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INFLATION CO-MOVEMENT IN THE ASEAN COUNTRIES

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We conduct frequency domain analyses to document some empirical regularities on international inflation co-movement in the ASEAN countries. The estimated cohesion index, a measure of co-movement in frequency domain, shows that inflation co-movement is stronger in the long run than in the short run, which has not been examined in depth in the literature using time domain analysis. There is strong evidence that inflation co-movement within the ASEAN countries is weaker than inflation co-movement within the G7 countries. We also find that the inflation in an ASEAN country, on average, fluctuates more closely with the inflation in the G7 countries than with the inflations in other neighboring ASEAN countries, implying that geographical proximity is not important in inflation synchronization. These empirical findings suggest that the inflation in advanced countries is likely to be the main source of international inflation co-movement, which is more important than regional factor in explaining the fluctuations of inflation in the ASEAN countries.

Keywords: Inflation, Co-movement, Cohesion Index
JEL Classification: C32, E31, F42

1. INTRODUCTION

A growing number of studies document the global inflation synchronization: the fluctuations of inflation rates have moved together internationally. Ciccarelli and Mojon (2010) show that inflation of 22 OECD countries have a common factor that accounts for 70 percent of their variances. Mumtaz, Simonelli, and Surico (2011) also find that, using a dynamic factor model, the share of inflation variation due to a global factor has become larger since 1985. Ha, Kose and Ohnsorge (2019) report that a global factor accounts for 22 percent of variation in domestic inflation rates since 2001 in a large sample of countries. Henriksen, Kydland, and Sustek (2013) also document fluctuations in price levels are substantially more synchronized across countries at business cycle frequencies than fluctuations in real output. They have put forward a theory of international comovements in inflation and nominal interest rates based on technology spillovers.

In addition to the global factor, several studies document the importance of regional factor in explaining the national inflations. Neely and Rapach (2008) report that the world and regional components account for 35 percent and 16 percent, respectively, of inflation variability on average across countries. Mumtaz, Simonelli, and Surico (2011) also stress that international co-movements within regions have accounted for the bulk of fluctuations in business cycle and inflation. Ha, Kose and Ohnsorge (2019) also find that inflation has synchronized not only in advanced countries but also in emerging market and developing economies. For the periods of 2001-2017, they report global factor's contributions amount to 27 percent for the advanced economies and 18 percent for the emerging market and developing economies. They also document that the contribution of group specific factor is 21 percent and 8 percent, respectively.

This paper also investigates inflation co-movement but for the different sample and with different methodology. First, while existing papers examine inflation co-movement in a sample of advanced and emerging market economies to uncover the contribution of global and regional factors, they do not investigate a specific group of countries. This paper, in contrast, focuses on the ASEAN (Association of Southeast Asian Nations) member countries to find out the inflation co-movements within the ASEAN group and between the ASEAN and the advanced economies. As a regional community, the ASEAN member countries are closely connected with each other in many aspects including economy, trade as well as geography. Thus, the ASEAN is good sample countries to explore inflation co-movement within the region and between the other regions.

Second, previous literatures analyze inflation co-movement in time domain. In particular, many papers employ a dynamic factor model to estimate global factor and regional factor to measure the contributions of these factors to fluctuations of national inflation. This paper, in contrast, takes a different approach in which inflation co-movement is estimated in frequency domain of the underlying time series. Specifically, we follow frequency-based methods of Croux, Forni, and Reichlin (2001, CFR hereafter) which propose the notion of dynamic correlation to construct a multivariate index of co-movement. In this frequency domain analyses, long run and short run co-movement of inflation can be appropriately identified.

This paper is organized as follows. Section 2 describes how the extent of co-movement is measured based on the methods of CFR. Section 3 report empirical results on the inflation co-movement within the ASEAN countries and compare them with the co-movement within the G7 countries. Section 4 analyzes the inflation co-movement between the ASEAN and the G7 countries. Section 5 concludes

2. MODELS AND METHODOLOGY

2.1. Spectral Representation of Correlations

We consider co-movement between stationary time series variables in the frequency domain using the methods proposed by CFR. To introduce the methods, we first consider a bivariate covariance stationary time series, $z_t = \{x_t, y_t\}'$, for $t = 1,2,\ldots,T$, where T is the sample size.

Label auto-covariance functions of x_t and y_t as $R_x = E(x_t - \mu_x)(x_{t-j} - \mu_x)$ and $R_y = E\big(y_t - \mu_y\big)\big(y_{t-j} - \mu_y\big)$ with $\mu_x = E(x_t)$, $\mu_y = E(y_t)$, respectively. Also, cross covariance function is denoted as $R_{xy} = E(x_t - \mu_x)(y_{t-j} - \mu_y)$.

Given these, we below define the spectral density matrix of z_t, which is Fourier transformation of the variance-covariance functions

$$f(\lambda) = \begin{pmatrix} f_x(\lambda) & f_{xy}(\lambda) \\ f_{xy}(\lambda) & f_y(\lambda) \end{pmatrix} \text{ for } 0 \le \lambda \le 2\pi, \tag{1}$$

and $f_x(\lambda) > 0, f_y(\lambda) > 0$,

where $f_x(\lambda) = \sum_{j=-\infty}^{\infty} R_x(j)\exp(-ij\lambda) = R_x(0) + 2\sum_{j=1}^{\infty} R_x(j)\cos(j\lambda)$,
$f_y(\lambda) = \sum_{j=-\infty}^{\infty} R_y(j)\exp(-ij\lambda) = R_y(0) + \sum_{j=1}^{\infty} R_y(j)\cos(j\lambda)$,
$f_{xy}(\lambda) = \sum_{j=-\infty}^{\infty} R_{xy}(j)\exp(-ij\lambda)$,
(See Priestley, 1981; Brockwell and Davis, 2013).

