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Predictability dynamics of emerging sovereign CDS markets

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HIGHLIGHTS

- Time-varying weak-form efficiency of emerging sovereign CDS markets is analyzed.
- We use permutation entropy with a rolling-window framework.
- Emerging sovereign CDS markets have different degrees of time-varying efficiency.
- CDS markets can be weak-form efficient even in the crises episodes.
- We find strong negative relation between sovereign risk and CDS market efficiency.

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ABSTRACT

We compare the time-varying weak-form efficiency of Credit Default Swap (CDS) markets of 15 emerging countries by using permutation entropy approach. We find that CDS markets have different degrees of time-varying efficiency. Using several robustness test, we find that Thailand, China, South Korea and Malaysia have the most efficient CDS markets while South Africa, Colombia and Turkey are the least efficient. Our results show that CDS markets can be efficient even in the crisis episodes. Our findings also suggest a strong negative relation between sovereign risk and CDS market efficiency.

1. Introduction

Since the trading of credit default swaps (CDSs) began in 1994, market participants have used this credit derivative market not only for transferring credit risk but also as an indicator of the potential default risk of sovereign and corporate bonds. A typical CDS contract involves one party agreeing to sell credit protection (protection seller) to another party (protection buyer) who pays periodically a fee over the contract's tenor. If a credit event occurs, the protection buyer terminates the fee payments and receives compensation from the protection seller. Despite the global importance of this market, there have only been a few studies of its price efficiency in any of the forms defined by Fama (1970), — weak, semi-strong, and strong. Our study focuses on the weak-form of market efficiency for the sovereign sector of the CDS market, a market not covered in previous studies.

The implication of a weak-form efficient sovereign CDS market is that information is impounded into CDS spreads in a timely manner, and that the country's default probability has an unpredictable pattern. Whereas in the case of weak-form inefficiency, the default probability follows a more or less predictable path over a long horizon. In other words, trading the weak-from inefficient sovereign CDS contracts could be profitable for an investor who is skilled enough to exploit market inefficiencies. On the other hand, weak-form efficient sovereign CDSs are less likely to be used as the sole trading instrument to gain speculative returns. From a macroeconomic perspective, if CDSs are assumed to be a general indicator of a country's economy, the predictability pattern may not only be observed in daily CDS changes, but also in other economic indicators as well.

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Only five studies have examined the price efficiency of the CDS market, four focusing on the corporate CDS sector and one on the sovereign CDS sector. Two studies, Zhang and Zhang (2013) and Jenkins et al. (2016), test the semi-strong form for the U.S. corporate CDS market. Both studies find that this sector of the CDS market is informationally efficient. However, although Jenkins et al. (2016) find that the U.S. corporate CDS market is efficient before and after the global crisis in 2008, they call into question its efficiency during the crisis period. Avino and Nneji (2014) find that European corporate CDS spreads are characterized by the existence of a predictable pattern and conclude that this CDS market sector is not weak-form efficient. Investigating the U.S. and European corporate CDS markets, Kiesel et al. (2016) conclude that the market is not truly efficient. Investigating the weak-form, Gunduz and Kaya (2013) is the only study that focuses on the sovereign CDS markets for 10 Eurozone developed countries. They report that the European CDS market has been efficient even during the recent financial crisis.

In this study we look at the pricing efficiency in its weak-form for a sector the CDS market that has not been covered by previous studies: the emerging sovereign CDS market. Our methodological framework differs from prior studies on the weak-form of the efficiency of the CDS market in two ways. First, prior studies generally estimate a fixed level of market efficiency for the entire sample period. In contrast, we employ a time-varying approach by using rolling samples, giving us the flexibility of not being forced to impose cutoff dates which are usually subject to criticism in empirical studies. Second, we employ a relatively new methodology, permutation entropy, introduced by Bandt and Pompe (2002). This methodology, has several advantages over the methodologies used in prior studies.

We find that emerging sovereign CDS markets (1) have different degrees of time-varying dependence structures, (2) can be efficient even in crisis episodes and, (3) exhibit a strong negative relation between CDS market efficiency and sovereign risk.

