbol{x}_t$:

$$\boldsymbol{x}_t = \sum_{i=1}^{p} \boldsymbol{\Phi}_i \boldsymbol{x}_{t-i} + \boldsymbol{\varepsilon}_t \tag{2}$$

where $\boldsymbol{\varepsilon}_t \sim (\mathbf{0}, \boldsymbol{\Sigma})$ is a vector of non-autocorrelated disturbances. The moving average representation for $\boldsymbol{x}_t$ is:

$$\boldsymbol{x}_t = \sum_{i=0}^{\infty} \mathbf{A}_i \boldsymbol{\varepsilon}_{t-i} \tag{3}$$

where the $N \times N$ coefficient matrices $\boldsymbol{A}_i$ obey the recursion $\mathbf{A}_i = \boldsymbol{\Phi}_1 \mathbf{A}_{i-1} + \boldsymbol{\Phi}_2 \mathbf{A}_{i-2} + \cdots + \boldsymbol{\Phi}_p \mathbf{A}_{i-p}$ with $\boldsymbol{A}_0$ being an identity matrix and $\boldsymbol{A}_i = 0$ for $i < 0$. The moving average coefficients are relevant to understand the system dynamics and connectedness measures. Next, through the LASSO algorithm, the parameters in $\boldsymbol{\Phi}_i$ can be obtained by solving:

$$\widehat{\boldsymbol{\Phi}} = \underset{\boldsymbol{\Phi}}{arg\,min} \sum_{t=1}^{T} \left(\boldsymbol{x}_t - \sum_{i=1}^{p} \boldsymbol{\Phi}_i \boldsymbol{x}_{t-i} \right)^2 \tag{4}$$

subject to the constraint:

$$\sum_{i=1}^{p} |\boldsymbol{\Phi}_i|^q \leq c$$

where LASSO solves the penalized regression with $q = 1$. Smoothly convex penalties (for example, $q = 2$) produce shrinkages, as is the case with ridge regression. From the forecast error variance decomposition of the sparse VAR model, Demirer et al. (2018) compute the connectedness measures proposed by Diebold and Yilmaz (2012, 2014). These measures use the generalized VAR modeling framework proposed by Koop et al. (1996) and Pesaran and Shin (1998), hereinafter KPPS, to produce variance decompositions invariant to the ordering of the series. For $H = 1, 2, \ldots$, we denote the KPPS H-step-ahead forecast error variance decomposition as:

$$\theta_{ij}^{g}(H) = \frac{\sigma_{jj}^{-1} \sum_{h=0}^{H-1} \left(\boldsymbol{e}_i' \boldsymbol{A}_h \boldsymbol{\Sigma} \boldsymbol{e}_j \right)^2}{\sum_{h=0}^{H-1} \left(\boldsymbol{e}_i' \boldsymbol{A}_h \boldsymbol{\Sigma} \boldsymbol{A}_h' \boldsymbol{e}_i \right)} \tag{5}$$

where $\boldsymbol{\Sigma}$ is the variance matrix of the error vector $\boldsymbol{\varepsilon}_t$, σ_{jj} is the standard deviation of the error of the j-th equation and $\boldsymbol{e}_i$ is a selection vector with value one at the i-th element and zero otherwise. As the sum of the elements of each row in Eq. (5) is not equal to 1 $\left(\sum_{j=1}^{N} \theta_{ij}^{g}(H) \neq 1 \right)$, in order to obtain a unit sum of each row of the variance decomposition matrix, the following normalization has to be conducted for each entry:

$$\widetilde{\theta}_{ij}^{g}(H) = \frac{\theta_{ij}^{g}(H)}{\sum_{j=1}^{N} \theta_{ij}^{g}(H)} \tag{6}$$

where by construction $\sum_{j=1}^{N} \widetilde{\theta}_{ij}^{g}(H) = 1$ and $\sum_{i,j=1}^{N} \widetilde{\theta}_{ij}^{g}(H) = N$. Thus, Eq. (6) constitutes a natural measure of the pairwise directional connectedness from firm/country j to firm/country i. Using the KPSS variance decomposition, the total spillover or system-wide connectedness can be represented by:

$$S^{g}(H) = \sum_{\substack{i,j=1 \\ i \neq j}}^{N} \frac{\widetilde{\theta}_{ij}^{g}(H)}{\sum_{i,j=1}^{N} \widetilde{\theta}_{ij}^{g}(H)} = \sum_{\substack{i,j=1 \\ i \neq j}}^{N} \frac{\widetilde{\theta}_{ij}^{g}(H)}{N} \tag{7}$$

This spillover measure quantifies the contribution of the shocks of the energy firm/country i to the forecast error variance (Diebold and Yilmaz, 2009). Next, the total directional spillover received by energy firm/country i from all other energy firms/countries j is:

$$S_{i \leftarrow \circ}^{g}(H) = \sum_{\substack{j=1 \\ j \neq i}}^{N} \frac{\widetilde{\theta}_{ij}^{g}(H)}{\sum_{i,j=1}^{N} \widetilde{\theta}_{ij}^{g}(H)} = \sum_{\substack{j=1 \\ j \neq i}}^{N} \frac{\widetilde{\theta}_{ij}^{g}(H)}{N} \tag{8}$$

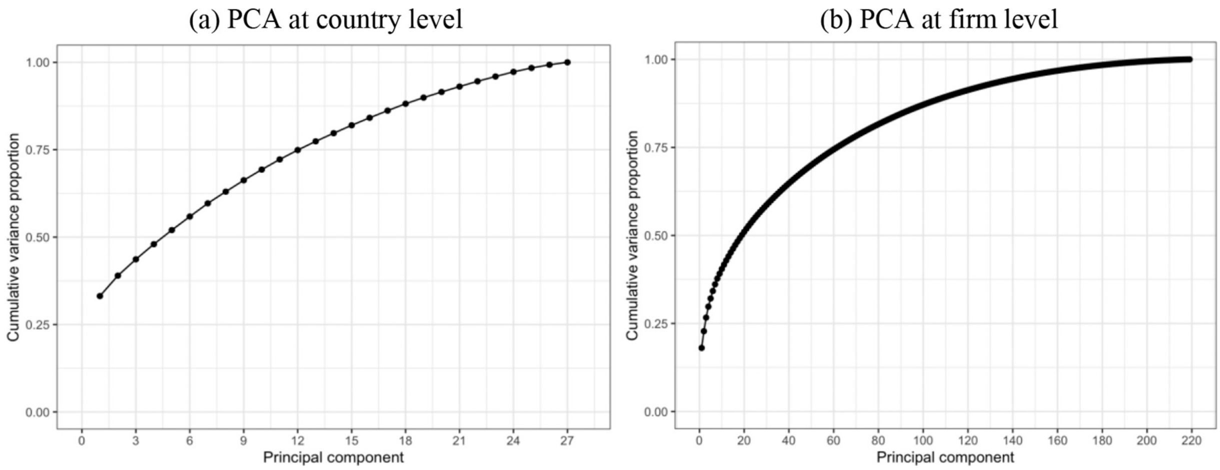


Fig. 1. Principal components and the explained share of energy stock returns variance.
Notes: Fig. 1 shows the explained share of energy stock returns variance, both at the (a) country level and (b) firm level, as a function of the number of principal components. Source: Authors' computation.

Similarly, the total directional spillover from firm/country i to the other energy firms/countries j is:

$$S^{g}_{\circ\leftarrow i}(H) = \sum_{\substack{j=1 \\ j\neq i}}^{N} \frac{\widetilde{\theta}^{g}_{ji}(H)}{\sum_{i,j=1}^{N}\widetilde{\theta}^{g}_{ji}(\mathrm{H})} = \sum_{\substack{j=1 \\ j\neq i}}^{N} \frac{\widetilde{\theta}^{g}_{ji}(H)}{N} \tag{9}$$

Finally, the net spillover from firm/country i to the remaining energy firms/countries j is:

$$S^{g}_{i}(H) = S^{g}_{\circ\leftarrow i}(H) - S^{g}_{i\leftarrow\circ}(H) \tag{10}$$

Based on our two-step methodology, all spillover measures reflect shocks determined by idiosyncratic factors of the energy firms/countries and are unaffected by the systematic common factors.

4. Empirical results

4.1. Effects of global common factors on energy stock returns

Fig. 1 shows the amount of variance explained by each of the principal components associated with our original series, in decreasing order, at both country and firm levels. To implement the method proposed by Fan et al. (2021), we estimate Eq. (1) by OLS regression for each time series of stock returns for either the country or firm, depending on whether the analysis is developed at the country or firm level. The regressors correspond to the k-first principal components. The selection criterion considers that the principal components must explain at least 50% of the stock returns variance. For this reason, for the country-level analysis, we used the first five principal components, which explain 52.01% of the returns variance, while for the firm-level analysis, the first 20 components were used, accounting for 51.03% of the variance. Our results are robust to variations of these numbers.

Fig. 2a shows the Pearson correlations between energy stock markets at the country level. Two relevant facts stand out. First, in most cases we observe positive and significant correlations between energy stock markets. The markets of China and Vietnam show the lowest correlations. This indicates that among emerging countries the energy stock markets are closely integrated, which allows for contagion and risk spillovers and limits diversification opportunities within these markets. Second, in most cases the correlations between the energy stock markets of Sri Lanka, Mongolia and Bosnia-Herzegovina, on the one hand, and the other markets, on the other, present insignificant correlations. Initially, these results indicate that these markets allow risk diversification within the energy sector. Fig. 3a shows similar patterns in the correlations between the energy stock returns at the firm level.

Residual stock returns, obtained following Eq. (1), correspond to idiosyncratic components of countries and firms. Figs. 2b and 3b show the correlations of the residual returns at the country and firm levels, respectively. These returns show lower correlations than those presented in Figs. 2a and 3a, respectively. We conclude from visual inspection that non-idiosyncratic components in emerging energy stock markets play a prominent role in understanding diversification and risk transmission across markets.

4.2. Network comparison

Demirer et al. (2018) extend the methodology proposed by Diebold and Yilmaz (2012, 2014) using a LASSO-VAR model. This approach allows us to compute the connectedness measures using a high-dimensional data structure. In our case, we follow the

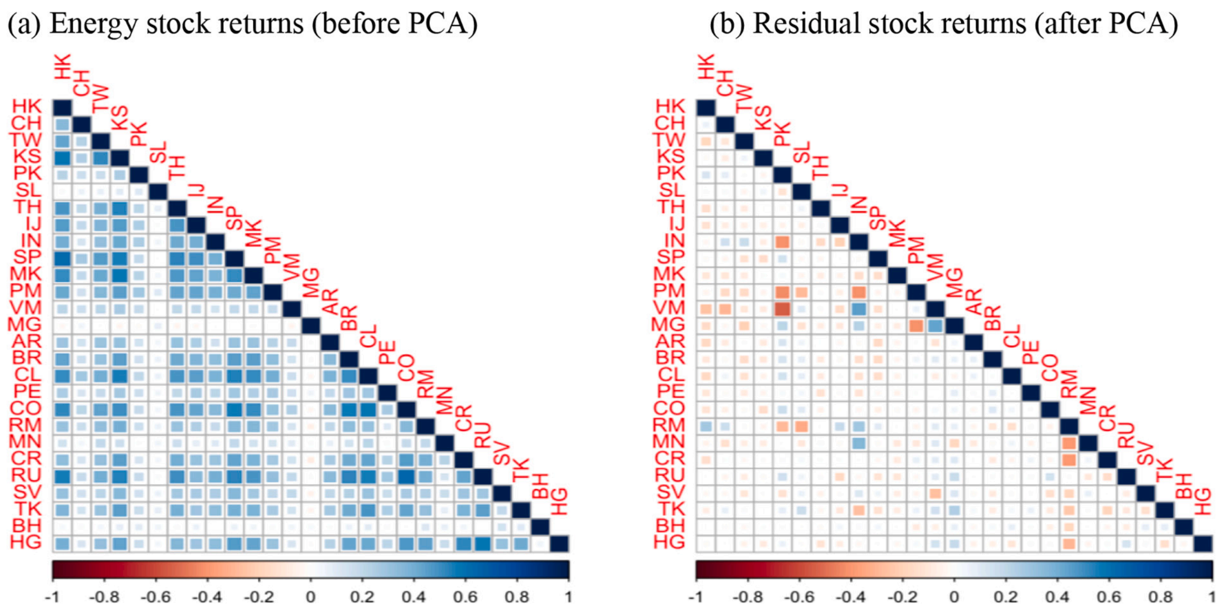


Fig. 2. Unconditional correlation matrix for energy stock returns at country level.
Notes: Fig. 2 shows the correlation matrices between the stock returns of the 27 energy markets before (Panel a) and after (Panel b) removing the common global factors estimated by PCA. Source: Authors' computation.

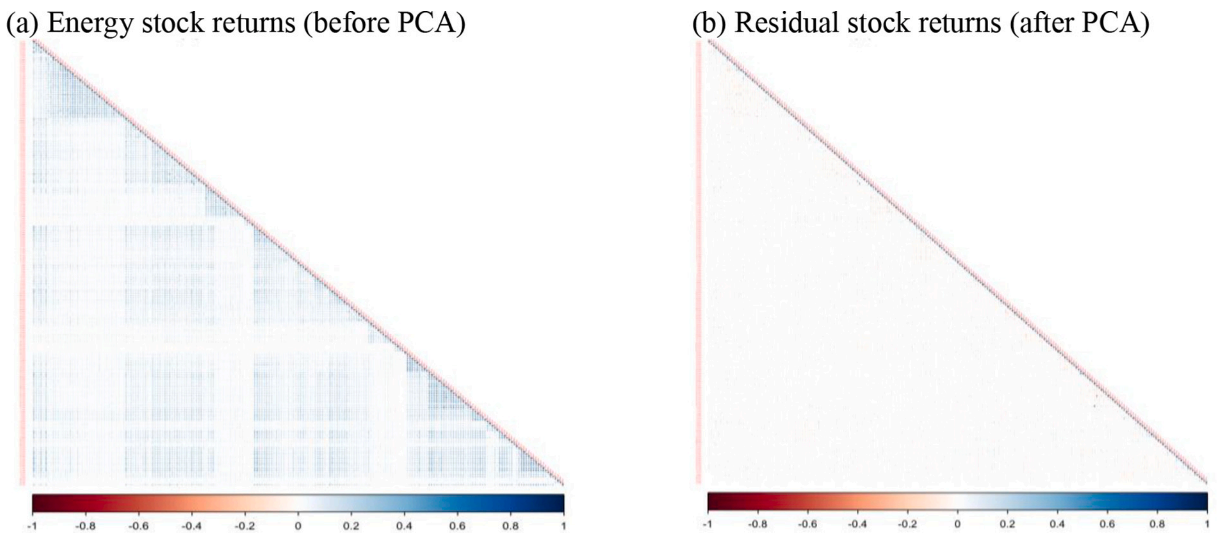
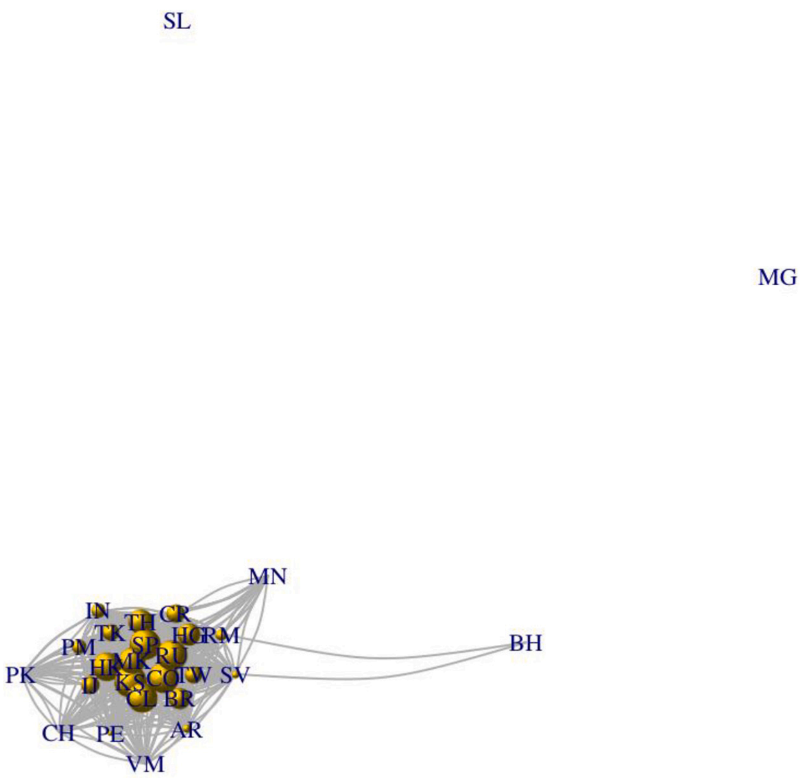


Fig. 3. Unconditional correlation matrix for energy stock returns at firm level.
(a) Energy stock returns (before PCA) (b) Residual stock returns (after PCA).
Notes: Fig. 3 shows the correlation matrices between the stock returns of the 219 energy firms before (Panel a) and after (Panel b) removing the common global factors estimated by PCA. Source: Authors' computation.

approach of Demirer et al. (2018) and we use a LASSO-VAR(1) model. To compute the spillover measurement, we consider a KPPS 10-week-ahead forecast error variance decomposition.[1] At the country level, the spillover statistic for the energy stock returns of the total system is 61.43%, while for the idiosyncratic returns it falls to 24.45%. At the firm level, the corresponding spillover index is 82.97%, falling to 39.92% for energy returns once common global factors are taken into consideration. This finding reveals the importance of the systematic and non-idiosyncratic common factors, which act as a channel that facilitates the transmission of shocks between energy stock markets.