Note that the diagonal terms denote the auto-spectral densities, whereas the off-diagonal term equals to the cross spectral density. The cross spectral density function is generally complex-valued, due to asymmetry of cross covariance functions, for example, $R_{xy}(j) \neq R_{yx}(j)$. Following CFR, we replace the cross spectral density with the co-spectrum, which is the real parts of cross spectral density. Then, computational complexity is greatly reduced. Define the co-spectrum as $f^*_{xy}(\lambda) = \sum_{j=-\infty}^{\infty} R_{xy}(j)\cos(j\lambda)$, and a resulting correlation measure as follows,

$$\rho_{xy}(\lambda) = \frac{f^*_{xy}(\lambda)}{\sqrt{f_x(\lambda) f_y(\lambda)}}. \tag{2}$$

Note that the co-spectrum is even function of λ, i.e., $f^*_{xy}(\lambda) = f^*_{xy}(-\lambda)$ (Priestley, 1981). We call the measure (2) as the dynamic correlations. This measure is analogous to the coherency measure, which is a widely used statistics for correlation in natural science and engineering contexts. As previously mentioned, the coherency measures involve complex values, known as quadrature of the spectrum. On the other hand, the dynamic correlations only include real-valued quantities, which give advantage for practical usage. Another important property of the dynamic correlation measures comes from the fact that it is basically model-free. Thus, co-movement can be analyzed without relying on any specific models such as vector autoregression models.

Dynamic correlations measure degree of pairwise co-movement between the two variables at different frequencies. Thus, one can examine the correlations from the low frequency to the high frequency. Note that the frequencies λ admit following relationship (Hamilton, 1994; Estrella, 2007):

$$\lambda_j = 2\pi j/\mathrm{T}. \tag{3}$$

As in (3), the frequency is inversely related with the period, T/j, where the period is required amount of time until one cycle is completed. Thus, low and high frequencies correspond to long-run and short-run relationship between the two variables. For example, if the observational frequencies are monthly and dynamic correlation is measured at the $\lambda = 1$. Then, the value of the measure is understood as the co-movement of the two series at about 6 month periods.

Besides, at the zero frequency, the dynamic correlations deliver the long-run relations between the two time series. The zero-frequency quantities have drawn a lot of attention in time series econometrics context. Below in our empirical analysis, we investigate the pattern of correlations at different frequencies.

2.2. Estimation of Correlation by Frequencies

In order to obtain consistent estimates for the dynamic correlations, we consider kernel-based nonparametric estimators for auto and co-spectral densities defined in (1) and (2), given by:

$$\hat{f}_{xy}(\lambda) = \sum_{j=1-T}^{T-1} k(j/M)\hat{R}_{xy}(j)\cos(j\lambda), \tag{4}$$

$$\hat{f}_x(\lambda) = \hat{R}_x(0) + 2\sum_{j=1}^{T-1} k(j/M)\hat{R}_x(j)\cos(j\lambda),$$

$$\hat{f}_y(\lambda) = \hat{R}_y(0) + 2\sum_{j=1}^{T-1} k(j/M)\hat{R}_y(j)\cos(j\lambda),$$

where k(·) is a kernel weighting function with the bandwidth M. Also, sample covariance is given by

$$\hat{R}_{xy} = \begin{cases} T^{-1}\sum_{t=j+1}^{T}(x_t - \bar{x})(y_{t-j} - \bar{y}), & j \geq 0 \\ T^{-1}\sum_{t=1}^{T+j}(x_t - \bar{x})(y_{t-j} - \bar{y}), & j < 0 \end{cases}, \tag{5}$$

where $\bar{x}$ and $\bar{y}$ are the sample means of x and $\bar{y}$, respectively. The sample variance of x equals to

$$\hat{R}_x = \begin{cases} T^{-1}\sum_{t=j+1}^{T}(x_t - \bar{x})(x_{t-j} - \bar{x}), \ j \geq 0 \\ T^{-1}\sum_{t=1}^{T+j} \ (x_t - \bar{x})(x_{t-j} - \bar{x}), \ j < 0 \end{cases}, \tag{6}$$

and the sample variance of y is defined analogously (Andrews, 1991; Newey and West, 1994).

Then, we obtain consistent estimator for the dynamic correlations in (2), denoted as $\hat{\rho}_{xy}$.

As for the kernel function, we employ Bartlett kernel given by

$$\mathrm{k(x)} = \begin{cases} 1 - |x|, & -1 < x < 1 \\ 0, & otherwise \end{cases}. \tag{7}$$

Though simple, Bartlett kernel is in wide use. Besides, it is known that the choice of kernel functions has very little impact on density estimation in the context of heteroskedasticity and autocorrelation consistent variance-covariance matrix estimation. Thus, one can try other quadratic or higher-order kernels in practice, but little gains are expected in term of performance of estimation.

The bandwidth M determines the number of sample covariance and variance terms for estimation of spectral densities. While there have been various ways for the bandwidth selections we follow rather simple rule in the empirical analysis as in Kwiatkowski et al (1992) given by

$$\mathrm{M} = \left[4\left({}^{T}\!/_{100}\right)^{\frac{2}{9}}\right]. \tag{8}$$

where [x] denotes the closest integer to x, which does not exceed x. Thus, the bandwidths control the lag truncation in density estimations above. For example, if the sample size is 200, then M=2. The selection rule (8) only depends on the sample-size. Note that in order to achieve consistency of spectral density estimators, required conditions equal to $\mathrm{M} \equiv \mathrm{M(T)} \to 0$ and ${}^{M}\!/_{T} \to 0$, as $\mathrm{T} \to \infty$. In other words, the bandwidths grow with the sample size T, with a slower rate than T. The bandwidths that we use in (8) satisfy the condition. Alternatively, one can make use of data-dependent bandwidth selections such as Andrews (1991) and Newey and West (1994), at extra computational costs.