2. Methodology

As noted above, we apply permutation entropy to test for weak-form efficiency. Given the time series of CDS spreads, we first consider market efficiency as a dependency concept and translate the problem of dependency into a symbolic dynamic. Then we use the special entropy measure associated with these symbols to test the dependence present in the time series. This approach has four advantages as explained by Sensoy et al. (2015). First, the measure depends only on ordinal patterns of time series and since it is unaffected by the data's volatility, it can detect non-linear temporal dependence in contrast to autocorrelation.[1] Second, because there is no assumption about the distribution of the data, it has a general applicability compared to the variance ratio test (Lo and MacKinlay, 1988).[2] Third, no moment is required to apply the methodology to time series. This is relevant because asset returns have been shown to be non-normally distributed and, for some distributions such as the Pareto distribution, the variance is infinite (Rachev et al., 2005). Finally, the test is invariant under monotonic transformation of the data which guarantees that no information is lost.[3] Zunino et al. (2012) and Sensoy et al. (2015) apply permutation entropy in testing the efficient market hypothesis.

In this section, in describing our methodology we mainly follow the work of Matilla-Garcia and Marin (2008). Let $\{X_t\}_{t\in I}$ be a real-valued time series. For a positive integer $m \geq 2$, S_m denotes the symmetric group of order $m!$ (i.e. the group formed by all the permutations of length m). Let $\pi_i = (i_1, i_2, \ldots, i_m) \in S_m$. An element π_i in the symmetric group S_m is called a *symbol*, and m is usually referred to as the *embedding dimension*.

Now we define an ordinal pattern for a symbol $\pi_i = (i_1, i_2, \ldots, i_m) \in S_m$ at a given time $t \in I$. For this purpose, we consider that the time series is embedded in an m-dimensional space as $X_m(t) = (X_{t+1}, X_{t+2}, \ldots, X_{t+m})$ for $t \in I$. Then, it is said that "t is of π_i type" if and only if $\pi_i = (i_1, i_2, \ldots, i_m)$ is the unique symbol in the group S_m satisfying the two following conditions: (1) $X_{t+i_1} \leq X_{t+i_2} \leq \cdots \leq X_{t+i_m}$ and (2) $i_{s-1} \leq i_s$ if $X_{t+i_{s-1}} = X_{t+i_s}$. The second condition guarantees uniqueness of the symbol π_i. This is justified if the values of X_t have a continuous distribution so that equal values are uncommon, with a theoretical probability of occurrence of 0.

Notice that for all t such that t is of π_i-type, the m-history $X_m(t)$ is converted into a unique symbol π_i. This π_i describes how the ordering of the dates $t + 0 < t + 1 < \cdots < t + (m - 1)$ is converted into the ordering of the values in the time series under scrutiny.

Also, given a time series $\{X_t\}_{t\in I}$ and an embedding dimension m, one could easily compute the relative frequency of a symbol $\pi \in S_m$ by

$$p(\pi) := p_\pi = \frac{\#\{t \in I \mid t \text{ is of } \pi\text{-type}\}}{|I| - m + 1}$$

where $|I|$ denotes the cardinality of set I. Under this setting, the *permutation entropy* of a time series $\{X_t\}_{t\in I}$ for an embedding dimension m is defined as the *Shannon's entropy* of the $m!$ distinct symbols as the following:

$$h(m) = -\sum_{\pi\in S_m} p_\pi \ln(p_\pi).$$

Permutation entropy $h(m)$, is the information contained in comparing m consecutive values of the time series. By definition, $0 \leq h(m) \leq \ln(m!)$ where the lower bound is achieved for an increasing or decreasing sequence of values, and the upper bound for a completely random system where all $m!$ possible permutations appear with the same probability. More simply, higher permutation entropy means that the data-generating process is more complex and unpredictable. If a financial time series has a permutation entropy that is significantly low, it implies market inefficiency because the weak-form of market efficiency suggests the unpredictability of future movements for the financial variables (In our analysis, we normalize the permutation entropies (dividing by $\ln(m!)$) to achieve a maximum level of 1).