[1] Previous literature usually uses a 10-steps-ahead horizon (see for example Zhang, 2017; Ahmad and Rais, 2018; Lundgren et al., 2018; Singh et al., 2019; Evrim et al., 2020; Foglia and Angelini, 2020; Fuentes and Herrera, 2020).

(a) Energy stock returns (before PCA)
Total spillover index: 61.43%



(b) Residual stock returns (after PCA)
Total spillover index: 24.45%

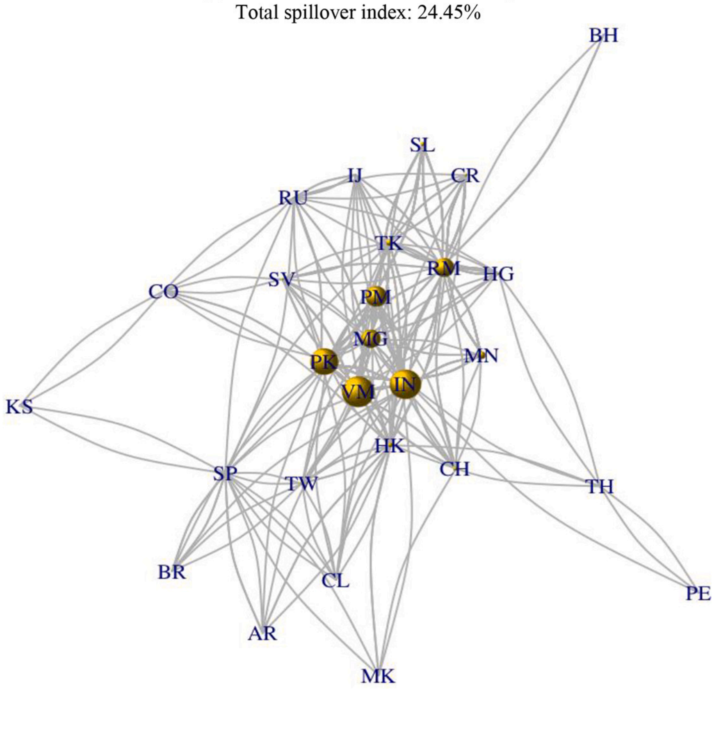


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Fig. 4. Spillover network at the country level.
Note: Spillover network was computed through LASSO-VAR(1). Spillover statistics consider a KPPS 10-week-ahead forecast error variance decomposition. The size of the nodes represents the relative importance of the spillovers to other energy markets. Source: Authors' computation.

Figs. 4 and 5 present the spillover networks and matrices at the country level, corresponding to the forecast error variance decomposition of the whole system. Fig. 4a shows that most of the energy stock markets are highly connected. The energy markets of Sri Lanka, Mongolia, Bosnia-Herzegovina and Montenegro are the least sensitive to shocks from other markets, followed by China, Vietnam, Pakistan, Peru, Argentina and Slovenia, which also receive relatively small shocks. At first glance, all these markets would allow highly diversified portfolios to be constructed in the energy sector, using stocks listed on the emerging markets. However, these possibilities are affected by the incidence of global common factors.

When these global factors are considered, the network based on residual stock returns presents a more dispersed structure (Fig. 4b), which explains the lower spillover index (24.45%) and the fewer number of linkages between the markets in the new representation. Diversification opportunities should ideally be explored in the least connected markets within the network of idiosyncratic returns. Fig. 5 shows the matrix of spillovers transmitted and received by the 27 energy markets. To the extent that these spillovers are less intense, the level of connectivity between markets is lower. This means that the nodes that represent these markets within the global network are located in the most peripheral areas. That is why when we compare Figs. 4b and 5b, we observe that the energy markets with lower idiosyncratic spillovers are represented by less connected nodes within the network and located in external areas. Similarly, the energy stock markets with the highest spillovers in Fig. 5b are those located in the central zone of the network described in Fig. 4b. Finally, when we compare Figs. 4a and 5a we can conclude that the greater magnitude of the spillovers and the denser structure of the global network of energy markets is due to the incidence of common global factors.

We observed similar results at the firm level, although with a greater degree of heterogeneity within each country. Fig. 6 depicts the spillover network between the 219 energy firms. This shows that the total spillover of the entire stock returns system was 82.97%, with 126 firms being net receivers of shocks and 93 net transmitters. The energy stocks of Chinese and Russian firms generate the largest spillovers (Fig. 6a). The energy companies from Mongolia and Bosnia-Herzegovina do not experience significant spillovers with energy firms from other markets. Other markets, including those of South Korea, Thailand, Taiwan, Vietnam, Philippines, Sri Lanka, Pakistan, Montenegro, Argentina, Brazil and Peru are located in the periphery of the network and have more significant spillovers with relation to energy markets located in the core area of the network. In general, the firms of these countries are net receivers of shocks. Here again, these results are influenced by global common factors.

When we control for global non-idiosyncratic factors, the total spillover index falls to 39.92%. This, in line with what was observed at the country level, corroborates the relevance of non-idiosyncratic components for risk transmission. As occurred at the country level, the network of idiosyncratic components presents a more dispersed structure and less intense spillovers between firms (Fig. 6b). In this case, 135 energy firms are net receivers of shocks and 84 are net transmitters. The periphery of the network is made up of companies from South Korea, Pakistan, Thailand, Taiwan, Vietnam, Philippines, Indonesia, Mongolia, Bosnia-Herzegovina, China, Czech Republic, Argentina and Brazil. Interestingly, the renewable energy firms show similar levels of connectedness to those shown by conventional energy firms within the same country.

4.3. Diversification opportunities in the emerging markets energy network

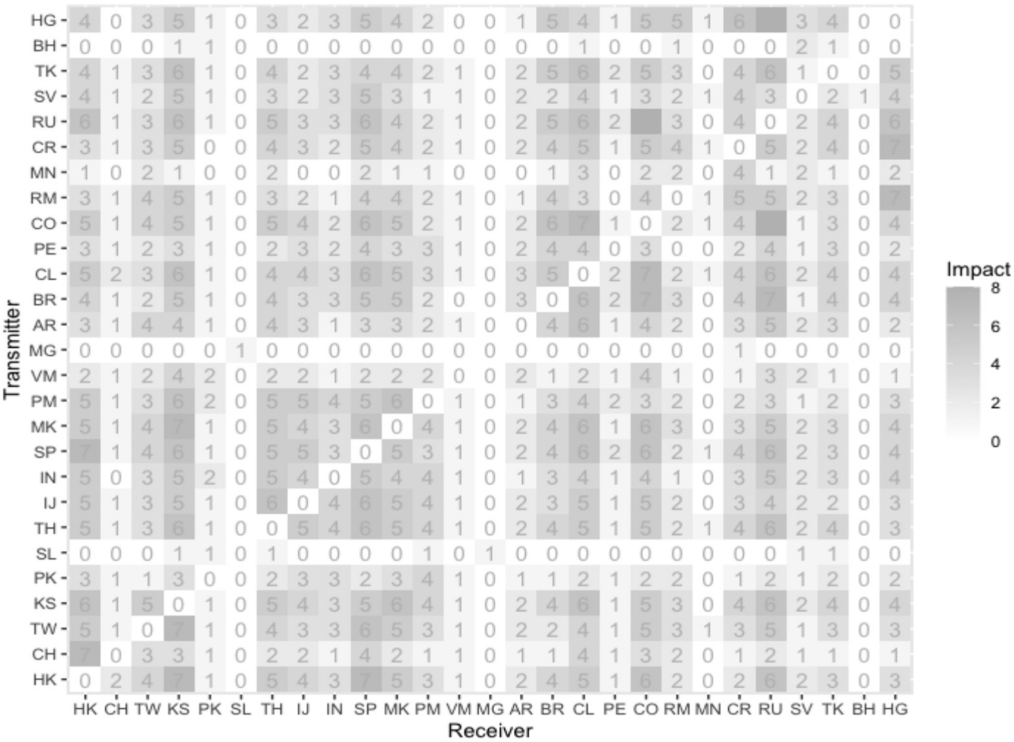
The results discussed in the previous section reveal that non-idiosyncratic components of energy stock markets in emerging economies constitute an important amplification mechanism for international spillovers of risk. After removing the effect of the common factor structure, the effects of the idiosyncratic component of each country or market can be visualized (Barigozzi and Brownlees, 2019; Fan et al., 2021). This decomposition has direct implications for investment decisions since this component reflects the incidence of the specific qualities of the companies or markets, and it is completely diversifiable through energy stock portfolios.

Table 2 lists the 11 energy markets presenting the lowest spillovers received from other markets using the idiosyncratic returns. At the country level, the markets of Peru, Bosnia-Herzegovina, South Korea, Thailand, and Argentina stand out as being the least vulnerable in the network of emerging stock energy markets. They are followed by the markets of Malaysia, Colombia, Chile, Brazil, Indonesia and Russia. These countries are also characterized by transmitting somewhat smaller spillovers than those that they receive.

Following Karim et al. (2022), we also calculate the centrality index as a way of comparing and complementing the location of the markets/companies within the global network of energy markets with respect to the spillovers received or transmitted. Naturally, a lower (higher) centrality index is associated with a market/firm located in the outer or peripheral (central) areas of the network and, ultimately, with a lower (higher) degree of exposure to shock transmission. After calculating the centrality index of each market/company, we determine the median centrality of the entire system, a figure that will be used as a benchmark to classify the position of each node as peripheral (below the median) or central (above the median). At the aggregate level, the markets in Table 2 present indicators that are lower than the median centrality of the entire system (20.0), which places them on the periphery of the market network. Thus, in addition to the low spillover effects they receive from the rest of the system and their lower connectedness degree to the network, endow these markets with relevant diversification characteristics that can be exploited by international investors. Appendix 3 shows the spillovers and centrality statistics for all the countries.

Table 3 lists the 35 companies with the lowest spillovers received from other emerging market energy companies. As with the results at the country level, these firms are the least vulnerable because they receive the least shocks from the system and transmit comparatively minor spillovers to other companies. In fact, almost two-thirds of these companies belong to the least vulnerable

(a) Energy stock returns (before PCA)
Total spillover index: 61.43%



(b) Residual stock returns (after PCA)
Total spillover index: 24.45%

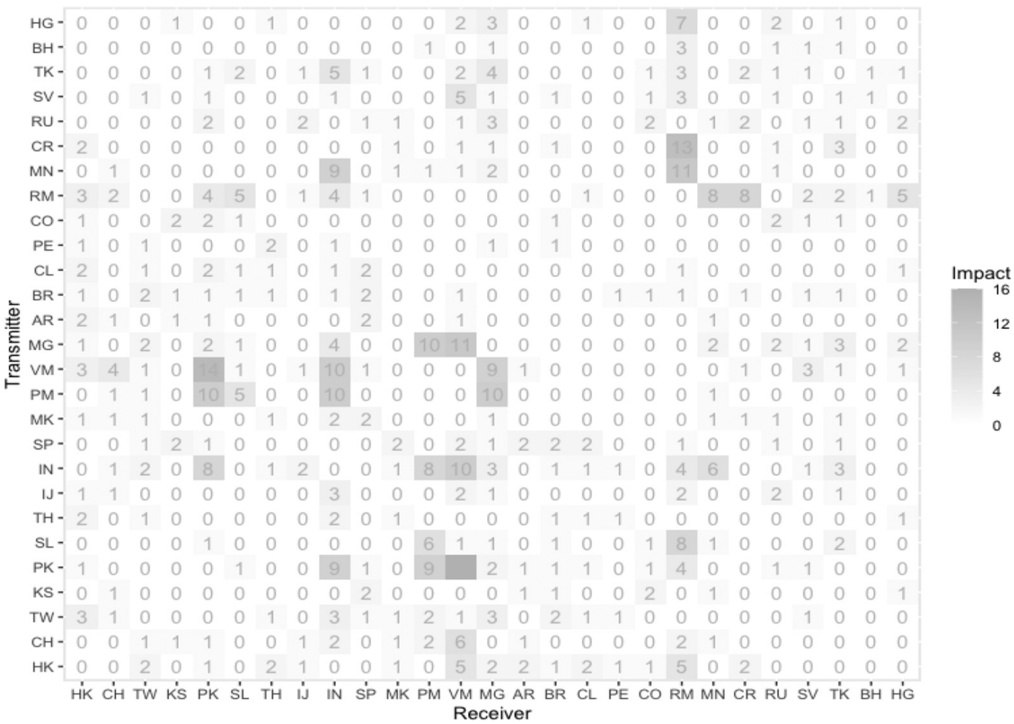


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Fig. 5. Spillover matrix at the country level.
Note: The spillover matrices in the two panels of the figure were computed through a LASSO-VAR(1) model. Spillover statistics consider a KPPS 10-week-ahead forecast error variance decomposition in the two cases. The spillover statistics have been scaled to a range between 0 and 100 and rounded to the nearest integer. For instance, if the spillover statistic is 3 in either of the matrices, it means that the spillover from the market in the first column of the figure to the market in the last row is 3%. Source: Authors' computation.

markets described in Table 2. However, greater heterogeneity can be seen between firms from different countries in addition to spillover effects of greater magnitude than those observed in the network at the country level. This shows that at the firm level, connectedness is more intense than that of the global network at the country level. Companies such as Kohinoor Energy Ltd. (Pakistan), Can Don Hydro Power and Vinh Son Song Hinh Hydropower (Vietnam), Sahacogen Chonburi Public Company Ltd. (Thailand) and Ultrapar Participacoes (Brazil) stand out as investment alternatives that favor portfolio diversification within emerging energy markets. Naturally, the firms described in Table 3 are located on the periphery of the network, corresponding to centrality indices lower than the median centrality of the entire system (13.0). See Appendix 4 for details on the centrality of all firms.

4.4. Idiosyncratically relevant emerging markets and firms

In this section we identify the most idiosyncratically relevant energy markets and firms within the global network. These are the ones that are able to generate high spillovers within the energy system that are not related to systematic shocks. These are located in the core areas of the network. In contrast, the least vulnerable markets or firms which are less exposed to idiosyncratic shocks from other markets or firms are located on the periphery of the network. Table 4 shows the energy markets with the largest spillovers transmitted to other countries, i.e., these markets have a greater idiosyncratic incidence on the global network of energy markets. In general, these markets present centrality indicators above the system median, placing them in the most central areas of the network (Karim et al., 2022). Markets such as Romania, India, Vietnam, Pakistan, Mongolia, Philippines, Hong Kong, Turkey, Montenegro, Sri Lanka and Taiwan transmit the most significant shocks to other emerging countries in the network. At the country level, it is evident that the markets described in Table 3 constitute relevant channels for international spillover risk transmission in emerging energy markets. Appendix 3 shows the spillovers and centrality statistics for all countries.

Table 5 shows the 35 energy companies with the highest spillovers to other firms. Two interesting points emerge that merit discussion. First, all these companies are net transmitters of shocks and, according to their centrality index, they are located in the core areas of the network. The magnitude of their spillovers, both transmitted and received, are greater than those observed in the network at the country level. For this reason, these energy firms can be said to facilitate the spread of risk between these energy companies at the global scale. Chinese (Huadian Power International Corporation, Huaneng Power International, China Petroleum & Chemical Corporation) and Brazilian companies (Centrais Eletricas Brasileiras, Petroleo Brasileiro, Centrais Eletricas Brasileiras, Companhia Energetica de Minas Gerais) stand out as relevant nodes in our network through which financial risk propagates. Second, there is a greater degree of heterogeneity in the identification of idiosyncratically important firms compared to that of countries. Less than a third of the idiosyncratically important companies indicated in Table 5 belong to the markets with the highest spillovers described in Table 4. Moreover, more than 50% of these firms belong to the less vulnerable and interconnected markets of the network. This reveals that a full network description, at the firm level, provides more detailed and useful information for investment decision making.

5. Conclusions and discussion

Previous studies of energy stock markets have considered market connectedness by using aggregate indices or by focusing solely on developed markets. Here, we have studied market connectedness using firm-level returns and by emphasizing the role of emerging markets in the global energy network. Methodologically, our study also differs from the previous literature insofar as we leverage recent advances in sparse VAR estimation within a time-series factor structure (see Fan et al., 2021). We separate the idiosyncratic from the non-idiosyncratic components of the energy stock returns, and estimate a network using the LASSO-VAR model, proposed by Demirer et al. (2018), to account for the high-dimensionality of our data.

Three main results emerge from our analysis. First, we show that emerging energy stock markets are closely integrated even after controlling for global energy factors. Moreover, the contribution of both systematic and idiosyncratic factors are clearly identified. The total cross spillover of our system at the country level is 61.43%, but once we filter out the non-idiosyncratic effects, this falls to 24.45%. At the firm level, the same procedure reduces total cross spillover from 82.97 to 39.92%. For this reason, we stress the importance of common systematic factors of asset prices for understanding energy market connectedness. In other words, global common factors largely determine shock transmission between energy firms in emerging markets. Nevertheless, our results also allow us to identify energy markets (and firms) that are able to generate high spillovers within the energy-finance system that are not related to systematic shocks. In summary, when monitoring emerging market energy companies, both for risk monitoring and portfolio pricing, systematic and idiosyncratic factors must be carefully considered in the lines proposed herein.