2.3 Construction of Asymptotic Confidence Intervals

Given the previous inferences, we construct the confidence intervals for the dynamic correlation estimates. In particular, we consider asymptotic confidence interval, based on asymptotic form of the variance of dynamic correlation estimators (e.g., Priestley, 1981; Brockwell and Davis, 2013, in the case of coherency). The asymptotic inferences can be justified as the sample size in our applications is large enough. As an alternative method, it is also possible to obtain bootstrap confidence interval, but with extra computational cost (e.g., Berkowitz and Diebold, 1998 in the case of spectrum, not the coherency). In addition, bootstrap inferences for the coherency or CF measures in our study do not exist in time series context.

Following Priestley (1981), the 95% asymptotic confidence interval for the correlation measures are given by

$$\hat{\rho}_{xy}(\lambda) \pm 1.96\sqrt{Var\left(\hat{\rho}_{xy}(\lambda)\right)} = \hat{\rho}_{xy}(\lambda) \pm 1.96\left[\left({}^{M}\!/_{2T}\int_{-\infty}^{\infty} k^2(x)dx(1-\hat{\rho}_{xy}^2(\lambda)\right)\right]^{\frac{1}{2}}. \quad (9)$$

In particular, $\int_{-\infty}^{\infty} k^2(x) = {}^{2}\!/_{3}$ in the case of Bartlett kernel, thus the bound on error of estimation becomes $\left[\left({}^{M}\!/_{3T}\right)(1-\hat{\rho}_{xy}^2(\lambda)\right]^{1/2}$.

Note that the confidence interval becomes narrower as the sample size gets larger, since ${}^{M}\!/_{T} \to 0$. More precisely, as the bandwidth $\mathrm{M} = O_p(T^{2/9})$, the error of estimation is as large as $\mathrm{M} = O_p(T^{-7/9})$, which, in turn, proves consistency of the dynamic correlations estimator.

2.4. Cohesion Indices

In this section, we construct the comovement index, labeled as COH, which is defined as weighted sums of all the correlations at frequencies,

$$\mathrm{COH}(\lambda) = \frac{\sum_{i=1}^{N}\sum_{j\neq i}^{N} w_i w_j \hat{\rho}_{ij}(\lambda)}{\sum_{i=1}^{N}\sum_{j\neq i}^{N} w_i w_j}, \quad (10)$$

where $0 \leq \lambda \leq 2\pi$, and $\{w_i\}, i = 1,2,\ldots,N$ denote the pre-specified weight given to the $\mathrm{i}-\mathrm{th}$ variable.

There are a total of $N!/[2(N-2)!] = \mathrm{N}\,(N-1)/2$ pairwise dynamic correlations, and appropriate positive-valued weights with the restriction $\sum_{i=1}^{N} w_i = 1$ can be applied. For example, relative income levels or population sizes become possible candidates for the weight in practice. Alternatively, one can consider a simple mean, where $w_i = 1$, for all i, given by

$$\mathrm{COH}(\lambda) = \frac{\sum_{i=1}^{N}\sum_{j>i}^{N} \hat{\rho}_{ij}(\lambda)}{N(N-1)/2}, \quad (11)$$

We can naturally extend the co-movement index in (10)-(11) to the case between the two vectors of series. Denote the cross dynamic correlations measures as $\hat{\rho}_{kh}(\lambda)$, for $\mathrm{k} = 1,2,\ldots,\mathrm{N}$ and $\mathrm{h} = 1,2,..,\mathrm{M}$. As is proposed by CFR, the cross-cohesion index, labeled as Cross-COH, is given by

$$\text{Cross} - \text{COH}(\lambda) = \frac{\sum_{k=1}^{N}\sum_{h=1}^{M} w_k w_h \hat{\rho}_{kh}(\lambda)}{\sum_{k=1}^{N}\sum_{h=1}^{M} w_k w_h}, \tag{12}$$

where, unlike (11), $\hat{\rho}_{kh} \neq 1$, when $\text{k} = \text{h}$, which is the correlation between the two different series.

3. INFLATION CO-MOVEMENT WITHIN THE REGION

3.1. Data

Table 1. Summary Statistics of Inflation Rates.

	Mean (annualized)	Median	Standard Deviation	Autocorrelation
ASEAN countries				
Brunei	0.29	0.024	0.479	-0.175
Cambodia	4.20	0.270	1.063	0.489
Indonesia	6.63	0.448	0.750	0.227
Lao PDR	5.80	0.376	0.820	0.569
Malaysia	2.16	0.177	0.417	0.304
Myanmar	12.51	0.760	1.602	0.617
Philippines	3.84	0.265	0.327	0.435
Singapore	1.61	0.098	0.506	-0.169
Thailand	2.07	0.156	0.488	0.347
Vietnam	6.49	0.398	0.801	0.562
Average	4.56	0.297	0.725	0.321
G7 countries				
Canada	1.94	0.179	0.372	0.203
France	1.46	0.122	0.314	-0.080
Germany	1.47	0.101	0.345	-0.291
Italy	1.78	0.177	0.195	0.189
Japan	0.13	0.000	0.300	0.196
UK	2.06	0.229	0.291	-0.056
US	2.16	0.186	0.382	0.489
Average	1.57	0.142	0.314	0.093
Northeast Asian countries				
China	2.16	0.100	0.625	0.232
Japan	0.13	0.000	0.300	0.196
Korea	2.50	0.184	0.369	0.251
Average	1.60	0.095	0.431	0.226

