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EXTRACTING AND MEASURING PERIODICITIES OF CREDIT AND HOUSING CYCLES: EVIDENCE FROM EIGHT ECONOMIES

Victor Pontines

The South East Asian Central Banks (SEACEN) Research and Training Centre (80416-M)
Kuala Lumpur, Malaysia

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* Senior Economist, The South East Asian Central Banks (SEACEN) Research and Training Centre. Address: Level 5, Sasana Kijang, Bank Negara Malaysia, No. 2. Jalan Dato' Onn 50480 Kuala Lumpur, Malaysia. Email: vpontines@seacen.org

Abstract

This paper employs the Empirical Mode Decomposition technique to extract the credit and housing cycles in the four emerging East Asian economies of Hong Kong, Korea, Malaysia and Thailand, and these are compared to four advanced economies of Germany, Japan, United Kingdom and the United States. Based on a Lomb-Scargle periodogram analysis, the study finds that, with the exception of the credit cycle in Korea, the periodicities of the credit and housing cycles of the East Asian emerging economies are either close to or below the stylized cut-off of eight years. On the other hand, the credit and housing cycles of the four advanced economies have periodicities that are longer than eight years, in line with recent evidence.

Keywords: Credit Cycle, Financial Cycle, Empirical Mode Decomposition, Period of the Cycle

JEL Classification: C22, E32, E51

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EXTRACTING AND MEASURING PERIODICITIES OF CREDIT AND HOUSING CYCLES: EVIDENCE FROM EIGHT ECONOMIES

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Victor Pontines

1. Introduction

Our experience of past episodes of financial crises has shown that credit booms sow the seeds of subsequent credit crunches (Aikman et al., 2015). Schularick and Taylor (2012) documented that rapid credit growth increases the probability of a banking crises. Linked to credit booms is the elevated rise in asset prices, especially residential property prices. According to many studies, housing busts can be very costly in terms of losses in output (e.g., Bordo and Jeanne, 2002). Further, examining the recent experience of the United States, Shiller (2007) views the housing bubble as the major, if not sole, cause of the worldwide economic and financial crisis of 2007-2009 (Funke and Paetz, 2013). It is no coincidence then that in discussions of macroprudential policies, restraining the growth in credit and asset prices have become the first line of defence in attenuating financial stability risks. Precise and timely policy actions on the part of the authorities, however, requires the correct identification of the current phase of the cycle in credit and asset prices to pinpoint risks that are building up in the economy. Carrying out this objective requires the appropriate measurement of the cyclical durations of these two series.

Set against this context, a number of authors have introduced the concept of a financial cycle that enters prominently in discussions on how to increase the resilience of the financial system (e.g., Claessens et al., 2011; Drehmann et al., 2012; Galati et al., 2016). While it appears that a consensus definition on this concept has not been reached, both credit and housing prices have been contended to best measure this financial cycle (Borio, 2014). Moreover, growing literature have developed recently which sought to characterize the proxy measures of the financial cycle using various statistical decomposition and filtering methods. One of the main evidence coming out of these studies is that proxy measures of the financial cycle operate at lower frequencies with a duration of between 8 and 32 years (e.g., Claessens et al., 2011; Drehmann et al., 2012; Aikman et al., 2015).

One crucial implication of this finding to policy is that financial vulnerabilities take some time to grow, which raises the possibility that policymakers can fall into a sense of complacency. However, this evidence was obtained using data on advanced economies, including the United States. The question on whether this evidence also applies to emerging economies is a relevant one. This paper contributes to this expanding literature by providing the evidence on the duration of proxy measures of the financial cycles in an emerging market context.[1] Specifically, the paper

[1] A very recent contribution is by Pontines (2017).

extracts the credit and housing cycles of four emerging East Asian economies, i.e., Hong Kong, Korea, Malaysia and Thailand, and compare these to similarly extracted cycles in four advanced economies, including the United States.[2]

To achieve our aim, this paper uses a statistical decomposition technique, which to the best of our knowledge, its application to economic and financial issues and particularly for extracting credit and housing cycles is distinctly unique in comparison to other studies.[3] Specifically, a technique called the Empirical Mode Decomposition (EMD) is used to extract the credit and housing cycles. This data-driven technique first introduced by Huang et al., (1998), has subsequently been applied to diverse fields such as physics, mechanics, engineering, astronomy, medicine and the environmental sciences. One of the key advantage of this method in ascertaining the periodicities of any series is that it does not impose which frequency is present in a series unlike conventional approaches such as band-pass filter methods. The method can then automatically decompose a series with periodic components of short-term and medium-term fluctuations that are referred to as intrinsic mode functions (IMFs). It is from these intrinsic mode functions that the cycles of interest can be formed.[4] The other advantage of this method is that it does not require a series to be linear or stationary prior to analysis unlike, for instance, the traditional Fourier spectrum analysis for which data needs to be stationary to determine the periodicity of a series.