2.1. Independence test

Matilla-Garcia and Marin (2008) developed a consistent test of independence by using permutation entropy. Accordingly, let $\{X_t\}_{t\in I}$ be a real-valued time series with $|I| = T$, and $h(m)$ denotes the permutation entropy of this series for a fixed integer embedding dimension $m > 2$. If $\{X_t\}_{t\in I}$ is i.i.d., then the affine transformation $G(m)$ of the permutation entropy, $G(m) = 2(T - m + 1)(\ln(m!) - h(m))$, is asymptotically $\chi^2_{m!-1}$ distributed. Then to test the null hypothesis that $\{X_t\}_{t\in I}$ is i.i.d., the decision rule at $100(1 - \alpha)\%$ confidence level is to accept the null hypothesis if $0 \leq G(m) \leq \chi^2_{m!-1,\alpha}$, otherwise reject the null hypothesis. Later, Lopez et al. (2010) show that the identicalness property in the null hypothesis can be dropped.

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[1] Autocorrelation is also sensitive to structural breaks such as mean or volatility shift.

[2] Moreover, the variance ratio test is asymptotic so that for a finite sample the sampling distributions of the test statistics is approximated by its limiting distribution. Lo and MacKinlay (1989) find that for small samples the null distribution is right skewed and under rejects in the left tail.

[3] Another alternative way to test the weak-form efficiency is using the Hurst (1951) parameter. However, Bassler et al. (2006) have recently shown that the estimation of the Hurst parameter alone cannot be used to determine the efficiency of markets. They showed that there are cases that are perfectly consistent with Markov processes when Hurst parameters $H \neq 0.5$.

The only point left to decide upon is the embedding dimension m in order to compute permutation entropy and therefore to calculate the $G(m)$ statistic. According to Matilla-Garcia and Marin (2008), for a given data set of T observations, the embedding dimension should be selected as the largest m that satisfies $5m! \leq T$.

3. Data

Our sample set, obtained from Bloomberg Financial Markets, covers the daily 5-year sovereign CDS spreads in US dollar terms (from January 5, 2004 to March 18, 2016) for the 15 emerging market countries (five Latin American, five Asian, and five EMEA countries) shown in Table 1. The starting point of the dataset is the earliest date that all CDS spreads were being calculated for the selected countries. Daily changes of each country's CDS spread is calculated as log-returns.

4. Results

We start by choosing a four-year (1,009 observations) time window (that shifts 5 points at a time) since it corresponds to the duration of a general political cycle and it is large enough to provide satisfactory statistical significance. The procedure is as follows. We calculate permutation entropy in each window for the corresponding time series. Then, we call a window "significant" if the null hypothesis of independence is rejected. The rolling-window approach reveals how often the null hypothesis is rejected by the selected test statistic, and hence the percentage of sub-samples with an insignificant test statistic (which we call the efficiency ratio) can be used to compare the relative efficiency of the CDS markets studied. (A similar rolling-window technique is used to test for market efficiency by Sensoy et al. (2015) for the equity markets.)

Fig. 1 displays time-varying permutation entropy for each CDS market. In the figure, blue and red markers represent the rejection status of the null hypothesis of independence at 5% and 1% significance levels respectively. The date on the horizontal axis stands for the end of the sample used in the estimation of permutation entropy. Therefore, for a date November 2007, the permutation entropy was evaluated for the sample beginning with 1,009 observations earlier and ending in November 2007 and so forth. We see that the emerging sovereign CDS market has different degrees of time-varying dependence. For example, the dependence level of Brazil, Chile and Philippines CDS markets are more volatile than others. On the other hand, China and South Korea CDS markets have fairly stable dependence levels.

Another important finding that can be observed from Fig. 1 is that CDS markets can be efficient even in the crisis period as in the case of China, South Korea, Malaysia, Thailand, and Poland. These markets are the ones with the highest efficiency ratios reported in Table 1. Hence, we can deduce that an economic crisis may not necessarily affect the market efficiency adversely. Based on log-returns and a four-year rolling window, the third and fourth columns in Table 1 shows the relative efficiency performances according to the previously introduced concept of efficiency ratios at the 1% and 5% significance levels. For both significance levels, Thailand, China, and South Korea are the most independent/unpredictable CDS markets and South Africa, Colombia and Turkey are the most dependent/predictable CDS markets. Interestingly, with the exception of Poland, top five CDS efficient countries are Asian countries.