Monthly inflation rate is measured by log difference of consumer price index (CPI) for the sample period of January 2000-August 2018. The CPI data are from the International Financial Statistics provided by the IMF. The number of the ASEAN member states is ten and all of the ASEAN countries (Brunei, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Vietnam) are included in the sample to examine the co-movement of inflation rates in the region.[1] The G7 countries (Canada, France, Germany, Italy, Japan, UK, and the US) and three northeast Asian countries (China, Japan, and Korea) are also considered to investigate a cross cohesion with the ASEAN countries.[2]

Table 1 reports the summary statistics of inflation rates in each country. The average inflation rate in the ASEAN countries is 0.380, which is as three times high as the average inflation rate in the G7 countries or the northeast three countries. Among the ASEAN countries, Myanmar recorded the highest inflation rate while Brunei exhibited the lowest inflation rate during the sample period. A high inflation rate, in general, tends to be associated with high volatility of inflation. Indeed, the average volatility of inflation rate in the ASEAN countries is over twice higher than the average volatility of inflation in the G7 countries. The average volatility in the ASEAN countries is also much higher than that of the northeast three countries.

The inflation rates in the ASEAN countries are more persistent than the inflation rates in the G7 countries. The average autocorrelation of inflation rate is 0.321 in the ASEAN countries while it is only 0.093 in the G7 countries. In particular, Myanmar, Lao PDR, and Vietnam exhibit highly persistent inflation rates.

3.2. Estimation results

This subsection investigates to what extent the fluctuations of inflation rates co-move within the ASEAN member countries. As described in Section II, the co-movement is measured by a cohesion index using the method of CFR. To this end, we first estimate a set of pairwise dynamic correlation of inflation rates in frequency domain between a pair of the ASEAN countries. Since ten ASEAN countries are included in our sample, forty five dynamic correlations are estimated at each frequency. Then the cohesion index is constructed by averaging these forty five pairwise correlations. Also, it is noted that asymptotic confidence intervals for the cohesion index are not available in econometrics context including CFR. Thus, we instead use averages of each upper and lower confidence limit in the set of dynamic correlations. Reasoning in doing so comes from a conjecture that the sum of sample variances of dynamic correlations yield, though not exact, approximations to the sample variance of sum of dynamic correlations. Then, computational cost for asymptotic confidence bands can significantly lessen, where otherwise it requires very tricky estimation problem of covariance structures of dynamic correlations.

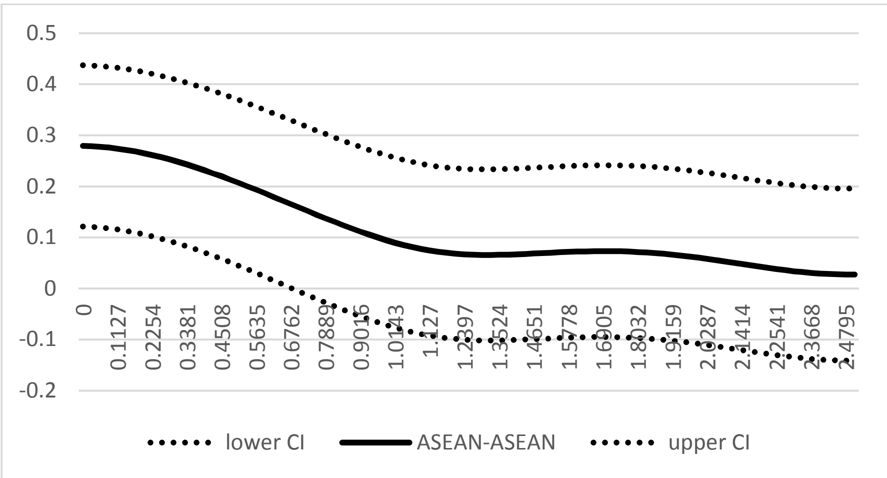
Figure 1 shows the estimated cohesion index of inflation rates within the ASEAN countries along with the 95 percent confidence intervals. The value of the cohesion

[1] ASEAN was established in 1967 by Indonesia, Malaysia, Philippines, Singapore and Thailand. Brunei Darussalam then joined in 1984, Vietnam in 1995, Lao PDR and Myanmar in 1997, and Cambodia in 1999. The sample period in this paper starts in 2000 to include all of the ASEAN member countries.

[2] The ASEAN countries and the three northeast Asian countries are called ASEAN+3 countries.

index is quite different depending on the frequency, λ. It is less than 0.1 and statistically insignificant when λ is greater than 0.7.[3] The cohesion index, however, tends to increase as λ becomes smaller and it approaches to 0.28 as λ approaches to the value of zero. Since small λ corresponds to a long-run relationship, the estimation results of the cohesion index suggest that there is no co-movement in the short-run but some co-movement in the long-run among the inflation rates in the ASEAN countries.

Figure 2 depicts the cohesion index of inflation among the G7 countries, which is computed by averaging twenty-one pairwise dynamic correlations between two G7 countries. Comparing two cohesion indexes in Figure 1 and Figure 2, it is clear that the inflations in the G7 countries are more cohesive than the inflations in the ASEAN countries. In the long run where λ=0, the cohesion index for the G7 countries is estimated to be 0.4997 while the cohesion index for the ASEAN countries is only 0.2793. At the business cycle frequency of λ=0.14 (approximately 48 months), the cohesion index for the G7 countries is also 0.23 point above the cohesion index for the ASEAN countries. In the short run cycle, the cohesion index for the G7 countries is statistically significant while it is not for the ASEAN countries. The cohesion index for the G7 countries is statistically significant when λ is less than 1.80 (approximately 3.5 month) but the cohesion index for the ASEAN countries becomes statistically significant only when λ is smaller than 0.68 (9.2 month).