Another novelty of our approach is that once the cycles are formed from the intrinsic mode functions, the periodicities of these cycles are determined using what is called the Lomb-Scargle periodogram, a tool first developed to determine periodicities of astronomical data. The main benefit of using this method is that it can provide the level of statistical significance of a peak in the periodogram. The main findings of this paper are as follows. With the exception of the credit cycle in Korea, the periodicities of the credit and housing cycles of the four East Asian emerging economies are either close to or below the stylized cut-off of eight years. For the four advanced economies, on the other hand, while there is variation in the periodicities, their credit and housing cycles have periods that are longer than eight years, which is in line with recent findings.

The paper is structured as follows. The next section briefly discusses the Empirical Mode Decomposition technique and the Lomb-Scargle periodogram. The third section presents the data and the empirical results. The last section concludes.

[2] The other three are Germany, Japan and the United Kingdom.
[3] Exceptions are Crowley (2009), Crowley and Schildt (2009) which both use EMD to extract embedded frequencies for various macroeconomic indicators in advanced economies, while Kozic and Sever (2014) use EMD to extract the business cycle in the United States.
[4] See, for instance, Kozic and Sever (2014).

2. The Methods

2.1 The Empirical Mode Decomposition

The essence of the EMD method is to decompose a time series according to how many frequencies are apparent in the data. The method is entirely empirical and does not assume that a time series is linear or stationary prior to analysis or impose which frequency is present within a series. The method's algorithm proceeds by identifying a set of independent intrinsic mode functions (IMFs) and a residual component. The IMFs are extracted through a sifting process following the required steps below:[5]

1) The local extrema, both maxima and minima of time series $x(t)$ are identified.
2) Cubic spline interpolation is used to generate upper and lower envelopes $e_{min}(t)$ and $e_{max}(t)$ to the sequences of maxima and minima.
3) The point-by-point mean ($m(t)$) of the upper and lower envelopes is taken:
$$m(t) = (e_{min}(t) \text{ and } e_{max}(t))/2 \quad (1)$$
4) The mean $m(t)$ is subtracted from the original time series $x(t)$ to yield a residual variable $d(t)$:
$$d(t) = x(t) - m(t) \quad (2)$$
5) At this point, the properties of $d(t)$ is verified whether it is an IMF or not. An IMF must satisfy two conditions: (i) the number of extrema (sum of maxima and minima) and the number of zero crossings must be equal or differ by one, and (ii) the mean must be equal to zero.
If $d(t)$ is an IMF, replace $x(t)$ by the residual $r(t)$ which is obtained from the difference between $d(t)$ and the original time series $x(t)$, $r(t) = x(t) - d(t)$. On the other hand, if $d(t)$ is not an IMF, replace the original time series $x(t)$ by $d(t)$.
6) Repeat steps 1) to 5) until the residual becomes a monotonic function from which no more IMFs can be extracted.

The original time series $x(t)$ can then be decomposed into N IMFs and a monotonic final residual $r_f(t)$:

$$x(t) = \sum_{j=1}^{N} \mathrm{IMF}_j + r_f(t) \quad (3)$$

The main interest are the IMFs. The IMFs are the extracted cycle series that have different significant periodic components of short-term and medium-term fluctuations. The significant periodic components in the IMFs as well as the cycles formed from these IMFs are then detected by utilizing what is called the Lomb-Scargle periodogram, which we turn to next.

[5] The analysis was performed in the R software using the EMD algorithm developed by Kim and Oh (2009).