Closely related to this last point, we identify the least vulnerable markets and firms within the energy market network. These markets or firms are located on the periphery of the network and are less exposed to shocks from other markets or firms. Countries such as Peru, Bosnia-Herzegovina, South Korea, Thailand, Argentina, Malaysia, Colombia, Chile, Brazil, Indonesia and Russia offer important advantages for risk diversification. At the firm level, our results are more heterogeneous. Companies such as Kohinoor Energy (Pakistan), Can Don Hydro Power and Vinh Son Song Hinh Hydropower (Vietnam), Sahacogen Chonburi Public (Thailand) and

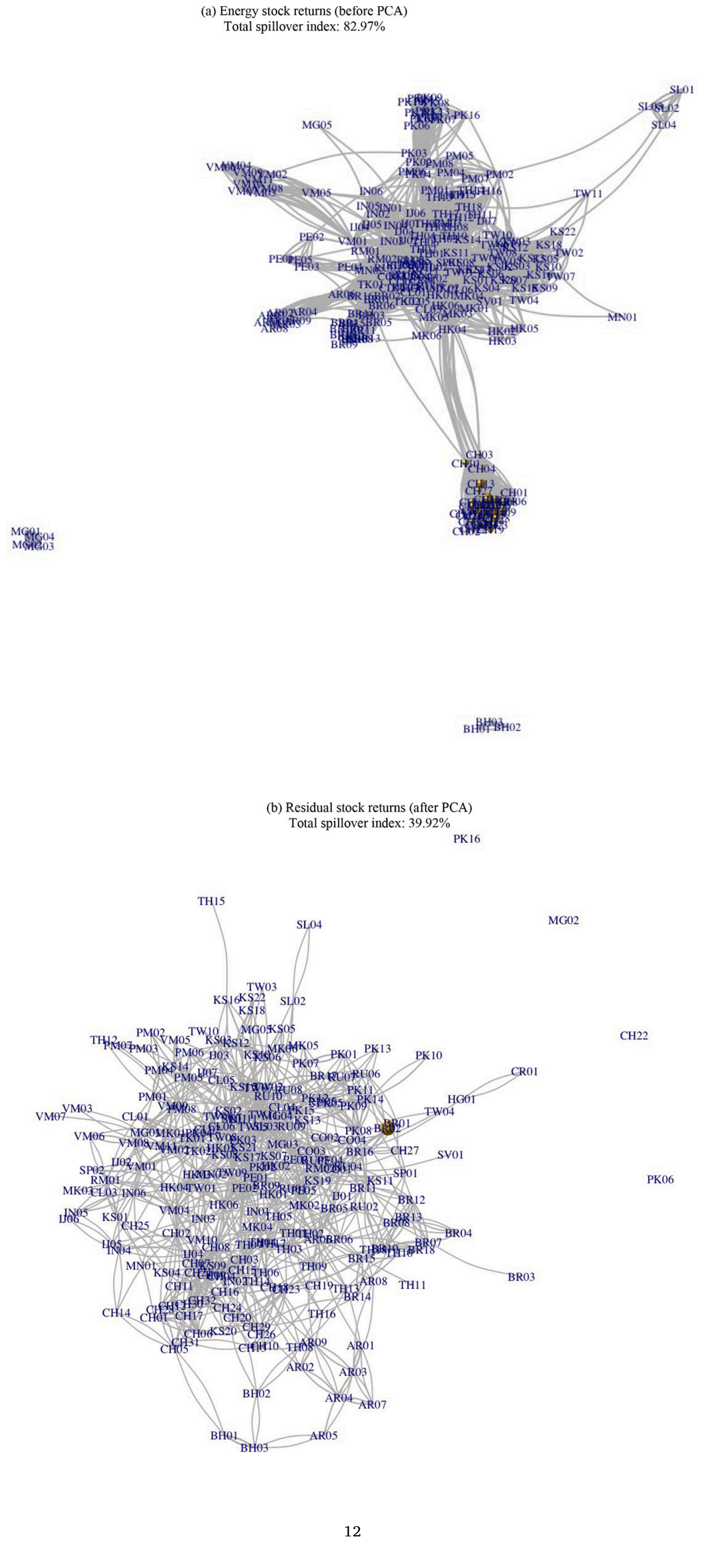

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Fig. 6. Spillover network at firm level.
Note: Spillover matrix was computed through LASSO-VAR(1). Spillover statistics consider a KPPS 10-week-ahead forecast error variance decomposition. The size of the nodes represents the relative importance of the spillovers to other energy firms. Source: Authors' computation.

Table 2
Energy markets with lowest level of connectedness in the network: *lowest spillovers from others.*

Country	Spillover From	Spillover To	Net Spillover	Centrality
Peru (PE)	7.94	6.36	−1.58	3
Bosnia-Herzegovina (BH)	8.23	5.89	−2.34	3
South Korea (KS)	10.13	8.86	−1.27	4
Thailand (TH)	11.26	9.15	−2.12	7
Argentina (AR)	11.37	9.12	−2.25	8
Malaysia (MK)	12.61	10.62	−1.99	6
Colombia (CO)	14.01	11.59	−2.43	10
Chile (CL)	14.60	12.39	−2.21	11
Brazil (BR)	15.96	13.74	−2.22	8
Indonesia (IJ)	16.02	11.93	−4.09	15
Russia (RU)	18.19	16.17	−2.02	18

Note: Spillover effects computed from LASSO-VAR(1) and considering a KPPS 10-week-ahead forecast error variance decomposition. The total spillover of the system was 24.45% at the country level. Centrality corresponds to the number of links related to each node (vertex), both incoming and outgoing from each node. The median of the centrality measure was 20. Source: Authors' computation.

Table 3
Energy firms with lowest level of connectedness in the network: *lowest spillovers from others.*

Country	Firm	Firm code	Spillover From	Spillover To	Net Spillover	Centrality
Pakistan	Kohinoor Energy Ltd.	PK16EN	26.92	21.38	−5.54	0
Vietnam	Can Don Hydro Power JSC.	VM07RE	27.56	23.75	−3.81	1
Thailand	Sahacogen Chonburi Public Co. Ltd	TH16EN	27.88	23.78	−4.10	3
Vietnam	Vinh Son Song Hinh Hydropower JSC.	VM03EN	28.23	23.42	−4.81	2
Brazil	Ultrapar Participacoes S.A.	BR03EN	28.78	21.87	−6.91	1
Mongolia	HB Oil JSC	MG05EN	29.19	25.03	−4.17	2
South Korea	Kukdong Oil & Chemicals Co., Ltd.	KS14EN	29.73	25.32	−4.41	5
Czech Republic	CEZ AS	CR01EN	30.28	26.32	−3.96	2
Argentina	Central Puerto SA.	AR05EN	30.41	26.80	−3.61	5
Taiwan	National Petroleum Co., Ltd.	TW04EN	30.51	26.62	−3.89	2
Hungary	MOL Hungarian Oil & Gas PLC	HG01EN	31.06	27.47	−3.60	3
Pakistan	Attock Petroleum Ltd.	PK11EN	31.13	27.73	−3.40	8
Thailand	SUSCO.	TH15EN	31.24	27.43	−3.81	1
Thailand	Siamgas & Petrochemicals.	TH10EN	31.59	27.70	−3.89	4
Indonesia	PT Elnusa.	IJ03EN	31.68	27.72	−3.96	6
Malaysia	Tenaga Nasional Berhad.	MK03EN	31.71	27.62	−4.09	2
Thailand	SPCG.	TH11EN	31.71	27.61	−4.10	1
Vietnam	PetroVietnam Low Press. Gas Distrib. JSC	VM05EN	31.74	27.35	−4.38	5
Montenegro	Jugopetrol ad Podgorica	MN02EN	31.84	25.87	−5.97	6
Mongolia	Sharyn Gol JSC	MG02EN	31.85	27.11	−4.74	0
South Korea	Korea Gas Corporation.	KS01EN	31.99	28.66	−3.33	7
China	Henan Ancai Hi-Tech Co., Ltd.	CH22EN	32.23	28.34	−3.89	0
Thailand	Rojana Indust. Park Public Company Ltd	TH12EN	32.29	25.49	−6.80	2
Argentina	Empresa Distrib. y Comercial Norte S.A.	AR07EN	32.42	29.48	−2.94	8
Montenegro	Elektroprivreda Crne Gore ad Niksic	MN01EN	32.48	26.19	−6.28	2
Indonesia	PT Medco Energi Internasional.	IJ02EN	32.53	28.79	−3.74	2
South Korea	SGC Energy Co.,Ltd.	KS05EN	32.62	29.37	−3.25	5
Thailand	Super Energy Corp. Public Company Ltd.	TH09EN	32.68	28.90	−3.78	8
Taiwan	Shan-Loong Transportation Co., Ltd.	TW09EN	32.74	29.15	−3.59	5
Indonesia	PT Rukun Raharja Tbk.	IJ06EN	32.90	29.48	−3.42	4
Brazil	Comp. Transm. Energia Eletrica Paulista	BR17EN	33.21	28.58	−4.63	10
China	Guang. Meiyan Jixiang Hydrop. Co. Ltd.	CH14EN	33.27	30.05	−3.22	5
Chile	AES Andes S.A.	CL03EN	33.33	30.32	−3.01	3
Argentina	Transportadora de Gas del Norte SA.	AR08EN	33.33	28.92	−4.41	5
Bosnia-Herzegovina	Rite Gacko	BH03EN	33.37	30.55	−2.82	16

Note: Spillovers effects computed from LASSO-VAR(1) and considering a KPPS 10-week-ahead forecast error variance decomposition. The total spillover of the system was 39.92% at the firm level. Centrality corresponds to the number of links related to each node (vertex), both incoming and outgoing from each node. The median of the centrality measure was 13. Source: Authors' computation.

Table 4
Most relevant energy markets in the network: *highest spillovers to others.*

Country	Spillover From	Spillover To	Net Spillover	Centrality
Romania (RM)	49.39	69.87	20.48	101
India (IN)	52.55	68.64	16.09	102
Vietnam (VM)	52.53	67.56	15.02	98
Pakistan (PK)	49.27	54.82	5.55	85
Mongolia (MG)	43.83	47.74	3.91	70
Philippines (PM)	41.22	41.19	−0.02	68
Hong Kong (HK)	27.35	25.92	−1.44	34
Turkey (TK)	27.91	25.28	−2.63	35
Montenegro (MN)	29.94	24.01	−5.93	39
Sri Lanka (SL)	24.10	19.56	−4.54	27
Taiwan (TW)	20.76	18.26	−2.50	20

Note: Spillovers effects computed from LASSO-VAR(1) and considering a KPPS 10-week-ahead forecast error variance decomposition. The total spillover of the system was 24.45% at the country level. Centrality corresponds to the number of links related to each node (vertex), both incoming and outgoing from each node. The median of the centrality measure was 20. Source: Authors' computation.

Table 5
Most relevant energy firms in the network: *highest spillovers to others.*

		Firm code	Spillover From	Spillover To	Net Spillover	Centrality
China	Huadian Power International Corporation Ltd	CH09EN	59.33	77.00	17.67	70
Brazil	Centrais Eletricas Brasileiras S.A.	BR13EN	57.88	71.64	13.76	63
China	Huaneng Power International, Inc.	CH08EN	57.31	71.57	14.26	54
Brazil	Petroleo Brasileiro S.A.	BR02EN	59.31	71.32	12.01	74
Brazil	Petroleo Brasileiro S.A.	BR01EN	58.44	68.02	9.58	72
Brazil	Centrais Eletricas Brasileiras S.A.	BR08EN	56.69	67.47	10.78	65
Brazil	Companhia Energetica de Minas Gerais- CEMIG	BR07EN	56.11	66.93	10.82	63
China	China Petroleum & Chemical Corporation.	CH03EN	54.28	66.12	11.84	44
Brazil	Companhia Energetica de Minas Gerais- CEMIG	BR18EN	55.20	64.36	9.16	61
Sri Lanka	Vidullanka.	SL03EN	52.79	64.31	11.51	38
Philippines	First Gen Corporation.	PM05EN	51.27	64.27	13.00	35
South Korea	S-Oil Corporation.	KS17EN	53.05	63.41	10.36	44
China	GD Power Development Co. Ltd.	CH07EN	53.73	61.77	8.04	48
Hong Kong	PetroChina Company Limited.	HK06EN	50.51	60.62	10.11	30
China	PetroChina Company Limited.	CH04EN	52.49	60.33	7.84	43
South Korea	SK Discovery Co. Ltd.	KS18EN	51.26	59.11	7.85	56
Romania	Transelectrica SA	RM02EN	48.63	56.89	8.26	17
Hong Kong	China Petroleum & Chemical Corporation.	HK04EN	48.99	56.71	7.72	17
Taiwan	Luxe Electric Co Ltd.	TW11RE	49.27	55.66	6.39	38
Peru	ENGIE Energia Peru S.A.A.	PE02EN	49.71	54.76	5.06	26
Malaysia	Petronas Gas Berhad.	MK02EN	47.81	54.47	6.65	20
Taiwan	Mosel Vitelic, Inc.	TW07RE	48.43	54.42	5.99	36
Russia	Tatneft PJSC	RU10EN	47.69	53.27	5.58	34
Colombia	Grupo Energia Bogota SA.	CO03EN	48.02	53.18	5.16	35
Pakistan	Sui Southern Gas Co. Ltd.	PK12EN	46.67	52.93	6.26	30
Russia	Federal Grid Co Unified Energy System PJSC	RU01EN	46.53	52.10	5.58	24
Taiwan	United Renewable Energy Co. Ltd.	TW02RE	47.00	51.86	4.86	24
Thailand	IRPC PCL.	TH05EN	46.30	51.78	5.49	28
Mongolia	Baganuur JSC	MG03EN	47.21	51.71	4.50	20
Russia	Tatneft PJSC (Pref)	RU11EN	48.06	51.61	3.55	31
China	Offshore Oil Engineering Co. Ltd.	CH13EN	46.37	51.43	5.07	33
Turkey	Aygaz A.S.	TK01EN	46.96	51.36	4.40	34
Chile	Antarchile S.A.	CL06EN	46.97	51.19	4.21	34
Peru	Enel Generacion Peru S.A.A.	PE01EN	47.24	50.94	3.70	28
Colombia	Celsia S.A.	CO04EN	46.56	50.58	4.02	34

Note: Spillover effects computed from LASSO-VAR(1) and considering a KPPS 10-week-ahead forecast error variance decomposition. The total spillover of the system was 39.92% at the firm level. Centrality corresponds to the number of links related to each node (vertex), both incoming and outgoing from each node. The median of the centrality measure was 13. Source: Authors' computation.

Ultrapar Participacoes (Brazil) stand out as specific investment alternatives given their peripheral location in the global stock energy network for emerging markets.

Third, and finally, we identify markets and firms that are idiosyncratically important for global energy networks in emerging market finance. These markets or firms are the main net transmitters of the idiosyncratic shocks and tend to be located in the network's core area. The markets of Romania, India, Vietnam, Pakistan, Mongolia, Philippines, Hong Kong, Turkey, Montenegro, Sri Lanka and Taiwan are the most relevant in this sense. At the firm level, Chinese (Huadian Power International, Huaneng Power International, China Petroleum & Chemical) and Brazilian firms (Centrais Eletricas Brasileiras, Petroleo Brasileiro, Centrais Eletricas Brasileiras, Companhia Energetica de Minas Gerais) have been identified as major transmitters of abnormally large shocks.

Declaration of Competing Interest

None.

Data availability

Data will be made available on request.

Appendix A. Appendix

Appendix 1
Firms sample.