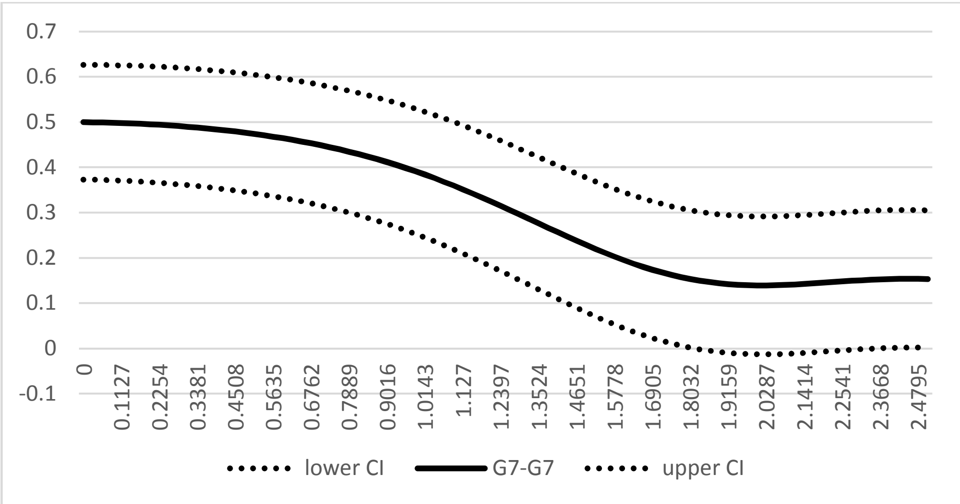


Note: x-axis represents the frequency, λ. Low (small λ) and high (big λ) frequencies correspond to long-run and short-run relationship between the inflation rates.

Figure 1. Cohesion Index of the Inflation Rate within the ASEAN Countries

[3] From the relationship between the frequency and the period in (3), $\lambda = 2\pi j/T$ implies the period of $T/j = 2\pi/\lambda$ (Hamilton, ch.6). Thus, $\lambda = 0.7$ corresponds to approximately 9 months period.

Figure 1 and Figure 2 tell us that inflation co-movement is much stronger within the G7 countries than within the ASEAN countries. This finding suggests the possibility that previous studies' evidence on the international synchronization of inflation mainly results from the inflation co-movement among advanced economies. The weak synchronization of inflation among the ASEAN countries, on the other hand, suggests that geographical proximity is not important and the regional factor in the ASEAN countries may play a minor role in international co-movement of inflation.



Note: x-axis represents the frequency, λ. Low (small λ) and high (big λ) frequencies correspond to long-run and short-run relationship between the inflation rates.

Figure 2. Cohesion Index of the Inflation Rate within the G7 Countries

Although the overall Inflation co-movement within the ASEAN countries is relatively weak, the extent of co-movement may differ across the member countries. To examine this, the cohesion index in Figure 1 is decomposed into country-level cohesion indexes. The cohesion index of country i is the average dynamic correlation between inflation rate of country i and inflation rates of other nine ASEAN member countries. The purpose of this exercise is to find out which country makes more contributions to inflation co-movement in the region.

Table 2 reports each country's cohesion index for $\lambda = 0, 0.17, 0.54$ and 1.04, which approximately corresponds to ∞, 36 months, 12 months and 6 months, respectively. The short run ($\lambda = 1.04$) country-level cohesion index is not statistically significant for all ASEAN countries in Table 2. This finding implies that, in the short run, no individual ASEAN country exhibits inflation co-movement with other ASEAN countries, consistent with Figure 1. The country-level cohesion index is estimated to be larger in the medium or long run than in the short run for every country. Furthermore, at $\lambda = 0.54$ and 0.17, the country-level cohesion index becomes statistically significant for seven countries.

Among the ten ASEAN countries, Cambodia's country level cohesion index is the largest in the medium and the long run. Thailand, Vietnam and Philippines also exhibit relatively strong inflation co-movement with other ASEAN countries as their country-level cohesion indexes are over 0.35 at $\lambda = 0.17$. On the other hand, it is found that the long run values of the cohesion indexes computed at $\lambda = 0$ are around 0.1 and not statistically significant for Brunei and Myanmar. At $\lambda = 0.17$, Indonesia as well as Brunei and Myanmar also fail to exhibit statistically significant estimate of the cohesion index.

Table 2. Cohesion Index of the Individual ASEAN Countries

	λ=0	λ=0.17	λ=0.54	λ =1.04
Brunei	0.0983	0.0904	0.0515	0.0405
Cambodia	0.4271*	0.4129*	0.3217*	0.1391
Indonesia	0.1736*	0.1579	0.0685	-0.0245
Lao PDR	0.2277*	0.2236*	0.1972*	0.1446
Malaysia	0.3163*	0.3042*	0.2320*	0.1082
Myanmar	0.1067	0.1031	0.0780	0.0154
Philippines	0.3823*	0.3686*	0.2796*	0.1141
Singapore	0.3098*	0.2971*	0.2116*	0.0447
Thailand	0.3893*	0.3739*	0.2812*	0.1479
Vietnam	0.3624*	0.3515*	0.2779*	0.1221

Note: Smaller λ corresponds to longer-run relationship between the inflation rates. * denotes the statistical significance at the 5% level.