2.2 Lomb-Scargle Periodogram

The Lomb-Scargle periodogram (Lomb, 1976; Scargle, 1982) is derived from, but not identical to the classical Fourier spectrum analysis and was developed for use in astronomical data. This method has the benefit of providing the level of statistical significance of a peak in the periodogram (Horne and Baliunas, 1986; Ruf, 1999). Suppose a time series $y(t)$, which in the present case an extracted IMF, the Lomb-Scargle periodogram can be computed as:[6]

$$P_N(\omega) = \frac{1}{2\sigma^2}\left\{\frac{[\sum_{i=1}^{N}(y(t)_i - \bar{y})\cos\,\omega(t_i - \tau)]^2}{\sum_{i=1}^{N}\cos^2\,\omega(t_i - \tau)}\right\} + \left\{\frac{[\sum_{i=1}^{N}(y(t)_i - \bar{y})\sin\,\omega(t_i - \tau)]^2}{\sum_{i=1}^{N}\sin^2\,\omega(t_i - \tau)}\right\} \quad (4)$$

where P_N is the exponential distribution. The phase τ is defined by:

$$\tau = \left(\frac{1}{2\omega}\right)\tan^{-1}\left[\frac{\sum_i \sin 2\omega t_i}{\sum_i \cos 2\omega t_i}\right] \quad (5)$$

P_N gives the normalized power as a function of the angular frequency ($\omega = 2\pi/P$) for all periods (P) tested. The normalization is through σ^2 which is the total variance of $y(t)$. We are also interested in the significance of any peak in P_N. The probability that at least one of the peaks in the periodogram is equal to or greater than $P_N(\max)$ can be calculated as:

$$p(P_N(\max)) = 1 - (1 - e^{-P_N(\max)})^N \quad (6)$$

3. Data and Empirical Results

The credit and housing cycles were extracted from data on quarterly credit-to-GDP and house prices of four advanced economies, i.e., Germany, Japan, United Kingdom (UK), the United States (USA) and four East Asian emerging economies, i.e., Hong Kong, Korea, Malaysia, Thailand.[7] The sample period is first quarter of 1979 (1979Q1) to last quarter of 2016 (2016Q4) with the exceptions of house price data for Hong Kong (1983Q1 – 2016Q4), Malaysia (1988Q1 – 2016Q4) and Thailand (1991Q1 – 2016Q4) which were only available at a later period. The credit-to-GDP and house price data were both obtained from the Bank for International Settlements (BIS) statistics on credit to the private, non-financial sector and residential property prices, respectively. These were also the same data used in Drehmann et al., (2012).

[6] The analysis was also performed in R using the lomb package developed by Thomas Ruf.

[7] The choice of the four East Asian emerging economies is dictated by the availability of long enough data on credit and house prices.

After employing EMD to the data, in addition to the final residual, the total number of IMFs extracted are shown in the first column (Panels A and B) of Table 1. Among the eight economies considered, three to five IMFs were extracted from the credit-to-GDP data (Panel A), while two to three IMFs were extracted from the house price data (Panel B). The periodicities of the individually extracted IMFs were next determined using the Lomb-Scargle periodogram.[8] Once their periodicities are determined, we follow the standard definition in the literature that business or short-term cycles have a stylized duration of at most 8 years, while proxy measures of the financial cycle operate at lower frequencies of at least 8 years and as such, those IMFs that have periods between 8 to 32 quarters, i.e., 2 to 8 years, are identified and combined, while those IMFs that have periods between 32 to 128 quarters, i.e., 8 to 32 years are also separately identified and combined. The last two columns of both panels of Table 1 show the distribution of the IMFs according to whether they belong to a short-term cycle or to a medium-term cycle across the economies considered. The message coming out of this table is that short- and medium-term cycles exist in all the eight economies for our credit-to-GDP data (Panel A), while both cyclical components exist in five of the eight economies for our house price data (Panel B). The interesting exceptions to the latter are the economies of Hong Kong, Malaysia and Thailand for which medium-term cycles do not exist. By combining the extracted IMFs that belong to the same relevant cycles, we can then construct the short- and medium-term components of our credit-to-GDP and house price data across the individual economies.

Figures 1 to 4 and Figures 5 to 8 show the cyclical components in the credit-to-GDP and house prices, respectively, in our eight economies. The figures depict the medium-term component (solid line) as well as the sum of both components (dashed line), the latter of which is then the full cycle, i.e., the credit and housing cycle. The difference between the medium-term component and the full cycle is the business or short-term cycle. It is clear from a visual inspection of these figures that there is sufficient heterogeneity across the countries. In Figures 1 to 4, among the four advanced economies, business cycle frequency fluctuations do not account for much of the overall variation in the credit-to-GDP ratio in Germany, UK and USA, whereas in Japan, there is a distinct business cycle frequency fluctuation (Figures 1-2). Among the four emerging economies, Korea's medium-term fluctuations stand out in accounting for much of the overall variation in its credit-to-GDP, significantly different from the other three emerging economies for which business cycle fluctuations account for more of the fluctuations (Figures 3-4). In comparing the advanced and emerging economies in Figures 1 to 4, we find that Korea's medium-term fluctuations appear dominant in the overall fluctuations of its credit-to-GDP and hence, its credit cycle would be longer and thus more comparable to the similarly longer credit cycles in the advanced economies. Finally, given that business cycle fluctuations are more distinct in accounting for overall fluctuations in credit-to-GDP, credit cycles in the remaining three emerging economies are shorter compared to the four advanced economies.