Country	Firm	Code	Ticker	Sector	Industry	Sub-industry
Hong Kong	CNOOC Limited	HK01EN	883 HK	Energy	Oil & Gas	Oil & Gas Producers
Hong Kong	CLP Holdings Limited.	HK02EN	2 HK	Utilities	Utilities	Electric Utilities
Hong Kong	The Hong Kong and China Gas Company Limited.	HK03EN	3 HK	Utilities	Utilities	Gas & Water Utilities
Hong Kong	China Petroleum & Chemical Corporation.	HK04EN	386 HK	Energy	Oil & Gas	Oil & Gas Producers
Hong Kong	Power Assets Holdings Limited.	HK05EN	6 HK	Utilities	Utilities	Electric Utilities
Hong Kong	PetroChina Company Limited.	HK06EN	857 HK	Energy	Oil & Gas	Oil & Gas Producers
China	China Yangtze Power Co., Ltd.	CH01EN	600,900 CH	Utilities	Utilities	Electric Utilities
China	EVE Energy Co., Ltd.	CH02RE	300,014 CH	Energy	Renewable Energy	Renewable Energy
China	China Petroleum & Chemical Corporation.	CH03EN	600,028 CH	Energy	Oil & Gas	Oil & Gas Producers
China	PetroChina Company Limited.	CH04EN	601,857 CH	Energy	Oil & Gas	Oil & Gas Producers
China	Xinjiang Goldwind Science & Technology Co., Ltd.	CH05RE	002202 CH	Energy	Renewable Energy	Renewable Energy
China	SDIC Power Holdings Co., Ltd.	CH06EN	600,886 CH	Utilities	Utilities	Electric Utilities
China	GD Power Development Co.,Ltd.	CH07EN	600,795 CH	Utilities	Utilities	Electric Utilities
China	Huaneng Power International, Inc.	CH08EN	600,011 CH	Utilities	Utilities	Electric Utilities
China	Huadian Power Internatioanal Corporation Limited.	CH09EN	600,027 CH	Utilities	Utilities	Electric Utilities
China	China Oilfield Services Limited.	CH10EN	601,808 CH	Energy	Oil & Gas	Oil & Gas Services & Equip
China	Shenergy Company Limited.	CH11EN	600,642 CH	Utilities	Utilities	Electric Utilities
China	Shenzhen Energy Group Co., Ltd.	CH12EN	000027 CH	Utilities	Utilities	Electric Utilities
China	Offshore Oil Engineering Co., Ltd.	CH13EN	600,583 CH	Energy	Oil & Gas	Oil & Gas Services & Equip
China	Guangdong Meiyan Jixiang Hydropower Co., Ltd.	CH14EN	600,868 CH	Utilities	Utilities	Electric Utilities
China	Guangxi Guiguan Electric Power Co.,Ltd.	CH15EN	600,236 CH	Utilities	Utilities	Electric Utilities
China	Guangdong Electric Power Development Co.,Ltd.	CH16EN	000539 CH	Utilities	Utilities	Electric Utilities
China	Shanghai Dazhong Public Utilities (Group) Co., Ltd.	CH17EN	600,635 CH	Utilities	Utilities	Gas & Water Utilities
China	COFCO Biotechnology Co., Ltd.	CH18RE	000930 CH	Energy	Renewable Energy	Renewable Energy
China	Datang Huayin Electric Power Co., Ltd.	CH19EN	600,744 CH	Utilities	Utilities	Electric Utilities
China	Jilin Electric Power Co., Ltd.	CH20EN	000875 CH	Utilities	Utilities	Electric Utilities
China	Inner Mongolia Mengdian Huaneng Thermal Power Corporation Ltd.	CH21EN	600,863 CH	Utilities	Utilities	Electric Utilities
China	Henan Ancai Hi-Tech Co., Ltd.	CH22EN	600,207 CH	Energy	Oil & Gas	Oil & Gas Producers
China	Shanghai Electric Power Company Limited.	CH23EN	600,021 CH	Utilities	Utilities	Electric Utilities
China	Jinneng Holding Shanxi Electric Power Co., Ltd.	CH24EN	000767 CH	Utilities	Utilities	Electric Utilities
China	Guangdong Shaoneng Group Co., Ltd.	CH25EN	000601 CH	Utilities	Utilities	Electric Utilities
China	Changchun Gas Co., Ltd.	CH26EN	600,333 CH	Utilities	Utilities	Gas & Water Utilities
China	Guanghui Energy Co., Ltd.	CH27EN	600,256 CH	Energy	Oil & Gas	Oil & Gas Producers
China	Huadian Energy Co., Ltd.	CH28EN	600,726 CH	Utilities	Utilities	Electric Utilities
China	Sichuan Chuantou Energy Co., Ltd.	CH29EN	600,674 CH	Utilities	Utilities	Electric Utilities
China	Shenzhen Guangju Energy Co., Ltd.	CH30EN	000096 CH	Energy	Oil & Gas	Oil & Gas Producers
China	Sinopec Oilfield Service Corporation.	CH31EN	600,871 CH	Energy	Oil & Gas	Oil & Gas Services & Equip
China	An Hui Wenergy Co., Ltd.	CH32EN	000543 CH	Utilities	Utilities	Electric Utilities
Taiwan	Formosa Petrochemical Corp.	TW01EN	6505 TT	Energy	Oil & Gas	Oil & Gas Producers

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Appendix 1 (*continued*)

Country	Firm	Code	Ticker	Sector	Industry	Sub-industry
Taiwan	United Renewable Energy Co., Ltd.	TW02RE	3576 TT	Energy	Renewable Energy	Renewable Energy
Taiwan	The Great Taipei Gas Co., Ltd.	TW03EN	9908 TT	Utilities	Utilities	Gas & Water Utilities
Taiwan	National Petroleum Co., Ltd.	TW04EN	9937 TT	Energy	Oil & Gas	Oil & Gas Producers
Taiwan	Shin Hai Gas Corporation.	TW05EN	9926 TT	Utilities	Utilities	Gas & Water Utilities
Taiwan	Shin Shin Natural Gas Co., Ltd.	TW06EN	9918 TT	Utilities	Utilities	Gas & Water Utilities
Taiwan	Mosel Vitelic, Inc.	TW07RE	2342 TT	Energy	Renewable Energy	Renewable Energy
Taiwan	Taiwan Land Development Corporation.	TW08RE	2841 TT	Energy	Renewable Energy	Renewable Energy
Taiwan	Shan-Loong Transportation Co., Ltd.	TW09EN	2616 TT	Energy	Oil & Gas	Oil & Gas Producers
Taiwan	Hsin-Kao Gas Company Ltd.	TW10EN	9931 TT	Utilities	Utilities	Gas & Water Utilities
Taiwan	Luxe Electric Co Ltd.	TW11RE	1529 TT	Energy	Renewable Energy	Renewable Energy
South Korea	Korea Gas Corporation.	KS01EN	036460 KS	Utilities	Utilities	Gas & Water Utilities
South Korea	Mi Chang Oil Industrial Co., Ltd.	KS02EN	003650 KS	Energy	Oil & Gas	Oil & Gas Producers
South Korea	Yesco Holdings Co., Ltd.	KS03EN	015360 KS	Utilities	Utilities	Gas & Water Utilities
South Korea	Korea Electric Power Corporation.	KS04EN	015760 KS	Utilities	Utilities	Electric Utilities
South Korea	SGC Energy Co.,Ltd.	KS05EN	005090 KS	Utilities	Utilities	Electric Utilities
South Korea	Incheon City Gas Co., Ltd.	KS06EN	034590 KS	Utilities	Utilities	Gas & Water Utilities
South Korea	Hankook Shell Oil Co., Ltd.	KS07EN	002960 KS	Energy	Oil & Gas	Oil & Gas Producers
South Korea	SK Innovation Co., Ltd.	KS08EN	096770 KS	Energy	Oil & Gas	Oil & Gas Producers
South Korea	Daesung Holdings Co., Ltd.	KS09EN	016710 KS	Utilities	Utilities	Gas & Water Utilities
South Korea	Samchully Co., Ltd.	KS10EN	004690 KS	Utilities	Utilities	Gas & Water Utilities
South Korea	SK Inc.	KS11EN	034730 KS	Energy	Oil & Gas	Oil & Gas Producers
South Korea	Busan City Gas	KS12EN	015350 KS	Utilities	Utilities	Gas & Water Utilities
South Korea	SK Gas Ltd.	KS13EN	018670 KS	Energy	Oil & Gas	Oil & Gas Producers
South Korea	Kukdong Oil & Chemicals Co., Ltd.	KS14EN	014530 KS	Energy	Oil & Gas	Oil & Gas Producers
South Korea	Hanjin Heavy Industries & Construction Holdings Co.,Ltd.	KS15EN	003480 KS	Utilities	Utilities	Gas & Water Utilities
South Korea	Seoul City Gas Co. Ltd.	KS16EN	017390 KS	Utilities	Utilities	Gas & Water Utilities
South Korea	S-Oil Corporation.	KS17EN	010950 KS	Energy	Oil & Gas	Oil & Gas Producers
South Korea	SK Discovery Co.,Ltd.	KS18EN	006120 KS	Utilities	Utilities	Elec & Gas Marketing & Trad.
South Korea	E1 Corp.	KS19EN	017940 KS	Energy	Oil & Gas	Oil & Gas Producers
South Korea	OCI Company Ltd.	KS20RE	010060 KS	Energy	Renewable Energy	Renewable Energy
South Korea	S-Oil Corp.	KS21EN	010955 KS	Energy	Oil & Gas	Oil & Gas Producers
South Korea	SK Discovery Corp Ltd	KS22EN	006125 KS	Energy	Oil & Gas	Oil & Gas Producers
Pakistan	The Hub Power Co. Ltd.	PK01EN	HUBC PA	Utilities	Utilities	Electric Utilities
Pakistan	Oil & Gas Development Co. Ltd.	PK02EN	OGDC PA	Energy	Oil & Gas	Oil & Gas Producers
Pakistan	Pakistan Petroleum Ltd.	PK03EN	PPL PA	Energy	Oil & Gas	Oil & Gas Producers
Pakistan	Pakistan Oilfields Ltd.	PK04EN	POL PA	Energy	Oil & Gas	Oil & Gas Producers
Pakistan	Pakistan State Oil Co. Ltd.	PK05EN	PSO PA	Energy	Oil & Gas	Oil & Gas Producers
Pakistan	Mari Petroleum Co. Ltd.	PK06EN	MARI PA	Energy	Oil & Gas	Oil & Gas Producers
Pakistan	Kot Addu Power Co. Ltd.	PK07EN	KAPCO PA	Utilities	Utilities	Electric Utilities
Pakistan	Sui Northern Gas Pipelines Ltd.	PK08EN	SNGP PA	Utilities	Utilities	Gas & Water Utilities
Pakistan	Attock Refinery Ltd.	PK09EN	ATRL PA	Energy	Oil & Gas	Oil & Gas Producers
Pakistan	K-Electric Ltd.	PK10EN	KEL PA	Utilities	Utilities	Electric Utilities
Pakistan	Attock Petroleum Ltd.	PK11EN	APL PA	Energy	Oil & Gas	Oil & Gas Producers
Pakistan	Sui Southern Gas Co. Ltd.	PK12EN	SSGC PA	Utilities	Utilities	Gas & Water Utilities
Pakistan	Shell Pakistan Ltd.	PK13EN	SHEL PA	Energy	Oil & Gas	Oil & Gas Producers
Pakistan	National Refinery Ltd.	PK14EN	NRL PA	Energy	Oil & Gas	Oil & Gas Producers
Pakistan	Pakistan Refinery Ltd.	PK15EN	PRL PA	Energy	Oil & Gas	Oil & Gas Producers
Pakistan	Kohinoor Energy Ltd.	PK16EN	KOHE PA	Utilities	Utilities	Electric Utilities
Sri Lanka	Lanka IOC PLC	SL01EN	LIOC SL	Energy	Oil & Gas	Oil & Gas Producers
Sri Lanka	Vallibel Power Erathna.	SL02EN	VPEL SL	Utilities	Utilities	Electric Utilities
Sri Lanka	Vidullanka.	SL03EN	VLL SL	Utilities	Utilities	Electric Utilities
Sri Lanka	Resus Energy.	SL04EN	HPWR SL	Utilities	Utilities	Electric Utilities
Thailand	PTT Public Company Limited.	TH01EN	PTT TB	Energy	Oil & Gas	Oil & Gas Producers
Thailand	PTT Exploration and Production Public Company Limited.	TH02EN	PTTEP TB	Energy	Oil & Gas	Oil & Gas Producers
Thailand	Thai Oil Public Company Limited.	TH03EN	TOP TB	Energy	Oil & Gas	Oil & Gas Producers
Thailand	Electricity Generating Public Company Limited.	TH04EN	EGCO TB	Utilities	Utilities	Electric Utilities
Thailand	IRPC PCL.	TH05EN	IRPC TB	Energy	Oil & Gas	Oil & Gas Producers
Thailand	Ratchaburi Group.	TH06EN	RATCH TB	Utilities	Utilities	Electric Utilities
Thailand	Bangchak Corporation Public Company Limited.	TH07EN	BCP TB	Energy	Oil & Gas	Oil & Gas Producers
Thailand	Esso Thailand.	TH08EN	ESSO TB	Energy	Oil & Gas	Oil & Gas Producers
Thailand	Super Energy Corporation Public Company Limited.	TH09EN	SUPER TB	Utilities	Utilities	Electric Utilities

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Appendix 1 (*continued*)

Country	Firm	Code	Ticker	Sector	Industry	Sub-industry
Thailand	Siamgas & Petrochemicals.	TH10EN	SGP TB	Energy	Oil & Gas	Oil & Gas Producers
Thailand	SPCG.	TH11EN	SPCG TB	Utilities	Utilities	Electric Utilities
Thailand	Rojana Industrial Park Public Company Limited.	TH12EN	ROJNA TB	Utilities	Utilities	Electric Utilities
Thailand	Eastern Power Group Public Company Limited.	TH13EN	EP TB	Utilities	Utilities	Electric Utilities
Thailand	Seven Utilities And Power Public Company Limited.	TH14EN	7UP TB	Energy	Oil & Gas	Oil & Gas Producers
Thailand	SUSCO.	TH15EN	SUSCO TB	Energy	Oil & Gas	Oil & Gas Producers
Thailand	Sahacogen Chonburi Public Company Limited.	TH16EN	SCG TB	Utilities	Utilities	Electric Utilities
Thailand	Eternal Energy Public Company Limited.	TH17EN	EE TB	Utilities	Utilities	Electric Utilities
Thailand	Solartron.	TH18RE	SOLAR TB	Energy	Renewable Energy	Renewable Energy
Indonesia	PT Perusahaan Gas Negara.	IJ01EN	PGAS IJ	Utilities	Utilities	Gas & Water Utilities
Indonesia	PT Medco Energi Internasional.	IJ02EN	MEDC IJ	Energy	Oil & Gas	Oil & Gas Producers
Indonesia	PT Elnusa.	IJ03EN	ELSA IJ	Energy	Oil & Gas	Oil & Gas Producers
Indonesia	PT Petrosea.	IJ04EN	PTRO IJ	Energy	Oil & Gas	Oil & Gas Producers
Indonesia	PT Energi Mega Persada Tbk.	IJ05EN	ENRG IJ	Energy	Oil & Gas	Oil & Gas Producers
Indonesia	PT Rukun Raharja Tbk.	IJ06EN	RAJA IJ	Energy	Oil & Gas	Oil & Gas Producers
Indonesia	PT Radiant Utama Interinsco Tbk.	IJ07EN	RUIS IJ	Energy	Oil & Gas	Oil & Gas Services & Equip
India	NTPC Ltd.	IN01EN	NTPC IB	Utilities	Utilities	Electric Utilities
India	Power Grid Corporation of India Limited.	IN02EN	PWGR IB	Utilities	Utilities	Electric Utilities
India	Reliance Industries Ltd.	IN03EN	RIL IB	Energy	Oil & Gas	Oil & Gas Producers
India	Oil and Natural Gas Corporation Limited.	IN04EN	ONGC IB	Energy	Oil & Gas	Oil & Gas Producers
India	Reliance Infrastructure Ltd.	IN05EN	RELI IN	Utilities	Utilities	Electric Utilities
India	Hindustan Petroleum Corporation Limited.	IN06EN	HPCL IN	Energy	Oil & Gas	Oil & Gas Producers
Singapore	Capallianz Holdings Ltd.	SP01EN	CAPL SP	Energy	Oil & Gas	Oil & Gas Producers
Singapore	Sembcorp Marine Ltd.	SP02EN	SMM SP	Energy	Oil & Gas	Oil & Gas Producers
Malaysia	Petronas Dagangan Berhad markets petroleum.	MK01EN	PETD MK	Energy	Oil & Gas	Oil & Gas Producers
Malaysia	Petronas Gas Berhad.	MK02EN	PTG MK	Energy	Oil & Gas	Oil & Gas Producers
Malaysia	Tenaga Nasional Berhad.	MK03EN	TNB MK	Utilities	Utilities	Electric Utilities
Malaysia	Dialog Group.	MK04EN	DLG MK	Energy	Oil & Gas	Oil & Gas Producers
Malaysia	YTL Power International Bhd.	MK05EN	YTLP MK	Utilities	Utilities	Electric Utilities
Malaysia	YTL Corporation Berhad.	MK06EN	YTL MK	Utilities	Utilities	Electric Utilities
Philippines	Aboitiz Ventures Inc.	PM01EN	AEV PM	Utilities	Utilities	Electric Utilities
Philippines	Manila Electric Company.	PM02EN	MER PM	Utilities	Utilities	Electric Utilities
Philippines	San Miguel Corporation.	PM03EN	SMC PM	Energy	Oil & Gas	Oil & Gas Producers
Philippines	Aboitiz Power Corporation.	PM04EN	AP PM	Utilities	Utilities	Electric Utilities
Philippines	First Gen Corporation.	PM05EN	FGEN PM	Utilities	Utilities	Electric Utilities
Philippines	Lopez Holdings Corp.	PM06EN	LPZ PM	Utilities	Utilities	Electric Utilities
Philippines	Petron Corporation.	PM07EN	PCOR PM	Energy	Oil & Gas	Oil & Gas Producers
Philippines	First Philippine Holdings Corporation.	PM08EN	FPH PM	Utilities	Utilities	Electric Utilities
Vietman	PetroVietnam Drilling & Well Services JSC.	VM01EN	PVD VM	Energy	Oil & Gas	Oil & Gas Producers
Vietman	Pha Lai Thermal Power JSC.	VM02EN	PPC VM	Utilities	Utilities	Electric Utilities
Vietman	Vinh Son Song Hinh Hydropower JSC.	VM03EN	VSH VM	Utilities	Utilities	Electric Utilities
Vietman	Thac Mo Hydro Power JSC.	VM04RE	TMP VM	Energy	Renewable Energy	Renewable Energy
Vietman	PetroVietnam Low Pressure Gas Distribution JSC.	VM05EN	PGD VM	Utilities	Utilities	Gas & Water Utilities
Vietman	Thac Ba Hydropower JSC.	VM06RE	TBC VM	Energy	Renewable Energy	Renewable Energy
Vietman	Can Don Hydro Power JSC.	VM07RE	SJD VM	Energy	Renewable Energy	Renewable Energy
Vietman	Petrolimex Gas JSC.	VM08EN	PGC VM	Energy	Oil & Gas	Oil & Gas Producers
Vietman	Ba Ria Thermal Power JSC.	VM09EN	BTP VM	Utilities	Utilities	Electric Utilities
Vietman	Khanh Hoa Power JSC.	VM10EN	KHP VM	Utilities	Utilities	Engineering & Construction
Vietman	An Pha Petroleum Group JSC.	VM11EN	ASP VM	Utilities	Utilities	Gas & Water Utilities
Mongolia	Tavantolgoi JSC (TTL)	MG01EN	TTL MO	Energy	Oil & Gas	Oil & Gas Producers
Mongolia	Sharyn Gol JSC	MG02EN	SHG MO	Energy	Oil & Gas	Oil & Gas Producers
Mongolia	Baganuur JSC	MG03EN	BAN MO	Energy	Oil & Gas	Oil & Gas Producers
Mongolia	Shivee Ovoo JSC	MG04EN	SHV MO	Energy	Oil & Gas	Oil & Gas Producers
Mongolia	HBOil JSC	MG05EN	HBO MO	Energy	Oil & Gas	Oil & Gas Producers
Argentina	Transener Cía. de Transp. de Energía Eléctr. en Alta Tensión	AR01EN	TRAN AR	Energy	Oil & Gas	Oil & Gas Producers
Argentina	Pampa Energia SA.	AR02EN	PAMP AR	Utilities	Utilities	Electric Utilities
Argentina	Transportadora de Gas del Sur S.A.	AR03EN	TGSU2 AR	Energy	Oil & Gas	Oil & Gas Producers
Argentina	Sociedad Comercial del Plata S.A.	AR04EN	COME AR	Energy	Oil & Gas	Oil & Gas Producers
Argentina	Central Puerto SA.	AR05EN	CEPU AR	Utilities	Utilities	Electric Utilities
Argentina	YPF S.A.	AR06EN	YPFD AR	Energy	Oil & Gas	Oil & Gas Producers
Argentina	Empresa Distribuidora y Comercializadora Norte S.A.	AR07EN	EDN AR	Utilities	Utilities	Electric Utilities