Table 3. Cohesion Index of the Individual G7 countries

	λ=0	λ=0.17	λ=0.54	λ =1.04
Canada	0.5816*	0.5913*	0.6170*	0.4968*
France	0.5358*	0.5299*	0.4959*	0.4306*
Germany	0.3464*	0.3291*	0.2469*	0.1520*
Italy	0.5838*	0.5696*	0.4942*	0.3526*
Japan	0.2722*	0.2844*	0.3321*	0.2907*
UK	0.5252*	0.5183*	0.4787*	0.4022*
US	0.6528*	0.6512*	0.6309*	0.5076*

Note: Smaller λ corresponds to longer-run relationship between the inflation rates. * denotes the statistical significance at the 5% level.

For most of the G7 countries, the country-level cohesion indexes are also estimated to be larger in the medium to long run than in the short run. The two exceptions are Canada and Japan where the cohesion indexes at λ=0.54 are larger than other frequencies. Although the extent of inflation co-movement differs across G7 countries, their cohesion indexes, in general, are much higher than the ASEAN countries' cohesion indexes. In the medium and the long run, the country level cohesion indexes are above or close to 0.5, except Germany and Japan. The cohesion index for the US is above 0.65 when λ is smaller than 0.54, exhibiting very strong inflation co-movement with other G7 countries. More interesting is that the country-level cohesion indexes of all the G7 Countries are economically and statistically significant even in the short run, which is not the case for the ASEAN countries. Indeed, the short run cohesion index at λ=1.04, is found to be over 0.4 for Canada, France, UK and the US.

4. INFLATION CO-MOVEMENT BETWEEN THE REGIONS

The previous section examines inflation co-movement within a group of countries. The estimated cohesion indexes show that inflation rates co-move more strongly within the G7 countries than within the ASEAN countries. Next, we investigate inflation co-movement between these two groups of countries based on cross-cohesion index. As documented in Section II, the cross-cohesion index is estimated by averaging the dynamic correlations of inflation between one of ASEAN countries and one of the G7 countries. Thus, a total of 70 dynamic correlations are estimated to construct the cross-cohesion index.

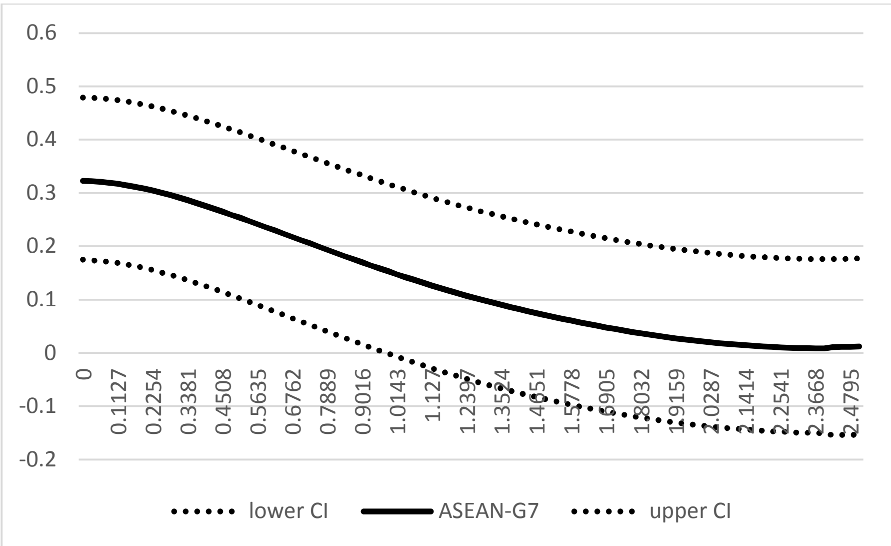
Figure 3 illustrates the estimated cross-cohesion index between the ASEAN countries and the G7 countries along with the 95 percent upper and lower confidence intervals. Similar to the cohesion indexes within the group in Figure 1 and Figure 2, the cross-cohesion index is estimated higher in the long run than in the short run.

Compared with Figure 1 and Figure2, the cross-cohesion index, at all frequencies, is above the cohesion index within ASEAN countries and below the cohesion index within G7 countries. In the long run ($\lambda = 0$), for example, the cross-cohesion between two groups is 0.3229, which is higher than 0.2793 of the cohesion index within the ASEAN countries and lower than 0.4997 of the cohesion index within the G7 countries. The threshold value of λ that the cross-cohesion index becomes statistically significant is 0.96, implying that the statistically significant inflation co-movement is found for the cycle longer than about 6.5 month between two groups of countries. It is noted that the threshold λ is 0.68 for the cohesion index within the ASEAN and 1.80 for the cohesion index within the G7.

This finding implies that the inflation in an ASEAN country, on average, fluctuates more closely with the inflation in the G7 countries than the inflations in other neighboring ASEAN countries. The finding also suggests that the inflation in advanced countries is a driving force of international inflation co-movement. Many existing papers document that the global factor accounts for substantial part of the fluctuations in national inflation. This paper then may argue that the global factor mainly reflects the inflation in advanced countries. If this is the case, it is possible that the inflation co-movement within the ASEAN countries partly attributable to a common global factor which also leads to the inflation co-movement between the ASEAN countries and the G7 countries.

The industrial structure and the trade patterns of individual ASEAN countries might explain why the regional factors are less important than the global factors (G7 countries) in understanding regional inflation dynamics. As long as the commodity prices (raw materials and agricultural products) are mainly determined by world demand, the inflation in a commodity exporting country would be more correlated with the world business cycle and thus global inflation. On the other hand, countries with weaker dependence on the global factors would exhibit different inflation dynamics.