[8] The results of the Lomb-Scargle periodogram analysis of the IMFs are available upon request.

We obtain a relatively similar narrative for Figures 5 to 8. Among the four advanced economies, medium-term components account for much of the overall variation in house prices in Germany, UK and USA, but to a lesser extent in Japan (Figures 5-6). Among the four emerging economies, as earlier noted, the medium-term components do not exist in the economies of Hong Kong, Malaysia and Thailand. As such, the housing cycles in these three economies are entirely accounted for by fluctuations in business cycle frequencies, although in Korea's case, both cycle components exist (Figures 7-8). Thus, Korea's housing cycle tend to appear longer than the other three East Asian emerging economies. Nevertheless, it appears that the housing cycles in the four emerging economies are shorter compared to those of the four advanced economies.

The preceding visual inspection to determine which cyclical components appear dominant and thus on the likely appropriate length of the credit and housing cycles in the eight economies, is reinforced by conducting a Lomb-Scargle periodogram analysis on the constructed credit and housing cycles. Figures 9 to 12 present the periodograms for the credit cycles, while Figures 13 to 16 present the periodograms for the housing cycles. In each periodogram, the focus is on the existence of a significant peak in the normalized power in the Lomb-Scargle periodogram. A significant peak is present when a particular value of the normalized power exceeds the one percent significance level cut-off (the horizontal dashed line in the Figures). In cases where there is more than one significant peak, the largest peak is chosen as this would be the most dominant compared to the other peaks. Next, we determine the location of this largest, significant peak. A peak that is shifted more to the left or closer to zero frequency would suggest a longer periodicity in the cycle. Based on this, all the periodograms in Figures 9 to 16 show at least one significant peak, but the location of these peaks and hence the magnitudes of the cycle frequencies differ across the eighth economies. In terms of the periodograms for the credit cycles, among the four advanced economies, Germany and the USA followed by the UK and then Japan, all have their largest, significant peaks closer to zero frequency, suggesting long periodicities in their credit cycles (Figures 9 to 10). Among the four emerging East Asian economies, Korea has the location of its largest, significant peak comparable to the four advanced economies, and as such its credit cycle is longer compared to the other three emerging East Asian economies. The latter have their largest, significant peaks at relatively higher frequencies suggesting shorter periodicities in the cycles for these economies (Figures 11 to 12).

The periodograms for the housing cycles in Figures 13 to 16 reveal almost similar findings. Among the four advanced economies, the USA and UK followed by Germany and then Japan all have their largest, significant peaks at relatively lower frequencies, also suggesting long periodicities in their housing cycles (Figures 13 to 14). Within the four emerging East Asian economies, all have the location of their largest, significant peaks at relatively higher frequencies, suggesting shorter periodicities in housing cycles with Korea having the longest housing cycle among the four (Figures 15 to 16).

The final and important finding from our preceding periodogram analysis is for the corresponding estimated periodicities[9] of the credit and housing cycles in the eight economies. The results are presented in Table 2. The estimated periodicities are clearly in harmony with our earlier visual inspection, and again brings to the fore the observation of a significant heterogeneity among the economies. Within the advanced economies, Germany (18.9 years) and the USA (18 years) both have the longest estimated credit cycles, while the USA has the longest estimated housing cycle at 13.5 years. Among the four, Japan has the shortest estimated credit and housing cycles at 9.2 years. Nonetheless, consistent with the earlier literature, these proxy measures of the financial cycles have periodicities that are longer than eight years. Among the four emerging Asian economies, with the exception of the credit cycle in Korea (14.5 years), the periodicities of the rest of the credit and housing cycles of these economies are either close to (e.g., Hong Kong's credit cycle) or below the rule-of-thumb cut-off of at least 8 years in periodicity of the proxy measures of the financial cycle observed in advanced economies.