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Appendix 1 (*continued*)

Country	Firm	Code	Ticker	Sector	Industry	Sub-industry
Argentina	Transportadora de Gas del Norte SA.	AR08EN	TGNO4 AR	Utilities	Utilities	Gas & Water Utilities
Argentina	Endesa Costanera.	AR09EN	CECO2 AF	Utilities	Utilities	Electric Utilities
Brazil	Petroleo Brasileiro S.A.	BR01EN	PETR4 BS	Energy	Oil & Gas	Oil & Gas Producers
Brazil	Petroleo Brasileiro S.A.	BR02EN	PETR3 BS	Energy	Oil & Gas	Oil & Gas Producers
Brazil	Ultrapar Participacoes S.A.	BR03EN	UGPA3 BS	Energy	Oil & Gas	Oil & Gas Producers
Brazil	Equatorial Energia SA.	BR04EN	EQTL3 BS	Utilities	Utilities	Electric Utilities
Brazil	Eneva S.A.	BR05EN	ENEV3 BS	Utilities	Utilities	Electric Utilities
Brazil	Cosan SA.	BR06EN	CSAN3 BS	Energy	Oil & Gas	Oil & Gas Producers
Brazil	Companhia Energetica de Minas Gerais- CEMIG.	BR07EN	CMIG4 BS	Utilities	Utilities	Electric Utilities
Brazil	Centrais Eletricas Brasileiras S.A.	BR08EN	ELET3 BS	Utilities	Utilities	Electric Utilities
Brazil	Energisa SA.	BR09EN	ENGI11 BS	Utilities	Utilities	Electric Utilities
Brazil	Engie Brasil Energia S.A.	BR10EN	EGIE3 BS	Utilities	Utilities	Electric Utilities
Brazil	Companhia Paranaense de Energia-Copel.	BR11EN	CPLE6 BS	Utilities	Utilities	Electric Utilities
Brazil	Transmissora Alianca de Energia Eletrica SA.	BR12EN	TAEE11 BS	Utilities	Utilities	Electric Utilities
Brazil	Centrais Eletricas Brasileiras S.A.	BR13EN	ELET6 BS	Utilities	Utilities	Electric Utilities
Brazil	CPFL Energia S.A.	BR14EN	CPFE3 BS	Utilities	Utilities	Electric Utilities
Brazil	EDP - Energias do Brasil SA.	BR15EN	ENBR3 BS	Utilities	Utilities	Electric Utilities
Brazil	Rio Paranapanema Energia S.A.	BR16EN	GEPA4 BS	Utilities	Utilities	Electric Utilities
Brazil	Companhia de Transmissao de Energia Eletrica Paulista.	BR17EN	TRPL4 BS	Utilities	Utilities	Electric Utilities
Brazil	Companhia Energetica de Minas Gerais- CEMIG.	BR18EN	CMIG3 BS	Utilities	Utilities	Electric Utilities
Chile	Colbun S.A.	CL01EN	COLBUN CC	Utilities	Utilities	Electric Utilities
Chile	Empresas Copec SA.	CL02EN	COPEC CC	Energy	Oil & Gas	Oil & Gas Producers
Chile	AES Andes S.A.	CL03EN	AESGENER CC	Utilities	Utilities	Electric Utilities
Chile	Enel Americas SA.	CL04EN	ENELAM CC	Utilities	Utilities	Electric Utilities
Chile	Enel Generacion Chile SA.	CL05EN	ENELGXCH CC	Utilities	Utilities	Electric Utilities
Chile	Antarchile S.A.	CL06EN	ANTAR CC	Energy	Oil & Gas	Oil & Gas Producers
Peru	Enel Generacion Peru S.A.A.	PE01EN	ENGEPEC1 PE	Utilities	Utilities	Electric Utilities
Peru	ENGIE Energia Peru S.A.A.	PE02EN	ENGIEC1 PE	Utilities	Utilities	Electric Utilities
Peru	Enel Distribucion Peru S.A.A.	PE03EN	ENDISPC1 PE	Utilities	Utilities	Electric Utilities
Peru	Refineria La Pampilla S.A.A.	PE04EN	RELAPAC1 PE	Energy	Oil & Gas	Oil & Gas Producers
Peru	Luz del Sur S.A.A.	PE05EN	LUSURC1 PE	Utilities	Utilities	Electric Utilities
Colombia	Ecopetrol SA.	CO01EN	ECOPETL CB	Energy	Oil & Gas	Oil & Gas Producers
Colombia	Interconexion Electrica S.A.	CO02EN	ISA CB	Utilities	Utilities	Electric Utilities
Colombia	Grupo Energia Bogota SA.	CO03EN	GEB CB	Utilities	Utilities	Gas & Water Utilities
Colombia	Celsia S.A.	CO04EN	CELSIA CB	Utilities	Utilities	Electric Utilities
Romania	Conpet SA Ploiesti	RM01EN	COTE RE	Energy	Oil & Gas	Oil & Gas Producers
Romania	Transelectrica SA	RM02EN	TEL RE	Utilities	Utilities	Electric Utilities
Montenegro	Elektroprivreda Crne Gore ad Niksic	MN01EN	EPCG ME	Utilities	Utilities	Electric Utilities
Montenegro	Jugopetrol ad Podgorica	MN02EN	JGPK ME	Energy	Oil & Gas	Oil & Gas Producers
Czech Republic	CEZ AS	CR01EN	CEZ CP	Utilities	Utilities	Electric Utilities
Russia	Federal Grid Co Unified Energy System PJSC	RU01EN	FEES RM	Utilities	Utilities	Electric Utilities
Russia	Gazprom Neft PJSC	RU02EN	GAZP RM	Energy	Oil & Gas	Oil & Gas Producers
Russia	RusHydro PJSC	RU03EN	HYDR RM	Utilities	Utilities	Electric Utilities
Russia	Inter RAO UES PJSC	RU04EN	IRAO RM	Utilities	Utilities	Elec & Gas Marketing & Trading
Russia	LUKOIL PJSC	RU05EN	LKOH RM	Energy	Oil & Gas	Oil & Gas Producers
Russia	Novatek PJSC	RU06EN	NVTK RM	Energy	Oil & Gas	Oil & Gas Producers
Russia	Rosneft Oil Co PJSC	RU07EN	ROSN RM	Energy	Oil & Gas	Oil & Gas Producers
Russia	Surgutneftegas PJSC	RU08EN	SNGS RM	Energy	Oil & Gas	Oil & Gas Producers
Russia	Surgutneftegas PJSC (Pref)	RU09EN	SNGSP RM	Energy	Oil & Gas	Oil & Gas Producers
Russia	Tatneft PJSC	RU10EN	TATN RM	Energy	Oil & Gas	Oil & Gas Producers
Russia	Tatneft PJSC (Pref)	RU11EN	TATNP RM	Energy	Oil & Gas	Oil & Gas Producers
Slovenia	Petrol dd Ljubljana	SV01EN	PETG SV	Energy	Oil & Gas	Oil & Gas Producers
Turkey	Aygaz A.S.	TK01EN	AYGAZ TI	Energy	Oil & Gas	Oil & Gas Producers
Turkey	Tupras Turkiye Petrol Rafinerileri A.S.	TK02EN	TUPRS TI	Energy	Oil & Gas	Oil & Gas Producers
Bosnia-Herzegovina	Elektrokrajina	BH01EN	EKBLRA BK	Utilities	Utilities	Electric Utilities
Bosnia-Herzegovina	Hidroelektrane Na Drini	BH02EN	HEDRRA BK	Utilities	Utilities	Electric Utilities
Bosnia-Herzegovina	Rite Gacko	BH03EN	RITERA BK	Utilities	Utilities	Electric Utilities
Hungary	MOL Hungarian Oil & Gas PLC	HG01EN	MOL HB	Energy	Oil & Gas	Oil & Gas Producers

Source: Bloomberg.

Appendix 2
Descriptive statistics: energy stock returns by firms.

Country	Code	Obs.	Mean	Median	Std. Dev.	Min	Max	Skewness	Kurtosis	Shapiro-Wilk	ADF test
Hong Kong	HK01EN	585	0.0382	−0.0009	4.8807	−21.8072	21.9828	0.0511	5.6748	5.918***	−24.957***
Hong Kong	HK02EN	585	0.0775	0.0951	1.9065	−9.6573	11.8184	0.0663	6.9276	6.370***	−24.396***
Hong Kong	HK03EN	585	0.1138	0.2050	2.2985	−13.1939	7.0642	−0.5134	5.3508	5.599***	−23.351***
Hong Kong	HK04EN	585	0.0222	−0.0537	3.7515	−11.6022	18.4366	0.3834	4.7178	4.554***	−23.936***
Hong Kong	HK05EN	585	0.0433	0.0955	2.5660	−13.4033	12.2959	−0.6282	7.4263	7.551***	−25.059***
Hong Kong	HK06EN	585	−0.1396	−0.3870	4.0099	−15.3577	17.1343	0.3098	3.9922	3.257***	−23.858***
China	CH01EN	585	0.1858	0.0134	2.4568	−11.2546	14.6288	0.2037	6.3906	6.280***	−24.265***
China	CH02RE	585	0.9191	0.5778	8.0478	−34.6392	38.1720	0.2325	5.5015	6.346***	−24.121***
China	CH03EN	585	−0.0889	−0.0582	3.4009	−21.2392	11.4055	−0.3201	6.7054	6.744***	−23.476***
China	CH04EN	585	−0.1428	−0.2013	3.1123	−20.6516	14.6601	0.1539	10.493	9.106***	−23.876***
China	CH05RE	585	0.1958	−0.0133	5.9875	−26.3405	33.5157	0.5370	6.8950	7.158***	−25.789***
China	CH06EN	585	0.2381	0.0345	3.8533	−37.3876	17.4997	−1.2131	19.4501	8.949***	−22.326***
China	CH07EN	585	0.0175	0.0000	4.0340	−32.7412	21.9903	−0.3764	17.9020	10.114***	−22.646***
China	CH08EN	585	−0.0025	−0.1409	4.2032	−24.2431	32.4480	0.5522	12.2863	8.497***	−24.492***
China	CH09EN	585	0.0514	−0.2047	4.7555	−35.8453	24.5463	0.0002	12.7370	9.170***	−24.614***
China	CH10EN	585	0.1330	−0.1151	5.4243	−38.3992	24.0060	−0.2380	8.9984	7.727***	−23.330***
China	CH11EN	585	0.0417	0.0000	3.8799	−27.6193	23.3128	−0.2018	15.8929	9.886***	−24.227***
China	CH12EN	585	0.2552	0.0000	5.3453	−36.9494	31.4579	−0.1847	17.9889	10.571***	−21.639***
China	CH13EN	585	0.0233	0.1292	5.3506	−41.0765	20.4919	−0.5670	11.4856	8.344***	−24.610***
China	CH14EN	585	0.2203	−0.0412	6.9655	−40.8946	52.5057	1.0035	15.1043	10.189***	−22.922***
China	CH15EN	585	0.1658	0.0193	4.6856	−33.7989	34.1409	−0.0934	15.5420	9.588***	−23.933***
China	CH16EN	585	0.0249	0.0000	4.2821	−35.1768	36.6573	0.3227	22.0135	10.099***	−26.674***
China	CH17EN	585	0.1104	−0.0428	6.1823	−32.2167	37.4084	0.6385	11.5267	9.386***	−22.371***
China	CH18RE	585	0.2193	0.1180	6.4173	−37.9098	35.6090	0.3574	10.0389	8.979***	−22.583***
China	CH19EN	585	0.2511	0.0000	6.7723	−41.0133	44.0328	0.8824	11.8934	9.409***	−21.434***
China	CH20EN	585	0.1653	−0.0415	5.7818	−37.1290	30.2190	0.4821	10.1629	9.223***	−22.061***
China	CH21EN	585	0.0877	−0.0596	4.9831	−40.1573	22.5929	−0.7103	13.9145	9.052***	−24.890***
China	CH22EN	585	0.3124	0.0000	7.8087	−39.8209	60.9121	1.1799	14.5304	9.489***	−23.063***
China	CH23EN	585	0.2073	0.0000	5.2577	−33.4612	28.1869	0.6055	11.6465	9.695***	−21.925***
China	CH24EN	585	0.1028	0.0000	5.6196	−40.2877	50.2238	0.5132	20.0235	9.980***	−22.438***
China	CH25EN	585	0.1426	0.0000	5.5800	−34.0097	21.7972	0.0037	7.4873	7.708***	−21.412***
China	CH26EN	585	0.0699	0.0278	6.4266	−29.8347	61.6453	1.9640	20.7974	9.790***	−25.626***
China	CH27EN	585	0.0876	−0.0877	5.3954	−29.5352	20.9930	−0.1846	6.6312	7.295***	−24.442***
China	CH28EN	585	0.0635	−0.2210	5.8937	−41.0144	31.1778	0.2766	12.9520	9.757***	−22.768***
China	CH29EN	585	0.2569	0.3937	4.0443	−25.3888	25.9322	−0.2019	13.4035	9.185***	−24.306***
China	CH30EN	585	0.2412	−0.0683	6.4085	−37.3747	48.3619	1.0617	16.1419	10.124***	−23.455***
China	CH31EN	585	0.0439	0.0000	6.4403	−45.4640	36.6446	−0.2862	15.2545	10.058***	−24.888***
China	CH32EN	585	0.0815	0.2142	4.6276	−28.4048	21.5211	−0.3923	7.3673	7.108***	−23.833***
Taiwan	TW01EN	585	0.1011	0.0000	3.5199	−16.0257	14.9129	−0.0669	5.7459	6.217***	−26.499***
Taiwan	TW02RE	585	−0.0020	−0.0934	6.4211	−25.1263	23.8989	0.2683	5.1566	6.510***	−22.037***
Taiwan	TW03EN	585	0.1429	0.1317	1.5184	−10.2701	8.0071	−0.3797	9.2465	7.787***	−24.488***
Taiwan	TW04EN	585	0.0857	0.0000	1.9305	−12.5615	9.0174	−0.3969	9.3553	8.260***	−23.478***
Taiwan	TW05EN	585	0.1984	0.1247	1.9635	−9.8668	12.5086	0.2950	8.2311	7.665***	−27.602***
Taiwan	TW06EN	585	0.1143	0.0831	2.0714	−11.1399	12.2597	−0.0190	7.4744	7.160***	−28.821***
Taiwan	TW07RE	585	0.1130	−0.6895	8.3568	−27.3713	40.1649	1.1429	7.1682	8.566***	−23.215***
Taiwan	TW08RE	585	0.0854	−0.0454	3.9105	−25.7627	38.0126	1.5766	23.186	10.270***	−24.854***
Taiwan	TW09EN	585	0.1587	0.1791	2.0186	−15.3411	6.2576	−1.4476	11.334	8.886***	−24.223***
Taiwan	TW10EN	585	0.2153	0.1461	2.3183	−10.4635	14.7486	0.2498	8.7613	8.258***	−25.473***
Taiwan	TW11RE	585	0.1049	0.2820	7.6402	−27.7944	31.9441	0.5575	5.4580	6.999***	−25.693***
South Korea	KS01EN	585	0.0675	−0.2324	5.0823	−32.2520	31.0772	0.2299	8.2793	7.113***	−25.220***
South Korea	KS02EN	585	0.1588	0.0437	3.5425	−34.1903	15.6913	−1.4262	19.4888	9.226***	−25.903***
South Korea	KS03EN	585	0.0894	0.0449	2.7962	−18.1952	16.1361	0.4470	11.1837	8.892***	−23.266***
South Korea	KS04EN	585	0.0204	0.0186	4.1929	−22.8226	13.8197	−0.1298	5.1162	4.870***	−24.419***
South Korea	KS05EN	585	0.1291	−0.0677	5.4340	−26.3805	32.5340	0.3129	6.5051	6.214***	−24.239***
South Korea	KS06EN	585	0.0465	0.0474	2.3025	−12.3573	9.2168	−0.2458	6.0461	6.791***	−25.013***
South Korea	KS07EN	585	0.1880	0.0189	3.4794	−14.1547	17.5366	0.4313	5.4611	6.119***	−24.077***
South Korea	KS08EN	585	0.2788	0.2603	6.1877	−32.0831	35.5706	0.3770	7.6918	7.198***	−25.482***
South Korea	KS09EN	585	0.3302	0.0745	4.8058	−22.1527	25.1488	0.6441	7.4583	7.909***	−22.401***
South Korea	KS10EN	585	0.0033	−0.1103	3.5547	−15.7328	16.9688	0.5181	5.5380	6.176***	−22.475***
South Korea	KS11EN	585	0.4228	0.1886	5.5065	−33.4817	25.5292	0.2060	6.7943	6.576***	−25.426***
South Korea	KS12EN	585	0.2314	0.0821	3.6516	−19.6493	48.8172	4.4124	63.2873	11.597***	−28.039***
South Korea	KS13EN	585	0.2453	0.0302	4.5371	−21.6615	29.2869	0.6929	7.4207	7.154***	−23.441***
South Korea	KS14EN	585	0.3216	0.1813	5.3236	−36.7543	67.8273	3.6715	55.3425	11.489***	−27.087***
South Korea	KS15EN	585	−0.0203	−0.5948	5.9729	−22.7168	24.6837	0.6363	5.0733	6.382***	−23.496***
South Korea	KS16EN	585	0.1509	0.1307	3.6716	−15.7095	16.4102	0.3825	6.2630	7.344***	−23.706***
South Korea	KS17EN	585	0.2092	0.0552	5.4449	−25.4673	28.3723	0.3484	6.1427	6.260***	−25.642***
South Korea	KS18EN	585	0.2611	0.0000	6.6295	−23.4500	62.4839	2.8651	26.2655	10.576***	−26.392***