We also see that the first five countries with the highest efficiency ratio in the third and fourth columns in Table 1 (Thailand, China, South Korea, Malaysia, and Poland) have the least daily average CDS levels during the sample period (98, 70, 85, 89 and 91 bps relatively), which means that these countries have the least sovereign default risk. Turkey, being the last ranked in the table (highly predictable), has the highest daily average sovereign default risk (233 bps) among emerging markets included in the study. We investigated this further by estimating the Pearson (Spearman rank) correlation between average CDS scores and the corresponding efficiency ratios. We found that these correlations are −0.71 (−0.58) and −0.68 (−0.53) for 1% and 5% efficiency significance levels respectively. Both correlations are significant at the 1% level, strongly suggesting that there is a strong negative relation between sovereign risk and CDS market efficiency. This finding is further supported by the following observations: The countries with the most weak-form efficient sovereign CDS markets in our sample, such as Thailand, China, South Korea, and Malaysia, have the highest current account surplus averages in the period of 2010 to 2016 (3.94%, 2.36%, 5.03%, and 5.63% respectively), whereas countries that have the least weak-form efficient sovereign CDS markets, such as South Africa, Colombia and Turkey, have the highest average current account deficits in the sample during the same period (−3.96%, −4.04%, and −5.59% respectively). A similar picture arises in terms of savings ratio (savings/GDP) during the same period. Besides, Turkey and South Africa are members of "fragile five economies".

Selection of window length is important when using a rolling-window framework because its selection may significantly affect the results. For this reason, we repeated the analysis in order to see if window length matters by using a shorter (3 years with 756 data points) or a longer (6 years with 1513 data points) window length. Table 1 shows the new efficiency ratios for these two window lengths. The results of both the three-year and six-year rolling window frameworks indicate that although there are some quantitative differences from the results presented for the four-year rolling window, the qualitative conclusion is very similar. Although there are some changes in the predictability ranking of some countries, the countries that can be classified as least predictable and most predictable are almost the same.

4.1. *Alternative approach*

In this subsection, we statistically compare the means of the permutation entropies generated by the four-year length rolling-windows in the previous analysis. The rolling-window procedure produces a collection of permutation entropy values, therefore there is a mean permutation entropy for each CDS market in our analysis. Since higher permutation entropy means that the data-generating process is more unpredictable, then a non-parametric statistical mean permutation entropy comparison between CDS markets can give us an alternative view about their predictability. In this case, the CDS market with a statistically significantly higher mean permutation entropy value is considered as less predictable. And, if there is no statistical difference between their mean permutation entropy values, we can confirm that there are some cases where efficiency performances of CDS markets are almost indistinguishable.

Different from the previous efficiency ratio approach, we also take the actual estimated permutation entropy values into account with this mean comparison methodology. Therefore, the results of this subsection and Section 4 are complementary. Fig. 2 shows the mean permutation entropy comparison between the CDS markets investigated. Based on the results presented in Fig. 2, we can assign the countries to four groups, from least predictable to the most predictable as follows: low predictable group (Thailand and China), low-to-mid predictable group (South Korea, Malaysia and Poland), mid-to-high predictable group (Brazil, Mexico, Philippines, Peru, Russia, Hungary and Chile), and high predictable group (Colombia, South Africa, and Turkey). This result confirms the findings presented in the second and third columns in Table 1, as well as indicating that efficiency performance of some emerging sovereign CDS markets are almost distinguishable.