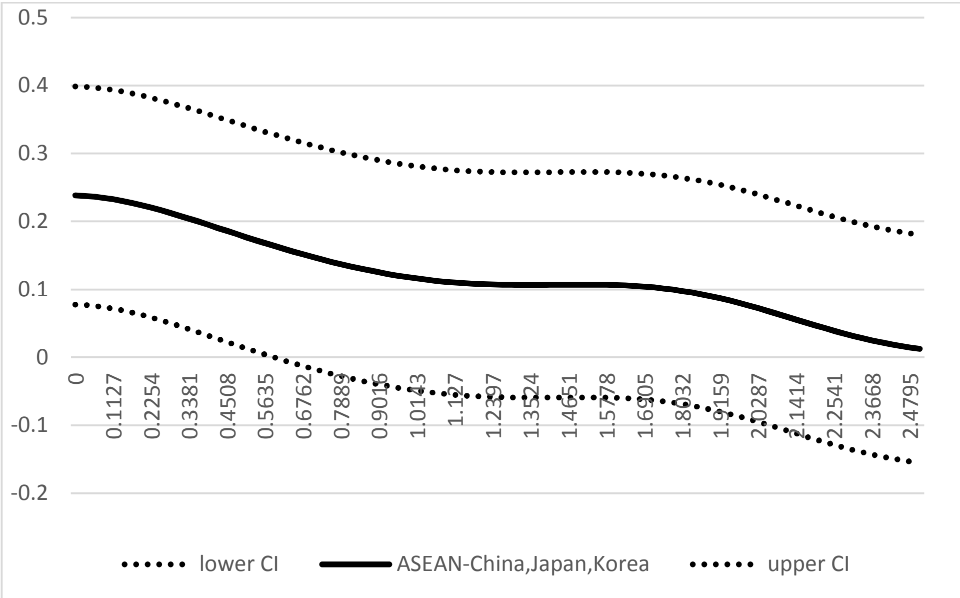
The different degree of exchange rate flexibility may also affect inflation dynamics. To the extent that a country imports consumer goods from foreign countries, the different degree of pass-through of exchange rate would affect domestic inflation dynamics. For example, Cambodia, which is a dollarized economy, shows a strong inflation co-movement with advanced countries.



Note: x-axis represents the frequency, λ. Low (small λ) and high (big λ) frequencies correspond to long-run and short-run relationship between the inflation rates.

Figure 3. Cross-cohesion Index of Inflation Rates between the ASEAN Countries and the G7 Countries

Figure 4 considers the cross-cohesion index of inflation between the ASEAN countries and the three northeast Asian countries (China, Japan, Korea). Despite the ASEAN countries' economic ties with China, Japan, and Korea, the inflation co-movement is not strong between the two groups of countries as illustrated in Figure 4. The short run co-movement does not exist and the long run cross-cohesion index is only 0.2383. Indeed, the inflation co-movement between the ASEAN countries and the three northeast countries is weaker than the co-movement within the ASEAN countries as well as the co-movement between the ASEAN and the G7 countries. This result reinforces that the inflation in advanced countries is the main driver of international inflation synchonization.



Note: x-axis represents the frequency λ. Low (small λ) and high (big λ) frequencies correspond to long-run and short-run relationship between the inflation rates.

Figure 4. Cross-cohesion Index of Inflation Rates between the ASEAN Countries and the Three Northeast Asian Countries (China, Japan, Korea)

We decompose the cross-cohesion index in Figure 3 into the country-level cross cohesion indexes. This exercise helps to identify which ASEAN country is more associated with the G7 countries in terms of inflation co-movement. The country-level cross cohesion index for ASEAN country i is the simple average of the dynamic correlations between country i's inflation rate and each of the G7 country's inflation rate.

Table 4 reports each ASEAN country's cross-cohesion index with the G7 countries at four different values of frequencies. In the short-run (i.e., λ=1.04), only four ASEAN countries (Cambodia, Lao PDR, Malaysia, and Thailand) exhibit statistically significant cross-cohesion with the G7 countries. When λ is higher than 0.54, the cross-cohesion index is estimated to be statistically significant for seven ASEAN countries. Meanwhile, Brunei, Indonesia and Myanmar fail to show economically and statistically significant cross-cohesion with the G7 countries both in the short run and in the long-run. An interesting finding is that, for these three countries, the cohesion index with other ASEAN countries is also statistically insignificant as reported in Table 2. Thus, the results in Table 2 and Table 4 imply that the inflation rate in Brunei, Indonesia and Myanmar does not co-move with the inflation rates in other ASEAN countries nor the G7 countries. This result leads to a conclusion that the inflation in these three countries is likely to be determined independently by idiosyncratic domestic factors, not influenced by foreign inflation.

Although the cross-cohesion indexes are statistically significant in seven ASEAN countries, the extent of inflation co-movement with G7 countries differ across countries. The cross-cohesion index for Thailand is highest among the ASEAN countries at every frequency, implying that inflation in Thailand fluctuates more closely with the inflations in G7 countries in the short run and in the long run.

It is also noteworthy that, for every ASEAN country, the cross-cohesion index in Table 4 is higher than the cohesion index with other ASEAN countries in Table 2. We argue again that this result is a supporting evidence that the global factor, not the regional factor, accounts for the fluctuations of inflation in ASEAN countries. Furthermore, we argue that the global factor is more likely to be associated with inflation in advanced countries.