(*continued on next page*)

Appendix 2 (*continued*)

Country	Code	Obs.	Mean	Median	Std. Dev.	Min	Max	Skewness	Kurtosis	Shapiro-Wilk	ADF test
South Korea	KS19EN	585	0.0039	−0.1624	3.8423	−22.7189	22.4038	0.3030	8.5777	7.837***	−23.771***
South Korea	KS20RE	585	0.1402	−0.0060	7.0583	−33.1345	34.9050	0.0622	5.7308	5.829***	−23.984***
South Korea	KS21EN	585	0.0895	−0.0308	4.1179	−18.9956	21.6573	0.1815	6.3101	6.570***	−22.827***
South Korea	KS22EN	585	0.5081	0.0360	8.1381	−30.2944	85.5560	4.4296	45.3368	11.737***	−27.892***
Pakistan	PK01EN	585	0.1363	0.0539	3.6626	−19.8776	15.0376	−0.1294	6.4358	6.716***	−23.340***
Pakistan	PK02EN	585	−0.0535	−0.0968	3.8308	−17.9723	24.4471	0.3327	7.6149	7.068***	−22.585***
Pakistan	PK03EN	585	0.0156	−0.0855	3.9505	−21.4350	16.0060	−0.0328	6.7243	7.036***	−22.719***
Pakistan	PK04EN	585	0.0863	0.1423	3.9810	−23.3817	13.3006	−0.4725	6.8162	6.913***	−21.318***
Pakistan	PK05EN	585	0.1286	0.0141	4.5259	−17.3724	18.2259	0.2288	5.0478	5.846***	−21.589***
Pakistan	PK06EN	585	0.6032	−0.0032	5.7001	−22.7086	26.9910	0.8491	7.0204	8.457***	−19.483***
Pakistan	PK07EN	585	−0.0388	−0.0838	4.1368	−20.1437	30.2746	0.9574	13.2366	9.273***	−22.426***
Pakistan	PK08EN	585	0.1737	−0.1296	5.9798	−27.7220	19.7580	0.1520	4.5872	5.678***	−22.571***
Pakistan	PK09EN	585	0.2256	−0.0105	6.1834	−27.7274	24.7649	0.0888	4.5365	5.222***	−22.685***
Pakistan	PK10EN	585	0.1684	−0.2902	6.0445	−18.4470	33.3543	0.8748	5.9803	7.120***	−23.257***
Pakistan	PK11EN	585	0.0535	−0.0333	3.8026	−22.5035	14.1214	−0.5161	6.9788	7.163***	−22.592***
Pakistan	PK12EN	585	0.1076	−0.3216	5.8995	−22.3533	21.5089	0.1865	4.2846	4.953***	−23.456***
Pakistan	PK13EN	585	0.1104	−0.2105	5.6054	−22.4682	35.0615	0.9151	8.5075	8.191***	−21.497***
Pakistan	PK14EN	585	0.3069	−0.0955	6.3982	−27.7989	32.9847	0.5216	6.8378	8.005***	−20.979***
Pakistan	PK15EN	585	0.2494	−0.6877	7.1588	−24.5431	36.0176	0.8207	5.8487	7.339***	−21.099***
Pakistan	PK16EN	585	−0.0002	−0.0707	4.4412	−22.8854	20.4871	0.0674	8.2306	8.586***	−25.638***
Sri Lanka	SL01EN	585	0.0365	−0.3137	4.5650	−15.4346	29.0896	0.9112	6.9555	7.313***	−21.594***
Sri Lanka	SL02EN	585	0.0667	−0.0233	4.5299	−19.3275	56.3584	3.7224	46.4120	11.132***	−25.495***
Sri Lanka	SL03EN	585	0.1455	−0.0325	4.1396	−14.2933	21.7005	1.0314	7.6639	8.280***	−26.305***
Sri Lanka	SL04EN	585	0.0752	−0.2208	4.9194	−35.6614	40.6692	1.1006	18.0847	9.745***	−30.646***
Thailand	TH01EN	585	0.1828	0.0607	4.1619	−26.2226	20.4661	0.0777	8.2162	7.341***	−24.975***
Thailand	TH02EN	585	0.0813	−0.0547	4.7108	−34.5602	24.8172	−0.4629	10.9584	8.201***	−23.175***
Thailand	TH03EN	585	0.1834	0.3282	4.8008	−25.9016	30.4687	0.0376	7.7926	6.979***	−23.707***
Thailand	TH04EN	585	0.2047	0.2104	3.1315	−21.1138	19.5677	−0.2184	10.7276	8.132***	−22.901***
Thailand	TH05EN	585	0.1030	−0.0554	4.9029	−22.6838	34.4971	0.8074	9.6620	7.941***	−23.815***
Thailand	TH06EN	585	0.1157	−0.0089	2.8832	−21.7066	22.7463	0.5118	15.8251	8.979***	−26.913***
Thailand	TH07EN	585	0.2042	0.2564	4.3968	−30.8072	22.3347	−0.2169	9.3702	7.701***	−22.981***
Thailand	TH08EN	585	0.2216	0.0650	5.7857	−32.4305	35.5246	0.4848	8.0812	7.579***	−21.769***
Thailand	TH09EN	585	0.8235	0.0000	8.3769	−33.7571	45.7843	0.9612	7.7197	8.517***	−23.907***
Thailand	TH10EN	585	0.3565	0.3916	5.6139	−26.8566	30.6398	−0.0986	6.3231	6.312***	−24.250***
Thailand	TH11EN	585	0.3704	0.0498	5.4068	−26.3521	41.9887	1.5412	15.4676	10.081***	−22.587***
Thailand	TH12EN	585	0.0233	−0.1905	4.9765	−25.5112	30.5031	0.4677	7.9677	7.410***	−24.071***
Thailand	TH13EN	585	0.3681	0.1509	4.6434	−19.4724	27.5012	0.7212	8.3523	8.100***	−22.074***
Thailand	TH14EN	585	0.4518	−0.5431	10.6120	−27.7273	95.8014	2.8843	20.5566	10.782***	−24.086***
Thailand	TH15EN	585	0.5285	−0.0787	6.0418	−28.1220	49.5311	1.6974	14.6899	9.769***	−21.527***
Thailand	TH16EN	585	0.0313	0.0000	3.1423	−16.9352	32.5916	1.9329	26.9679	10.526***	−22.514***
Thailand	TH17EN	585	0.0897	−0.4217	6.8888	−26.6256	39.5213	1.2375	8.7789	9.209***	−26.536***
Thailand	TH18RE	585	0.3661	−0.3730	8.3934	−47.9114	64.7740	1.5398	15.2776	9.956***	−22.953***
Indonesia	IJ01EN	585	−0.0800	0.1579	5.9799	−33.9336	30.2622	−0.2446	7.6187	7.560***	−21.818***
Indonesia	IJ02EN	585	0.2318	−0.5126	7.5272	−34.8063	45.6562	0.7723	7.7976	8.055***	−21.363***
Indonesia	IJ03EN	585	0.1675	−0.4265	7.1930	−31.1243	52.0809	1.4771	12.2897	9.466***	−22.059***
Indonesia	IJ04EN	585	0.3082	0.0000	7.7492	−29.5794	42.0689	1.2331	8.4068	9.066***	−21.978***
Indonesia	IJ05EN	585	−0.1216	−0.2725	9.0446	−49.3783	57.3487	1.1463	12.2412	10.003***	−22.147***
Indonesia	IJ06EN	585	0.5877	−1.0174	9.1717	−32.1486	61.1807	1.6431	9.9901	9.469***	−22.048***
Indonesia	IJ07EN	585	0.1673	−0.0856	6.7168	−21.3982	47.3455	2.1022	15.3786	10.449***	−26.340***
India	IN01EN	585	−0.1018	−0.3267	3.8978	−22.1985	17.7564	−0.1592	5.4527	5.186***	−24.099***
India	IN02EN	585	0.0904	0.0093	3.2963	−21.8411	12.8655	−0.2832	7.2222	6.460***	−25.192***
India	IN03EN	585	0.2404	0.2075	4.2654	−17.1531	18.6373	0.0230	4.4155	3.764***	−24.443***
India	IN04EN	585	−0.0863	−0.2074	4.5775	−23.2540	17.4856	−0.1226	5.2103	5.306***	−24.257***
India	IN05EN	585	−0.2661	0.0215	8.8993	−42.9359	47.2642	0.4494	7.9309	8.018***	−20.420***
India	IN06EN	585	0.2286	−0.1155	5.2743	−28.7803	30.0224	0.2464	5.9749	5.684***	−23.782***
Singapore	SP01EN	585	0.0431	0.0454	3.4687	−18.9947	14.1906	−0.2375	6.3160	6.551***	−22.686***
Singapore	SP02EN	585	−0.3213	−0.3668	5.3255	−27.6031	28.7838	0.3357	8.5437	8.244***	−22.761***
Malaysia	MK01EN	585	0.1567	0.0356	3.1280	−14.2338	16.8445	0.1680	6.7642	7.393***	−24.275***
Malaysia	MK02EN	585	0.0822	−0.0571	2.7570	−9.9075	12.6092	0.4441	4.9820	5.998***	−24.967***
Malaysia	MK03EN	585	0.0854	−0.0979	2.7728	−12.2814	18.6453	0.9575	10.1300	8.371***	−24.100***
Malaysia	MK04EN	585	0.3696	0.0465	3.5766	−18.6251	13.1650	0.0358	5.5770	6.799***	−27.463***
Malaysia	MK05EN	585	−0.1448	0.0092	3.4666	−21.0978	13.2559	−0.2188	6.0418	6.005***	−22.815***
Malaysia	MK06EN	585	−0.0657	−0.2370	4.1095	−21.3612	21.9366	0.2730	7.3757	7.492***	−25.487***
Philippines	PM01EN	585	0.3262	−0.0011	4.6612	−16.7005	33.2544	1.0603	9.8367	8.755***	−25.111***
Philippines	PM02EN	585	0.1176	−0.0396	3.8556	−15.7667	19.2229	0.1843	6.4518	7.144***	−23.973***
Philippines	PM03EN	585	0.2018	−0.0887	4.2437	−24.7892	25.7417	0.4574	10.8969	9.275***	−20.925***
Philippines	PM04EN	585	0.2204	0.0897	3.5306	−15.9153	20.5127	0.5893	6.5350	6.760***	−26.998***
Philippines	PM05EN	585	0.2741	0.1338	4.4799	−14.7623	21.0632	0.5061	5.1693	5.675***	−24.284***
Philippines	PM06EN	585	0.1072	−0.0238	5.0079	−16.0055	32.4899	0.9862	8.4658	8.252***	−23.600***

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Appendix 2 (*continued*)

Country	Code	Obs.	Mean	Median	Std. Dev.	Min	Max	Skewness	Kurtosis	Shapiro-Wilk	ADF test
Philippines	PM07EN	585	0.0191	−0.3261	5.3133	−20.1947	50.6427	2.2926	20.4129	10.042***	−22.770***
Philippines	PM08EN	585	0.1326	0.1487	3.4268	−17.3486	12.7058	−0.0950	5.1823	5.602***	−21.815***
Vietman	VM01EN	585	0.0239	−0.0094	5.8252	−19.8227	30.0087	0.2059	5.2348	5.482***	−24.144***
Vietman	VM02EN	585	0.1078	−0.0155	4.9784	−16.8679	21.8350	0.2266	4.5317	4.634***	−25.851***
Vietman	VM03EN	585	0.0437	0.0000	3.5492	−23.8492	22.4481	0.0166	10.8363	8.753***	−24.958***
Vietman	VM04RE	585	0.1701	0.0446	3.9636	−15.1739	18.1561	−0.1554	4.8087	5.451***	−28.000***
Vietman	VM05EN	585	0.0948	−0.0989	4.9048	−25.5966	28.7167	0.4217	8.9729	8.343***	−24.280***
Vietman	VM06RE	585	0.0462	0.0000	3.3253	−16.4901	12.5505	−0.2058	5.5992	5.973***	−30.915***
Vietman	VM07RE	585	0.0938	0.0048	3.3814	−19.9764	15.8204	−0.5148	8.9097	8.992***	−24.087***
Vietman	VM08EN	585	0.1649	0.0000	4.7597	−15.2492	20.0625	0.5451	5.6370	7.515***	−22.288***
Vietman	VM09EN	585	0.1013	−0.0746	5.0648	−17.5571	21.3334	0.7770	6.0906	8.079***	−24.511***
Vietman	VM10EN	585	−0.0478	−0.0406	3.5850	−21.1995	18.0530	0.2813	8.9599	8.739***	−27.518***
Vietman	VM11EN	585	0.0128	−0.1624	5.9894	−19.4315	27.5140	0.9776	6.5561	8.132***	−25.885***
Mongolia	MG01EN	585	0.5342	−0.0688	8.8406	−37.3328	69.4733	2.1897	18.0098	10.691***	−22.036***
Mongolia	MG02EN	585	0.1744	0.0000	9.3886	−30.7432	96.3662	3.2726	30.2942	11.024***	−23.921***
Mongolia	MG03EN	585	0.0420	−0.1662	8.8619	−22.1458	63.0646	2.2230	14.6068	10.004***	−23.250***
Mongolia	MG04EN	585	0.1881	0.0000	9.6385	−31.0736	67.1575	2.0296	12.5744	10.242***	−23.187***
Mongolia	MG05EN	585	−0.1055	0.0000	6.9659	−37.6430	49.5050	1.1381	14.2795	10.454***	−24.557***
Argentina	AR01EN	585	0.3805	−0.1659	8.8320	−63.5494	40.3742	−0.1025	8.8862	7.391***	−25.336***
Argentina	AR02EN	585	0.3768	0.2457	6.9615	−48.3529	30.1950	−0.2884	8.1124	6.920***	−24.730***
Argentina	AR03EN	585	0.3843	−0.1088	6.7711	−39.4318	28.6395	−0.1994	6.2935	6.082***	−24.050***
Argentina	AR04EN	585	0.2440	−0.1283	7.7112	−48.7941	27.6385	−0.1355	6.8167	6.668***	−25.353***
Argentina	AR05EN	585	0.3754	0.0027	7.3577	−55.3329	32.5712	−0.4385	10.1309	8.123***	−24.257***
Argentina	AR06EN	585	−0.0218	0.1820	7.5578	−52.2785	61.7665	0.0513	15.4067	8.986***	−24.017***
Argentina	AR07EN	585	0.3166	−0.2733	8.5099	−60.1875	55.3597	0.2848	11.1244	8.490***	−24.400***
Argentina	AR08EN	585	0.5446	−0.1316	9.0532	−54.5180	46.5670	0.1670	7.6753	7.553***	−23.239***
Argentina	AR09EN	585	0.1457	−0.5118	9.3493	−44.6882	57.5617	1.1088	9.7906	9.189***	−24.469***
Brazil	BR01EN	585	0.0110	0.1536	7.6342	−42.9901	40.9102	0.1423	7.6594	7.399***	−23.394***
Brazil	BR02EN	585	−0.0103	−0.0218	7.5896	−43.8948	36.1331	−0.0380	7.3298	7.112***	−23.539***
Brazil	BR03EN	585	0.0376	0.1490	5.0769	−33.8850	23.3308	−0.3269	8.6557	7.635***	−22.699***
Brazil	BR04EN	585	0.2974	0.4153	4.4429	−23.1956	23.8787	−0.4232	6.7299	6.408***	−23.134***
Brazil	BR05EN	585	−0.1874	0.0631	7.4172	−40.3168	28.1538	−0.7313	7.6841	7.713***	−22.952***
Brazil	BR06EN	585	0.2022	0.1842	5.6464	−29.4058	28.1089	−0.0900	5.9022	5.647***	−25.364***
Brazil	BR07EN	585	−0.0119	0.2552	6.5732	−28.7986	34.4180	0.1224	6.2253	6.368***	−22.236***
Brazil	BR08EN	585	0.1078	−0.2557	8.1672	−38.5587	36.2300	0.4485	6.0005	6.740***	−22.594***
Brazil	BR09EN	585	0.1573	0.0000	4.8485	−24.0646	21.3266	−0.3203	7.2616	7.700***	−23.536***
Brazil	BR10EN	585	0.0258	−0.0094	4.0079	−13.8098	15.0078	0.0386	3.9147	2.887***	−22.697***
Brazil	BR11EN	585	0.0489	0.1326	5.4685	−26.1350	20.8603	−0.1031	5.0881	5.112***	−22.672***
Brazil	BR12EN	585	0.0656	0.0000	4.1215	−19.8255	12.9905	−0.3083	5.1382	5.423***	−22.231***
Brazil	BR13EN	585	0.0927	−0.3847	7.5102	−41.0060	29.9756	−0.0109	6.1494	6.198***	−23.058***
Brazil	BR14EN	585	0.0061	0.1032	4.6463	−28.3158	26.6150	−0.4485	9.0597	7.753***	−23.410***
Brazil	BR15EN	585	−0.0132	0.0826	4.4302	−24.7559	18.5439	−0.1596	5.3843	4.972***	−23.434***
Brazil	BR16EN	585	−0.0924	0.0000	4.5579	−24.8064	25.5478	0.1607	8.9177	9.010***	−28.011***
Brazil	BR17EN	585	0.0100	0.0739	4.4125	−32.1708	16.8379	−0.7461	9.3041	7.428***	−23.445***
Brazil	BR18EN	585	0.0768	0.2271	6.5470	−31.3483	35.9330	0.2332	7.4808	7.150***	−21.296***
Chile	CL01EN	585	0.0162	−0.1245	3.8590	−20.3002	17.8359	0.0548	5.8497	5.857***	−25.495***
Chile	CL02EN	585	0.0495	0.1133	4.2813	−32.5473	20.7473	−0.3567	9.7503	7.287***	−24.856***
Chile	CL03EN	585	−0.0931	0.0000	3.9267	−26.7384	17.0543	−0.4121	7.8934	6.913***	−25.868***
Chile	CL04EN	585	0.0090	0.0436	4.2069	−32.4863	36.5761	0.3098	18.8867	9.229***	−26.474***
Chile	CL05EN	585	−0.1505	−0.2028	3.5334	−15.6063	16.5876	0.1267	5.4457	5.782***	−24.523***
Chile	CL06EN	585	−0.0040	−0.0882	3.8896	−19.1263	21.6970	0.3256	6.5302	6.313***	−24.335***
Peru	PE01EN	585	0.1818	0.0677	3.5901	−20.1127	16.5410	0.0582	6.6622	7.011***	−23.309***
Peru	PE02EN	585	0.0703	0.0000	2.3431	−7.7447	11.2246	0.5608	6.1034	7.807***	−19.457***
Peru	PE03EN	585	0.1513	0.0000	3.1369	−24.1615	20.1150	0.0236	12.8402	8.965***	−22.741***
Peru	PE04EN	585	−0.1077	−0.5238	6.7965	−23.6405	50.1014	1.7486	13.6806	9.093***	−24.140***
Peru	PE05EN	585	0.2042	0.0855	3.8066	−23.8751	29.9857	0.3710	18.5704	10.486***	−21.472***
Colombia	CO01EN	585	0.0592	0.2423	5.7742	−42.1184	34.5717	−0.3747	14.3147	9.125***	−23.334***
Colombia	CO02EN	585	0.1077	0.1134	4.6989	−35.0766	25.7781	−0.4254	12.0929	8.644***	−24.183***
Colombia	CO03EN	585	0.0819	0.1614	3.4837	−21.6286	15.3209	−0.3929	7.6736	7.264***	−26.236***
Colombia	CO04EN	585	−0.0333	0.0277	4.1715	−26.2419	21.4743	−0.5171	8.7663	7.509***	−24.624***
Romania	RM01EN	585	0.2188	0.0000	4.2623	−17.6525	21.0214	0.5561	7.1161	8.056***	−23.484***
Romania	RM02EN	585	0.1337	0.0303	3.9995	−14.8857	16.4246	−0.0054	5.3071	6.621***	−24.341***
Montenegro	MN01EN	585	0.0970	−0.0264	6.7147	−27.3290	42.5595	1.1170	9.9095	9.442***	−30.184***
Montenegro	MN02EN	585	0.0667	0.0000	3.6919	−27.0142	15.0207	−0.8360	12.7349	9.151***	−27.675***
Czech Republic	CR01EN	585	−0.0587	0.0712	3.5207	−20.5877	16.9212	−0.1008	6.7200	6.361***	−26.208***
Russia	RU01EN	585	0.0002	0.0000	6.7094	−32.5581	50.0000	0.4241	11.4422	8.662***	−23.101***
Russia	RU02EN	585	−0.0028	−0.1018	4.9299	−23.3063	20.3338	0.1085	5.3291	5.637***	−23.971***
Russia	RU03EN	585	−0.0703	−0.0772	5.4023	−27.4379	34.5178	0.1608	8.2074	7.486***	−23.412***
Russia	RU04EN	585	0.0295	−0.2328	5.9839	−28.5514	26.9758	0.0779	7.1863	7.540***	−23.208***