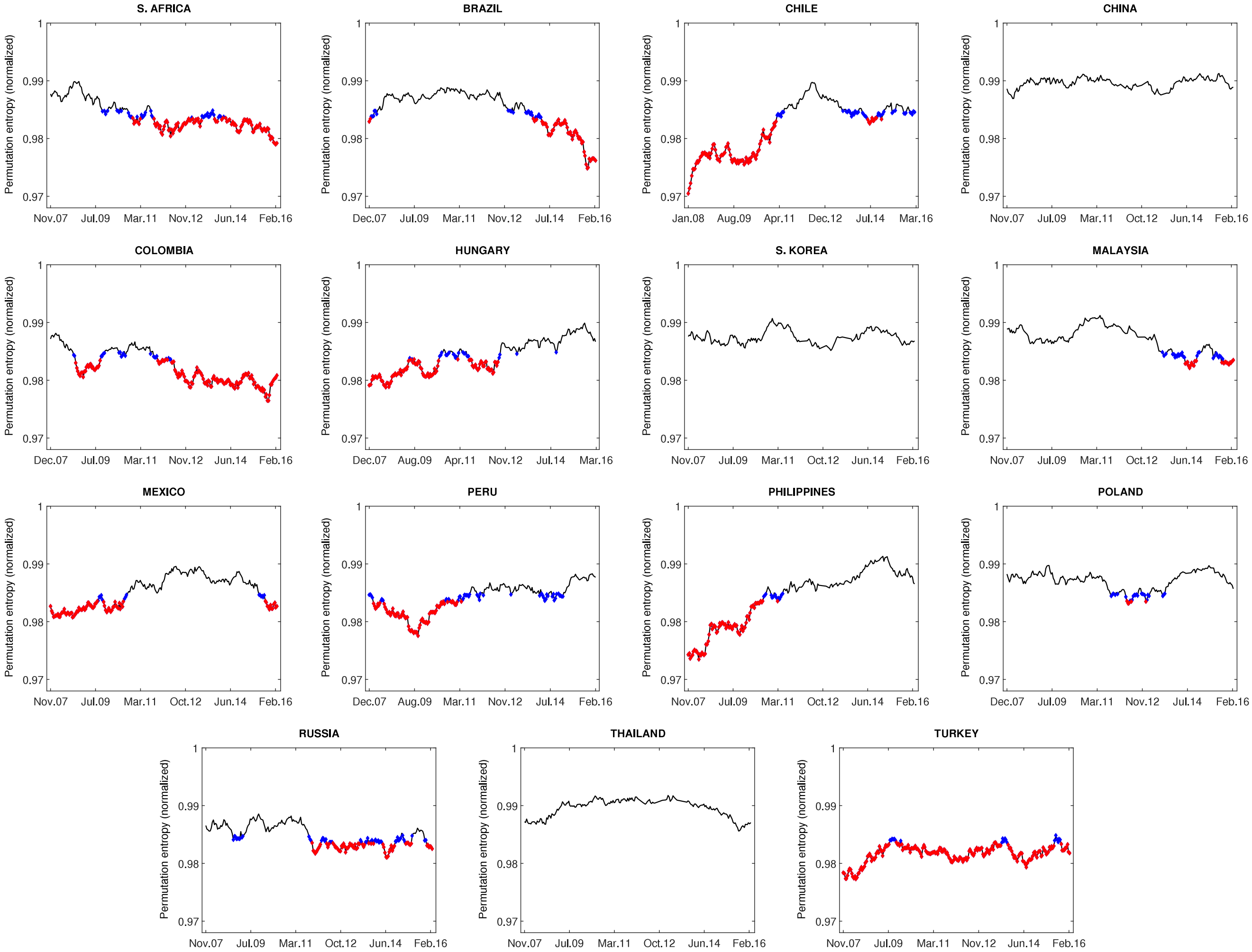

Fig. 1. Time varying normalized permutation entropies for each CDS log-return series. Blue and red markers denote the rejection of independence in series at 5% and 1% significance levels respectively. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 1
Average CDS (bps) and the efficiency ratios of emerging country CDS markets based on log-returns and GARCH(1,1) filtered returns.

Country	Avg. CDS	4-year window (log)		3-year window (log)		6-year window (log)		4-year window (GARCH)	
		1% level	5% level	1% level	5% level	1% level	5% level	1% level	5% level
Thailand	97.53	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
China	69.64	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
South Korea	84.65	1.000	1.000	1.000	1.000	1.000	1.000	0.984	0.820
Poland	91.36	0.975	0.865	0.933	0.760	1.000	0.993	0.939	0.903
Malaysia	88.58	0.888	0.756	0.883	0.779	0.904	0.836	0.930	0.825
Brazil	214.52	0.736	0.634	0.734	0.614	0.770	0.618	0.764	0.514
Russia	200.18	0.684	0.470	0.825	0.667	0.509	0.321	0.759	0.620
Peru	165.44	0.656	0.442	0.656	0.577	0.400	0.176	0.716	0.423
Mexico	118.75	0.644	0.579	0.718	0.560	0.855	0.681	0.715	0.580
Philippines	210.61	0.633	0.568	0.625	0.518	0.500	0.473	0.663	0.447
Chile	74.05	0.563	0.366	0.504	0.328	0.552	0.313	0.648	0.455
Hungary	202.30	0.556	0.444	0.685	0.478	0.484	0.331	0.586	0.395
South Africa	153.02	0.507	0.329	0.656	0.496	0.288	0.276	0.526	0.263
Colombia	185.73	0.380	0.282	0.515	0.311	0.152	0.079	0.250	0.079
Turkey	232.88	0.089	0.000	0.363	0.083	0.000	0.000	0.112	0.014