4. Conclusion

This paper uses the Empirical Mode Decomposition technique to extract the credit and housing cycles in four emerging East Asian economies and these are compared to similarly extracted cycles in four advanced economies, including the USA. After extracting these cycles, the paper then goes on to investigate whether the evidence recently put forward in the literature that proxy measures of the financial cycle operate at lower frequencies with a duration of between 8 and 32 years also applies to our four emerging East Asian economies. To ascertain the periodicities of our credit and housing cycles, we utilize a tool called the Lomb-Scargle periodogram. One important advantage of this tool is that it can provide the level of statistical significance of a peak in the periodogram.

The paper finds that with the exception of the credit cycle in Korea, the periodicities of the credit and housing cycles of the East Asian emerging economies are either close to or below the stylized cut-off of eight years. The four advanced economies, on the other hand, while there is variation in the periodicities, the credit and housing cycles of these four economies have periods that are longer than eight years, which is in line with recent findings.

Given that economies are still learning on how best to calibrate macroprudential policies, there is no one size fits-all policy approach. In economies that have longer credit and housing cycles and operate at medium-term frequencies, a stronger application of macroprudential policies is needed to complement traditional macroeconomic policy instruments, especially during periods when the real and financial sectors are not on even keel. In contrast, for economies that have relatively shorter credit and housing cycles and operate at short-term frequencies, macroprudential policies can still serve an important purpose. For instance, the economies that we examine here are small and open, for which external factors and developments drive

[9] This is easily computed as the inverse of the frequency pertaining to the largest, significant peak.

macroeconomic outcomes to a large extent. In this regard, macroprudential policies may need to be complemented by capital flow management (CFM) measures, albeit subject to the caveat of not 'overdoing' their applications as traditional macroeconomic policy instruments can still exert a powerful influence on the real and financial sectors of the economy.

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Table 1. Intrinsic Mode Functions (IMFs) belonging to relevant Cycles

Panel A. Credit-to-GDP

	Number of IMFs (1)	IMFs belonging to short-term cycle (2)	IMFs belonging to medium-term cycle (3)
Germany	5	IMF1	IMF2 + IMF3+ IMF4 + IMF5
Japan	3	IMF1 + IMF2	IMF3
UK	3	IMF1	IMF2 + IMF3
USA	4	IMF1	IMF2 + IMF3 + IMF4
Hong Kong	4	IMF1 + IMF2 + IMF3	IMF4
Korea	4	IMF1	IMF2 + IMF3 + IMF4
Malaysia	3	IMF1 + IMF2	IMF3
Thailand	3	IMF1 + IMF2	IMF3

Notes: (i) The number of Intrinsic Mode Functions (IMFs) refer to the total number of IMFs extracted during the sifting process of the empirical mode decomposition.
(ii) Short-term cycle defined as the period between 2 to 8 years.
(iii) Medium-term cycle defined as the period between 8 and 32 years.
(iv) The cycle to which individual IMFs belongs are determined according to their periodicities. The periodicities are then determined based on the largest and significant peak normalized power in the Lomb-Scargle periodogram.

Source: Author's calculations.

Table 1 (cont.). Intrinsic Mode Functions (IMFs) belonging to relevant Cycles

Panel B. House Prices

	Number of IMFs (1)	IMFs belonging to short-term cycle (2)	IMFs belonging to medium-term cycle (3)
Germany	3	IMF1 + IMF2	IMF3
Japan	3	IMF1	IMF2 + IMF3
UK	3	IMF1 + IMF2	IMF3
USA	3	IMF1 + IMF2	IMF3
Hong Kong	2	IMF1 + IMF2	-----
Korea	3	IMF1 + IMF2	IMF3
Malaysia	2	IMF1 + IMF2	-----
Thailand	3	IMF1 + IMF2 + IMF3	-----

Notes: (i) The number of Intrinsic Mode Functions (IMFs) refer to the total number of IMFs extracted during the sifting process of the empirical mode decomposition.
(ii) Short-term cycle defined as the period between 2 to 8 years.
(iii) Medium-term cycle defined as the period between 8 and 32 years.
(iv) The cycle to which individual IMFs belongs are determined according to their periodicities. The periodicities are then determined based on the largest and significant peak normalized power in the Lomb-Scargle periodogram.

Source: Author's calculations.