(*continued on next page*)

Appendix 2 (*continued*)

Country	Code	Obs.	Mean	Median	Std. Dev.	Min	Max	Skewness	Kurtosis	Shapiro-Wilk	ADF test
Russia	RU05EN	585	0.1729	0.1628	4.6648	−32.6067	28.5562	−0.1976	11.1534	8.271***	−25.233***
Russia	RU06EN	585	0.3394	0.1469	5.0123	−31.1920	35.4591	0.5278	10.6789	8.170***	−27.876***
Russia	RU07EN	585	0.1283	0.0271	5.3954	−34.3488	36.9316	−0.0707	11.5870	8.489***	−24.932***
Russia	RU08EN	585	0.0239	0.0539	5.2896	−29.9657	35.7079	0.2108	10.6840	8.473***	−23.655***
Russia	RU09EN	585	0.1250	0.1171	4.6312	−24.7345	20.4051	−0.6368	7.5736	7.800***	−24.551***
Russia	RU10EN	585	0.2622	0.0770	5.8531	−35.7163	53.5339	0.7862	18.1908	9.155***	−26.413***
Russia	RU11EN	585	0.3420	0.4560	5.6126	−38.4826	46.7378	0.0473	15.8986	8.972***	−25.297***
Slovenia	SV01EN	585	0.0382	0.0398	3.0347	−16.0297	15.6794	0.1009	6.4210	6.325***	−24.139***
Turkey	TK01EN	585	0.0092	0.1414	5.1358	−26.5766	23.9069	−0.1469	5.9313	6.048***	−25.621***
Turkey	TK02EN	585	0.0408	0.1181	5.3520	−26.0969	21.4428	−0.2295	5.5368	5.737***	−27.143***
Bosnia-Herzegovina	BH01EN	585	−0.1090	−0.1848	7.2505	−25.4409	72.7252	3.5713	37.8331	11.875***	−19.349***
Bosnia-Herzegovina	BH02EN	585	−0.0015	−0.1198	5.3721	−21.3938	41.1011	1.2584	14.8134	10.780***	−25.853***
Bosnia-Herzegovina	BH03EN	585	0.0807	−0.2043	9.8434	−34.6907	104.1982	3.1541	31.6141	11.367***	−22.585***
Hungary	HG01EN	585	0.0139	−0.0523	4.7626	−28.4657	27.6560	−0.0977	8.6828	7.614***	−26.263***

Note: ADF corresponds to Augmented Dickey-Fuller test. This test only considers the random walk specification. Superscripts ***, **, * indicate statistical significance at 1%, 5%, and 10%, respectively. Source: Authors' computation.

Appendix 3
Centrality index comparison at country-level.

Country	Spillovers for residual stock returns				Spillovers for standardized residual returns				Granger	Partial Corr.
	From	To	Net	Centrality	From	To	Net	Centrality	Centrality	Centrality
HK	27.35	25.92	−1.44	34	28.32	26.88	−1.45	37	42	26
CH	20.30	15.62	−4.68	19	18.87	14.19	−4.68	18	50	26
TW	20.76	18.26	−2.50	20	19.88	17.87	−2.01	18	44	26
KS	10.13	8.86	−1.27	4	9.99	9.06	−0.93	6	43	26
PK	49.27	54.82	5.55	85	49.63	54.30	4.67	85	40	26
SL	24.10	19.56	−4.54	27	23.44	19.05	−4.40	25	43	26
TH	11.26	9.15	−2.12	7	10.95	9.15	−1.80	7	49	26
IJ	16.02	11.93	−4.09	15	16.35	12.39	−3.96	17	48	26
IN	52.55	68.64	16.09	102	52.78	69.67	16.89	103	34	26
SP	18.69	17.37	−1.31	21	19.28	15.94	−3.34	18	41	26
MK	12.61	10.62	−1.99	6	12.57	11.46	−1.11	5	41	26
PM	41.22	41.19	−0.02	68	41.01	42.56	1.55	68	29	26
VM	52.53	67.56	15.02	98	52.27	65.02	12.75	95	42	26
MG	43.83	47.74	3.91	70	43.53	45.58	2.04	67	47	26
AR	11.37	9.12	−2.25	8	12.91	10.24	−2.66	10	51	26
BR	15.96	13.74	−2.22	8	17.16	15.70	−1.46	12	48	26
CL	14.60	12.39	−2.21	11	16.18	12.57	−3.61	12	45	26
PE	7.94	6.36	−1.58	3	6.70	5.53	−1.17	2	42	26
CO	14.01	11.59	−2.43	10	15.86	12.67	−3.19	15	48	26
RM	49.39	69.87	20.48	101	49.72	69.39	19.67	99	35	26
MN	29.94	24.01	−5.93	39	30.06	24.27	−5.79	35	46	26
CR	22.86	17.99	−4.87	28	23.55	17.31	−6.24	27	36	26
RU	18.19	16.17	−2.02	18	17.70	17.66	−0.05	17	45	26
SV	19.24	14.74	−4.50	18	18.88	15.53	−3.35	17	47	26
TK	27.91	25.28	−2.63	35	27.16	25.47	−1.69	36	49	26
BH	8.23	5.89	−2.34	3	8.29	6.23	−2.06	5	49	26
HG	19.99	15.89	−4.10	22	19.38	16.76	−2.62	24	46	26

Notes: Centrality degree corresponds to the number of links related to each node (vertex), both incoming and outgoing from each node. Residual returns were standardized using the conditional standard deviation calculated through a GARCH(1,1) model. Source: Authors' computation.

Appendix 4
Centrality index comparison at firm-level.

Country	Firm	Spillovers for residual stock returns				Spillovers for standardized residual returns				Granger	Partial Corr.
	Code	From	To	Net	Centrality	From	To	Net	Centrality	Centrality	Centrality
Hong Kong	HK01EN	40.44	37.83	−2.61	8	45.81	42.83	−2.98	12	418	218
Hong Kong	HK02EN	42.38	45.34	2.95	12	42.72	45.23	2.51	8	398	218
Hong Kong	HK03EN	44.27	48.29	4.02	18	43.11	46.53	3.42	22	398	218
Hong Kong	HK04EN	48.99	56.71	7.72	17	48.69	55.94	7.25	21	395	218
Hong Kong	HK05EN	42.16	43.43	1.26	14	42.15	44.60	2.46	16	410	218
Hong Kong	HK06EN	50.51	60.62	10.11	30	48.96	59.48	10.52	29	425	218

(*continued on next page*)

Appendix 4 (*continued*)

Country	Firm Code	Spillovers for residual stock returns: From	To	Net	Centrality	Spillovers for standardized residual returns: From	To	Net	Centrality	Granger Centrality	Partial Corr. Centrality
China	CH01EN	40.27	40.36	0.09	9	40.91	42.51	1.61	10	419	218
China	CH02RE	42.87	42.99	0.11	17	43.72	45.13	1.41	18	434	218
China	CH03EN	54.28	66.12	11.84	44	51.09	61.71	10.62	30	424	218
China	CH04EN	52.49	60.33	7.84	43	55.19	52.44	−2.75	29	431	218
China	CH05RE	37.82	34.51	−3.30	13	36.24	33.69	−2.55	9	434	218
China	CH06EN	45.71	49.05	3.34	22	47.02	54.40	7.39	30	426	218
China	CH07EN	53.73	61.77	8.04	48	54.11	60.54	6.43	43	425	218
China	CH08EN	57.31	71.57	14.26	54	56.61	72.29	15.68	51	418	218
China	CH09EN	59.33	77.00	17.67	70	58.44	78.24	19.80	64	423	218
China	CH10EN	44.92	46.99	2.07	29	46.64	49.98	3.34	27	424	218
China	CH11EN	40.86	43.46	2.60	19	40.45	44.05	3.61	21	413	218
China	CH12EN	42.02	43.76	1.74	18	38.12	39.22	1.09	17	419	218
China	CH13EN	46.37	51.43	5.07	33	45.15	50.33	5.18	28	424	218
China	CH14EN	33.27	30.05	−3.22	5	32.76	33.04	0.28	6	431	218
China	CH15EN	38.01	35.72	−2.29	9	36.94	38.86	1.92	10	419	218
China	CH16EN	46.38	47.02	0.64	20	41.71	43.49	1.78	20	423	218
China	CH17EN	39.11	35.48	−3.63	16	36.09	35.94	−0.15	13	431	218
China	CH18RE	35.23	32.24	−2.99	13	33.89	34.06	0.17	10	434	218
China	CH19EN	34.88	33.13	−1.75	4	35.38	37.70	2.32	15	433	218
China	CH20EN	43.26	42.17	−1.09	14	50.82	44.91	−5.91	16	431	218
China	CH21EN	47.13	48.49	1.36	36	44.23	44.69	0.46	32	421	218
China	CH22EN	32.23	28.34	−3.89	0	34.39	36.07	1.67	5	435	218
China	CH23EN	37.57	35.19	−2.39	15	37.73	36.99	−0.74	9	418	218
China	CH24EN	42.34	43.76	1.42	17	43.01	46.54	3.53	15	429	218
China	CH25EN	38.64	35.41	−3.23	4	47.08	38.74	−8.34	5	431	218
China	CH26EN	33.47	29.86	−3.61	8	31.88	31.27	−0.61	4	431	218
China	CH27EN	33.38	29.73	−3.65	4	35.55	33.41	−2.14	4	423	218
China	CH28EN	38.80	35.12	−3.68	11	35.70	35.70	0.00	12	433	218
China	CH29EN	36.78	34.70	−2.08	13	38.71	38.97	0.27	16	412	218
China	CH30EN	38.61	35.77	−2.83	14	37.55	33.25	−4.30	11	426	218
China	CH31EN	33.80	30.11	−3.69	8	32.72	30.82	−1.89	2	434	218
China	CH32EN	42.72	41.50	−1.21	17	46.70	33.15	−13.55	11	427	218
Taiwan	TW01EN	36.34	32.89	−3.45	5	40.54	37.47	−3.08	5	425	218
Taiwan	TW02RE	47.00	51.86	4.86	24	48.06	54.99	6.93	25	434	218
Taiwan	TW03EN	35.60	30.96	−4.64	2	36.64	36.85	0.22	5	397	218
Taiwan	TW04EN	30.51	26.62	−3.89	2	30.65	29.11	−1.55	2	406	218
Taiwan	TW05EN	41.78	44.42	2.64	18	42.11	47.14	5.03	21	399	218
Taiwan	TW06EN	41.31	41.96	0.65	18	42.24	45.36	3.12	19	424	218
Taiwan	TW07RE	48.43	54.42	5.99	36	47.83	56.85	9.03	37	432	218
Taiwan	TW08RE	33.76	30.43	−3.33	5	35.50	36.96	1.47	9	418	218
Taiwan	TW09EN	32.74	29.15	−3.59	5	32.70	30.89	−1.81	3	406	216
Taiwan	TW10EN	37.77	36.95	−0.82	2	43.57	38.39	−5.17	8	418	218
Taiwan	TW11RE	49.27	55.66	6.39	38	49.37	57.02	7.65	33	431	218
South Korea	KS01EN	31.99	28.66	−3.33	7	37.80	32.91	−4.89	12	427	218
South Korea	KS02EN	38.72	35.87	−2.85	15	36.99	39.73	2.74	14	416	218
South Korea	KS03EN	34.23	30.06	−4.17	8	43.19	30.93	−12.26	9	408	217
South Korea	KS04EN	37.85	36.25	−1.60	7	37.54	39.88	2.34	8	423	218
South Korea	KS05EN	32.62	29.37	−3.25	5	33.71	35.99	2.28	13	432	218
South Korea	KS06EN	38.87	39.26	0.39	16	40.07	43.86	3.79	26	416	218
South Korea	KS07EN	38.38	35.40	−2.98	5	45.54	37.99	−7.55	13	431	218
South Korea	KS08EN	46.72	50.52	3.80	26	45.64	48.93	3.30	25	429	218
South Korea	KS09EN	36.14	33.66	−2.48	3	37.04	34.85	−2.19	5	433	218
South Korea	KS10EN	36.49	34.66	−1.83	7	37.28	36.54	−0.74	8	430	218
South Korea	KS11EN	36.30	33.89	−2.41	3	34.72	34.96	0.24	4	433	218
South Korea	KS12EN	39.85	39.15	−0.70	15	37.12	36.30	−0.83	10	414	218
South Korea	KS13EN	38.26	37.06	−1.20	11	38.73	36.20	−2.53	15	415	218
South Korea	KS14EN	29.73	25.32	−4.41	5	27.66	23.82	−3.84	3	428	217
South Korea	KS15EN	44.38	47.72	3.34	23	45.18	52.84	7.65	23	432	218
South Korea	KS16EN	38.90	36.96	−1.95	7	36.66	36.55	−0.11	13	414	218
South Korea	KS17EN	53.05	63.41	10.36	44	59.26	67.05	7.79	47	428	218
South Korea	KS18EN	51.26	59.11	7.85	56	50.44	58.98	8.55	54	429	218
South Korea	KS19EN	39.78	40.46	0.68	13	43.78	44.49	0.70	16	416	217
South Korea	KS20RE	35.54	32.04	−3.50	4	42.62	35.83	−6.79	6	433	218
South Korea	KS21EN	45.85	47.55	1.70	26	48.91	52.24	3.33	30	410	218
South Korea	KS22EN	47.77	49.31	1.54	51	49.69	52.62	2.94	54	434	218
Pakistan	PK01EN	37.11	35.30	−1.81	14	40.00	37.12	−2.88	12	423	218
Pakistan	PK02EN	44.68	48.16	3.48	29	44.65	52.22	7.57	31	426	218
Pakistan	PK03EN	41.92	42.55	0.63	21	42.10	43.83	1.73	23	416	218