4.2. *Results using GARCH filtered returns*

A stylized fact that has been observed for financial market returns is that they exhibit volatility clustering (Rachev et al., 2005). CDS markets returns in our study exhibit the same behavior. Matilla-Garcia and Marin (2008) noted that the existence of the ARCH effect in the data may reduce the statistical power of the permutation entropy test. In order to overcome this problem, we repeat our analysis in Section 4 by using GARCH (1, 1) filtered returns. In particular, we estimate the following model: $r_t = \mu + \varepsilon_t$, where $r_t = [r_{1,t}, \ldots, r_{n,t}]'$ is the vector of n CDS returns, μ is a vector of constants with length n, and $\varepsilon_t = [\varepsilon_{1,t}, \ldots, \varepsilon_{n,t}]'$ is the vector of residuals. Following that, we get the conditional volatilities $h_{i,t}$ from univariate GARCH(1,1) process $h^2_{i,t} = \omega + \alpha\varepsilon^2_{i,t-1} + \beta h^2_{i,t-1}$. Consequently, we implement the permutation entropy methodology on the standardized residuals $u_{i,t} = \varepsilon_{i,t}/h_{i,t}$.

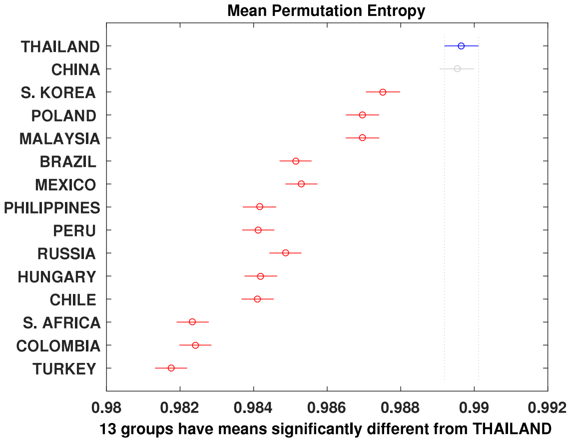

Fig. 2. Non-parametric mean comparison between the permutation entropies of CDS markets. Circles (i.e. their projections onto the horizontal axis) denote the mean permutation entropy values of the corresponding market. Solid bars passing through the circles determine the 95% confidence interval for the mean permutation entropies.

The last two columns in Table 1 show the efficiency ratios based on the standardized return series. Although there are slight changes in the ranking of some countries (compared to the third and fourth columns of Table 1), the conclusion is almost the same: Thailand, China, South Korea, Malaysia, and Poland being the least predictable CDS markets; South Africa, Colombia and Turkey are the most predictable ones.

5. Conclusion

The efficiency of financial markets has always been on the agenda of investors, policy makers, regulators, and researchers. Our study is the first to study the pricing efficiency of the sovereign CDS market for developing countries. Employing permutation entropy combined with an independence test, we test for the weak-form of market efficiency for 15 sovereign CDS markets of emerging countries. By adopting a time-varying approach, weak-form efficiency of the daily CDS of these 15 countries are investigated from early 2004 to mid 2016. There are four principal findings.

First, we find that degree of dynamic efficiency varies among CDS markets. This finding supports the idea that time-varying models might be considered as superior to static approaches in efficiency analysis. Second, CDS markets can be efficient even in the crisis periods, indicating that adverse effects of financial crises on CDS market efficiency can be limited or non-existent at all. Third, we find that CDS markets of all Asian countries in our sample, as well as Poland, perform better in terms of market efficiency. Finally, we find that there is a strong negative linear and rank correlation between a country's sovereign CDS efficiency and the daily average CDS levels. Accordingly, default risk of a sovereign debt can be an important factor impacting the pricing efficiency of its CDS market.

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