Table 4. Cross-cohesion Index with the G7 Countries by Individual ASEAN Countries

	λ=0	λ=0.17	λ=0.54	λ =1.04
Brunei	0.1655	0.1626	0.1462	0.1306
Cambodia	0.4638*	0.4497*	0.3703*	0.2360*
Indonesia	0.0758	0.0612	-0.0197	-0.1046
Lao PDR	0.3845*	0.3794*	0.3490*	0.2815*
Malaysia	0.3221*	0.3135*	0.2653*	0.1671*
Myanmar	0.1199	0.1173	0.0997	0.0298
Philippines	0.4304*	0.4031*	0.2512*	0.0398
Singapore	0.2981*	0.2792*	0.1786*	0.0773
Thailand	0.5889*	0.5827*	0.5409*	0.4075*
Vietnam	0.3801*	0.3671*	0.2936*	0.1558

Note: Smaller λ corresponds to longer-run relationship between the inflation rates. * denotes the statistical significance at the 5% level.

Alternatively, we can decompose the cross-cohesion index in Figure 3 into the country-level cohesion index for each G7 country. This decomposed country-level cross cohesion index is the average dynamic correlation between G7 country i's inflation rate and the ten ASEAN countries' inflation rates. Table 5 provides the country level cross-cohesion index for each of seven G7 countries.

The cross-cohesion indexes are statistically significant only for three countries (Canada, Italy, and US) in the short run (λ=1.04), yet they are significant for all countries in the long run. Among the G7 countries, inflation co-movement with the ASEAN countries is strong for the US and Italy but relatively weak for Germany and Japan. An interesting finding is that Germany and Japan also show weak inflation co-movement with other G7 countries as in Table 3, suggesting that idiosyncratic domestic factors play important roles in the fluctuations of inflation in these two countries.

Table 5. Cross-cohesion Index with the ASEAN Countries by Individual G7 Countries

	λ=0	λ=0.17	λ=0.54	λ =1.04
Canada	0.2797*	0.2753*	0.2468*	0.1707*
France	0.3320*	0.3163*	0.2296*	0.1090
Germany	0.2571*	0.2451*	0.1829*	0.0935
Italy	0.3841*	0.3765*	0.3218*	0.1831*
Japan	0.2201*	0.2128*	0.1706*	0.0995
UK	0.3668*	0.3409*	0.2078*	0.0529
US	0.3782*	0.3696*	0.3221*	0.2402*

Note: Smaller λ corresponds to longer-run relationship between the inflation rates. * denotes the statistical significance at the 5% level.

5. CONCLUSION

Frequency domain analyses enable us to document new empirical regularities on international inflation co-movement in the ASEAN countries, which have not been examined in depth in the literature using time domain analysis. Empirical results show that inflation co-movement is stronger in the long run than in the short run. There is strong evidence that inflation co-movement within the ASEAN countries is weaker than inflation co-movement within the G7 countries. We also find that the inflation in an ASEAN country, on average, fluctuates more closely with the inflation in the G7 countries than with the inflations in other neighboring ASEAN countries, implying that geographical proximity is not important in inflation synchronization. These findings suggest that the inflation in advanced countries is likely to be the main source of international inflation co-movement, which is more important than a regional factor in explaining the fluctuations of inflation in the ASEAN countries.

While the analysis tries to establish a set of stylized facts about inflation co-movement in the ASEAN countries, the findings in this paper call for further analysis on the sources of international inflation co-movements. Neely and Rapach (2011) point out that common shocks, similarities in central bank reaction functions, and international trade potentially produce common components in international inflation rates. The empirical findings in this paper suggest the possibility that the sources of inflation co-movement among the advanced countries may be different from the sources of inflation spillovers from the advanced countries to the emerging market economies.

REFERENCES

Andrews, D.W.K. (1991), “Heteroskedasticity and Autocorrelation Consistent Covariance Matrix Estimation,” *Econometrica*, 59, 817-858.

Berkowitz, J. and F. Diebold (1998), Bootstrapping Multivariate Spectra, *Review of Economics and Statistics*, 80, 4, 664-666.

Brockwell, P.J. and R. Davis (2013), *Time Series: Theory and Methods*, Springer Science & Business Media.

Ciccarelli, M. and B. Mojon (2010), “Global Inflation,” *Review of Economics and Statistics*, 92(3), 524-535.

Croux, C., M. Forni, and L. Reichlin (2001), “A measure of Co-movement for Economic Variables: Theory and Empirics, ” *Review of Economics and Statistics*, 83, 232-241.

Estrella, A. (2007), “Extracting Business Cycle Fluctuations: What Do Time Series Filters Really Do? ”, Staff Report, No. 289, Federal Reserve Bank of New York.

Ha, J., M.A. Kose, and F. Ohnsorge (2019), “Global Inflation Synchronization,” Policy Research Working Paper, World Bank Group.

Hamilton, J. D. (1994), *Time series analysis,* Vol. 2, Princeton: Princeton University Press.

Henriksen, E., F. Kydland, and R. Sustek (2013), “Global Correlated Nominal Fluctuations,” *Journal of Monetary Economics*, 60, 613-631.

Kwiatkowski, D. et al. (1992), “Testing the Null of Stationarity against the Alternative of a Unit Root: How Sure are We that Economic Time Series Have a Unit Root?”, *Journal of Econometrics*, 54, 159-178.

Mumtaz, H., S. Simonelli, and P. Surico (2011), “International Co-movements, Business Cycles and Inflation: a Historical Perspectives,” *Review of Economic Dynamics,* 14, 176-198.

Neely, C. and D. Rapach (2008), “Is Inflation an International Phenomenon?”, Federal Reserve Bank of St. Louis Working Paper, 2008-025.

Newey, W. and K. West (1994), “Automatic Lag Selection in Covariance Matrix Estimation, ” *Review of Economic Studies*, 61, 631-653.
Priestley, M.B. (1981), *Spectral Analysis and Time Series,* New York: Academic Press.

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