(*continued on next page*)

Appendix 4 (*continued*)

Country	Firm	Spillovers for residual stock returns				Spillovers for standardized residual returns				Granger	Partial Corr.
	Code	From	To	Net	Centrality	From	To	Net	Centrality	Centrality	Centrality
Pakistan	PK04EN	39.97	39.94	−0.03	11	42.27	41.95	−0.31	12	422	218
Pakistan	PK05EN	38.82	37.92	−0.90	16	37.79	37.42	−0.37	13	421	218
Pakistan	PK06EN	34.26	29.70	−4.56	0	46.33	33.03	−13.30	4	432	218
Pakistan	PK07EN	36.54	35.20	−1.34	12	38.79	37.55	−1.24	13	421	218
Pakistan	PK08EN	44.43	47.94	3.51	25	48.90	52.64	3.74	25	428	218
Pakistan	PK09EN	44.04	46.52	2.48	30	44.60	49.03	4.43	30	425	218
Pakistan	PK10EN	35.05	31.34	−3.71	3	38.97	32.61	−6.36	5	428	218
Pakistan	PK11EN	31.13	27.73	−3.40	8	31.53	30.72	−0.81	9	425	218
Pakistan	PK12EN	46.67	52.93	6.26	30	47.43	57.88	10.45	29	420	218
Pakistan	PK13EN	33.66	30.33	−3.33	4	36.40	33.31	−3.08	6	429	218
Pakistan	PK14EN	40.70	40.79	0.09	27	41.39	43.91	2.52	28	420	218
Pakistan	PK15EN	41.97	42.55	0.58	14	40.03	40.87	0.85	13	430	218
Pakistan	PK16EN	26.92	21.38	−5.54	0	37.96	24.27	−13.69	6	423	218
Sri Lanka	SL01EN	41.72	42.03	0.31	19	41.80	42.37	0.57	22	430	218
Sri Lanka	SL02EN	36.90	34.39	−2.51	5	37.96	37.97	0.01	8	423	218
Sri Lanka	SL03EN	52.79	64.31	11.51	38	54.96	65.08	10.12	38	401	218
Sri Lanka	SL04EN	34.98	27.86	−7.12	2	54.60	31.32	−23.28	9	430	217
Thailand	TH01EN	45.11	48.76	3.64	28	53.20	54.35	1.15	35	416	218
Thailand	TH02EN	41.50	40.06	−1.44	18	48.16	43.91	−4.25	20	423	218
Thailand	TH03EN	46.15	48.27	2.12	30	55.34	51.69	−3.65	32	423	218
Thailand	TH04EN	40.63	41.01	0.37	23	40.46	42.25	1.79	16	421	218
Thailand	TH05EN	46.30	51.78	5.49	28	45.90	52.41	6.51	26	420	218
Thailand	TH06EN	38.47	36.03	−2.43	24	47.91	34.72	−13.19	15	421	218
Thailand	TH07EN	40.04	37.80	−2.24	19	50.32	36.53	−13.79	17	417	218
Thailand	TH08EN	39.12	38.83	−0.29	6	39.66	41.52	1.86	5	429	218
Thailand	TH09EN	32.68	28.90	−3.78	8	31.89	27.68	−4.21	6	434	218
Thailand	TH10EN	31.59	27.70	−3.89	4	31.25	29.69	−1.56	6	434	218
Thailand	TH11EN	31.71	27.61	−4.10	1	31.47	29.21	−2.26	2	427	218
Thailand	TH12EN	32.29	25.49	−6.80	2	43.33	25.78	−17.55	2	422	218
Thailand	TH13EN	34.19	31.77	−2.41	7	34.49	35.52	1.03	10	424	218
Thailand	TH14EN	34.23	31.12	−3.12	7	32.72	32.16	−0.56	6	435	218
Thailand	TH15EN	31.24	27.43	−3.81	1	40.27	31.45	−8.81	6	432	218
Thailand	TH16EN	27.88	23.78	−4.10	3	27.40	27.09	−0.31	4	417	218
Thailand	TH17EN	41.07	40.12	−0.94	14	47.29	43.51	−3.78	19	428	218
Thailand	TH18RE	38.32	37.24	−1.07	6	37.98	41.29	3.30	11	436	218
Indonesia	IJ01EN	36.49	34.25	−2.23	2	40.08	37.31	−2.77	4	430	218
Indonesia	IJ02EN	32.53	28.79	−3.74	2	34.10	32.90	−1.20	3	435	218
Indonesia	IJ03EN	31.68	27.72	−3.96	6	32.92	32.31	−0.60	7	432	218
Indonesia	IJ04EN	41.47	42.63	1.17	10	42.29	46.62	4.34	11	434	218
Indonesia	IJ05EN	35.56	33.73	−1.83	4	36.45	38.69	2.24	3	434	218
Indonesia	IJ06EN	32.90	29.48	−3.42	4	32.99	32.75	−0.24	2	433	218
Indonesia	IJ07EN	38.97	37.26	−1.72	12	37.82	39.97	2.14	8	433	218
India	IN01EN	39.92	37.84	−2.09	10	48.50	40.82	−7.68	9	417	218
India	IN02EN	39.14	36.75	−2.39	8	47.60	38.75	−8.85	11	415	217
India	IN03EN	40.26	37.73	−2.53	12	49.14	38.55	−10.59	15	421	218
India	IN04EN	39.50	39.44	−0.06	10	38.96	39.99	1.03	8	418	218
India	IN05EN	35.23	32.79	−2.45	5	36.22	36.40	0.18	2	432	218
India	IN06EN	37.10	35.71	−1.39	14	37.50	37.42	−0.07	8	425	218
Singapore	SP01EN	35.79	33.32	−2.47	5	39.22	34.85	−4.37	5	409	218
Singapore	SP02EN	34.49	31.07	−3.42	4	36.52	32.93	−3.59	7	433	218
Malaysia	MK01EN	42.60	44.10	1.50	7	49.61	45.18	−4.43	12	416	218
Malaysia	MK02EN	47.81	54.47	6.65	20	48.41	54.51	6.10	22	408	218
Malaysia	MK03EN	31.71	27.62	−4.09	2	33.78	26.04	−7.73	4	413	218
Malaysia	MK04EN	38.88	37.17	−1.70	6	40.49	41.53	1.04	11	415	218
Malaysia	MK05EN	40.50	40.47	−0.03	15	43.37	41.24	−2.13	14	422	218
Malaysia	MK06EN	37.97	36.84	−1.13	15	37.94	38.47	0.54	11	420	218
Philippines	PM01EN	42.26	43.17	0.91	26	42.78	41.90	−0.88	25	420	218
Philippines	PM02EN	33.51	29.81	−3.70	7	33.51	31.32	−2.19	7	420	218
Philippines	PM03EN	35.50	33.34	−2.15	8	37.29	40.28	2.99	17	424	218
Philippines	PM04EN	41.11	42.24	1.13	24	38.74	40.99	2.24	21	417	218
Philippines	PM05EN	51.27	64.27	13.00	35	50.56	63.17	12.61	37	400	218
Philippines	PM06EN	36.49	33.04	−3.45	17	34.80	32.57	−2.23	18	405	218
Philippines	PM07EN	34.24	31.36	−2.87	7	40.10	36.72	−3.38	11	427	218
Philippines	PM08EN	43.21	45.70	2.50	18	41.15	44.16	3.01	18	397	218
Vietman	VM01EN	44.46	48.34	3.88	15	44.55	52.61	8.06	18	427	218
Vietman	VM02EN	40.52	39.84	−0.68	21	44.81	41.46	−3.35	23	420	218
Vietman	VM03EN	28.23	23.42	−4.81	2	33.18	24.88	−8.30	4	416	218
Vietman	VM04RE	41.39	40.82	−0.57	17	54.56	42.45	−12.10	12	424	218

(*continued on next page*)

Appendix 4 (*continued*)

Country	Firm Code	Spillovers for residual stock returns From	To	Net	Centrality	Spillovers for standardized residual returns From	To	Net	Centrality	Granger Centrality	Partial Corr. Centrality
Vietman	VM05EN	31.74	27.35	−4.38	5	35.04	27.58	−7.47	7	428	218
Vietman	VM06RE	37.49	35.42	−2.08	8	42.26	37.69	−4.57	10	413	218
Vietman	VM07RE	27.56	23.75	−3.81	1	32.47	27.96	−4.51	5	416	218
Vietman	VM08EN	40.79	41.52	0.72	23	41.72	45.27	3.55	25	400	218
Vietman	VM09EN	45.68	48.79	3.10	25	44.83	49.57	4.73	25	407	218
Vietman	VM10EN	35.29	33.41	−1.88	6	33.74	33.13	−0.61	7	423	218
Vietman	VM11EN	43.42	45.27	1.85	20	43.96	49.51	5.55	26	424	218
Mongolia	MG01EN	34.85	31.82	−3.03	6	34.29	34.63	0.34	6	432	218
Mongolia	MG02EN	31.85	27.11	−4.74	0	38.82	30.56	−8.26	5	433	218
Mongolia	MG03EN	47.21	51.71	4.50	20	46.57	55.67	9.09	19	431	218
Mongolia	MG04EN	43.58	45.22	1.64	13	43.62	47.70	4.08	17	432	218
Mongolia	MG05EN	29.19	25.03	−4.17	2	29.01	30.05	1.03	5	430	218
Argentina	AR01EN	38.19	37.85	−0.34	12	38.56	40.26	1.70	12	427	218
Argentina	AR02EN	36.16	35.48	−0.67	9	37.31	41.52	4.21	12	420	218
Argentina	AR03EN	37.96	38.03	0.07	21	38.07	41.87	3.80	20	419	218
Argentina	AR04EN	37.27	36.63	−0.64	12	36.31	37.34	1.03	12	428	218
Argentina	AR05EN	30.41	26.80	−3.61	5	30.00	29.95	−0.05	8	424	218
Argentina	AR06EN	39.74	39.02	−0.71	17	40.25	45.71	5.46	12	432	218
Argentina	AR07EN	32.42	29.48	−2.94	8	39.27	33.81	−5.46	8	429	218
Argentina	AR08EN	33.33	28.92	−4.41	5	33.29	32.70	−0.59	5	426	218
Argentina	AR09EN	36.08	33.97	−2.11	12	39.26	36.81	−2.45	15	430	218
Brazil	BR01EN	58.44	68.02	9.58	72	58.74	67.73	8.99	66	426	218
Brazil	BR02EN	59.31	71.32	12.01	74	61.55	73.73	12.18	68	426	218
Brazil	BR03EN	28.78	21.87	−6.91	1	38.91	22.73	−16.17	4	429	218
Brazil	BR04EN	33.60	29.81	−3.79	6	32.24	29.66	−2.58	6	420	218
Brazil	BR05EN	35.34	31.99	−3.35	11	43.92	30.69	−13.23	6	434	218
Brazil	BR06EN	37.81	35.66	−2.14	13	37.54	37.47	−0.07	9	420	218
Brazil	BR07EN	56.11	66.93	10.82	63	57.00	72.91	15.90	65	412	218
Brazil	BR08EN	56.69	67.47	10.78	65	57.23	72.83	15.60	68	427	218
Brazil	BR09EN	36.86	33.24	−3.63	5	50.32	37.87	−12.45	10	426	218
Brazil	BR10EN	42.88	42.29	−0.59	20	44.38	42.55	−1.83	26	403	218
Brazil	BR11EN	37.14	35.42	−1.72	10	35.81	34.89	−0.92	9	416	218
Brazil	BR12EN	40.33	38.95	−1.38	16	40.36	43.01	2.66	15	413	218
Brazil	BR13EN	57.88	71.64	13.76	63	57.80	76.25	18.44	65	428	218
Brazil	BR14EN	33.94	30.50	−3.44	10	35.12	33.28	−1.84	12	422	218
Brazil	BR15EN	36.64	34.60	−2.04	11	36.54	36.07	−0.47	12	413	218
Brazil	BR16EN	35.64	33.28	−2.36	8	37.10	37.22	0.12	2	431	218
Brazil	BR17EN	33.21	28.58	−4.63	10	40.18	28.97	−11.21	5	419	218
Brazil	BR18EN	55.20	64.36	9.16	61	56.19	71.14	14.95	65	416	218
Chile	CL01EN	35.79	33.18	−2.61	6	42.79	33.76	−9.03	11	420	218
Chile	CL02EN	43.41	45.06	1.65	33	45.08	46.74	1.66	32	415	218
Chile	CL03EN	33.33	30.32	−3.01	3	33.74	33.83	0.08	3	415	218
Chile	CL04EN	33.38	30.57	−2.81	5	31.05	28.98	−2.07	7	418	218
Chile	CL05EN	37.08	35.96	−1.11	9	37.28	36.69	−0.59	11	403	218
Chile	CL06EN	46.97	51.19	4.21	34	51.42	53.04	1.62	31	412	217
Peru	PE01EN	47.24	50.94	3.70	28	47.99	51.51	3.52	28	422	218
Peru	PE02EN	49.71	54.76	5.06	26	58.45	53.46	−4.99	21	352	218
Peru	PE03EN	42.20	40.93	−1.27	21	46.81	43.72	−3.09	27	418	218
Peru	PE04EN	39.22	38.43	−0.79	14	39.57	41.36	1.79	9	433	218
Peru	PE05EN	41.85	40.14	−1.71	15	50.27	42.85	−7.43	20	420	218
Colombia	CO01EN	45.17	47.89	2.72	20	44.63	48.32	3.69	18	431	218
Colombia	CO02EN	46.03	48.25	2.22	29	54.37	50.91	−3.45	29	424	218
Colombia	CO03EN	48.02	53.18	5.16	35	48.37	58.65	10.28	39	419	218
Colombia	CO04EN	46.56	50.58	4.02	34	46.24	52.06	5.82	36	427	218
Romania	RM01EN	37.75	36.87	−0.88	8	36.94	36.04	−0.90	6	415	218
Romania	RM02EN	48.63	56.89	8.26	17	48.45	57.29	8.84	17	396	218
Montenegro	MN01EN	32.48	26.19	−6.28	2	42.48	30.32	−12.16	5	435	218
Montenegro	MN02EN	31.84	25.87	−5.97	6	43.45	27.77	−15.68	8	421	218
Czech Republic	CR01EN	30.28	26.32	−3.96	2	30.47	28.17	−2.30	3	409	218
Russia	RU01EN	46.53	52.10	5.58	24	46.23	55.11	8.88	27	428	218
Russia	RU02EN	44.09	46.85	2.76	13	44.47	49.57	5.11	15	426	218
Russia	RU03EN	39.28	38.00	−1.28	14	37.44	37.20	−0.24	16	423	218
Russia	RU04EN	44.62	46.66	2.04	13	45.47	48.47	2.99	15	423	218
Russia	RU05EN	42.84	41.93	−0.91	17	43.03	48.76	5.73	26	423	218
Russia	RU06EN	38.07	34.09	−3.99	10	42.03	38.14	−3.89	13	426	218
Russia	RU07EN	41.47	41.85	0.38	13	42.50	44.39	1.89	16	407	218
Russia	RU08EN	41.36	38.22	−3.14	13	50.11	40.26	−9.85	16	415	218
Russia	RU09EN	41.88	43.66	1.78	24	43.00	50.82	7.82	22	422	218

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Appendix 4 (*continued*)

Country	Firm Code	Spillovers for residual stock returns From	To	Net	Centrality	Spillovers for standardized residual returns From	To	Net	Centrality	Granger Centrality	Partial Corr. Centrality
Russia	RU10EN	47.69	53.27	5.58	34	47.67	55.42	7.75	38	417	218
Russia	RU11EN	48.06	51.61	3.55	31	46.91	54.37	7.45	33	410	218
Slovenia	SV01EN	34.84	32.71	−2.13	1	35.41	35.00	−0.41	3	407	218
Turkey	TK01EN	46.96	51.36	4.40	34	48.39	49.95	1.56	30	429	218
Turkey	TK02EN	46.59	49.83	3.24	25	50.87	49.72	−1.15	24	426	218
Bosnia-Herzegovina	BH01EN	38.59	37.55	−1.04	14	38.43	36.47	−1.96	10	435	218
Bosnia-Herzegovina	BH02EN	33.75	29.78	−3.97	6	46.83	28.50	−18.33	4	431	218
Bosnia-Herzegovina	BH03EN	33.37	30.55	−2.82	16	33.29	32.31	−0.98	10	435	218
Hungary	HG01EN	31.06	27.47	−3.60	3	30.24	30.78	0.54	5	418	218

Notes: Centrality degree corresponds to the number of links related to each node (vertex), both incoming and outgoing from each node. Residual returns were standardized using the conditional standard deviation calculated through a GARCH(1,1) model. Source: Authors' computation.

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