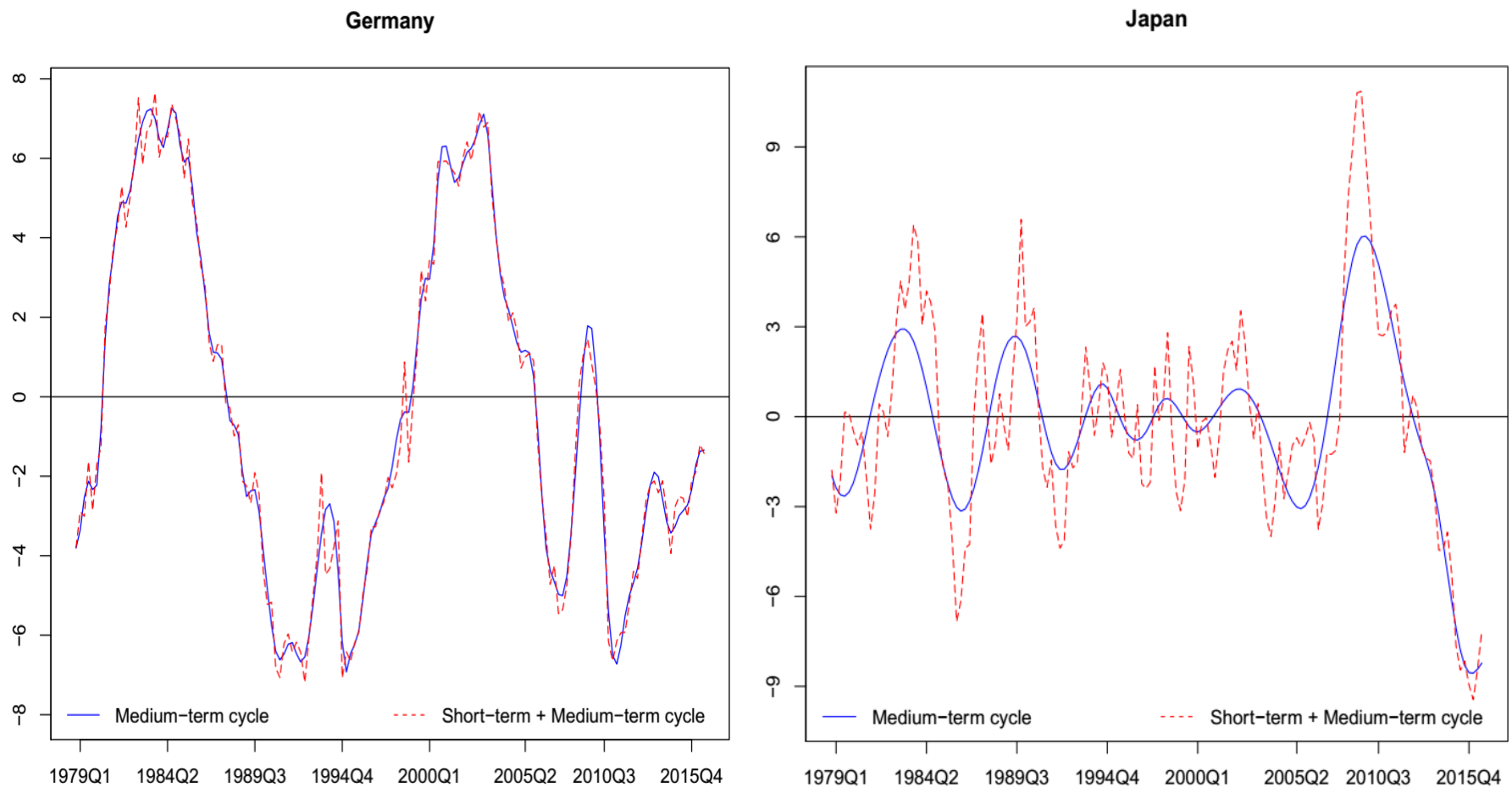
Table 2. Periodicities of the Credit and Housing Cycles, in Quarters (Years)

	Credit Cycle	Housing Cycle
Germany	75.5 (18.9)	47.2 (11.8)
Japan	36.8 (9.2)	36.8 (9.2)
UK	52.1 (13.0)	50.3 (12.6)
USA	71.9 (18.0)	53.9 (13.5)
Hong Kong	31.5 (7.9)	17.5 (4.4)
Korea	58.1 (14.5)	25.2 (6.3)
Malaysia	22.9 (5.7)	19.8 (4.9)
Thailand	26.0 (6.5)	17.2 (4.3)

Notes: (i) The values underlined and in parentheses are the periodicities expressed in quarters and in years, respectively.
(ii) The periods are determined based on the largest and significant peak normalized power in the Lomb-Scargle periodogram. Significance level of 1 percent was used to evaluate the significance of the peak normalized power.

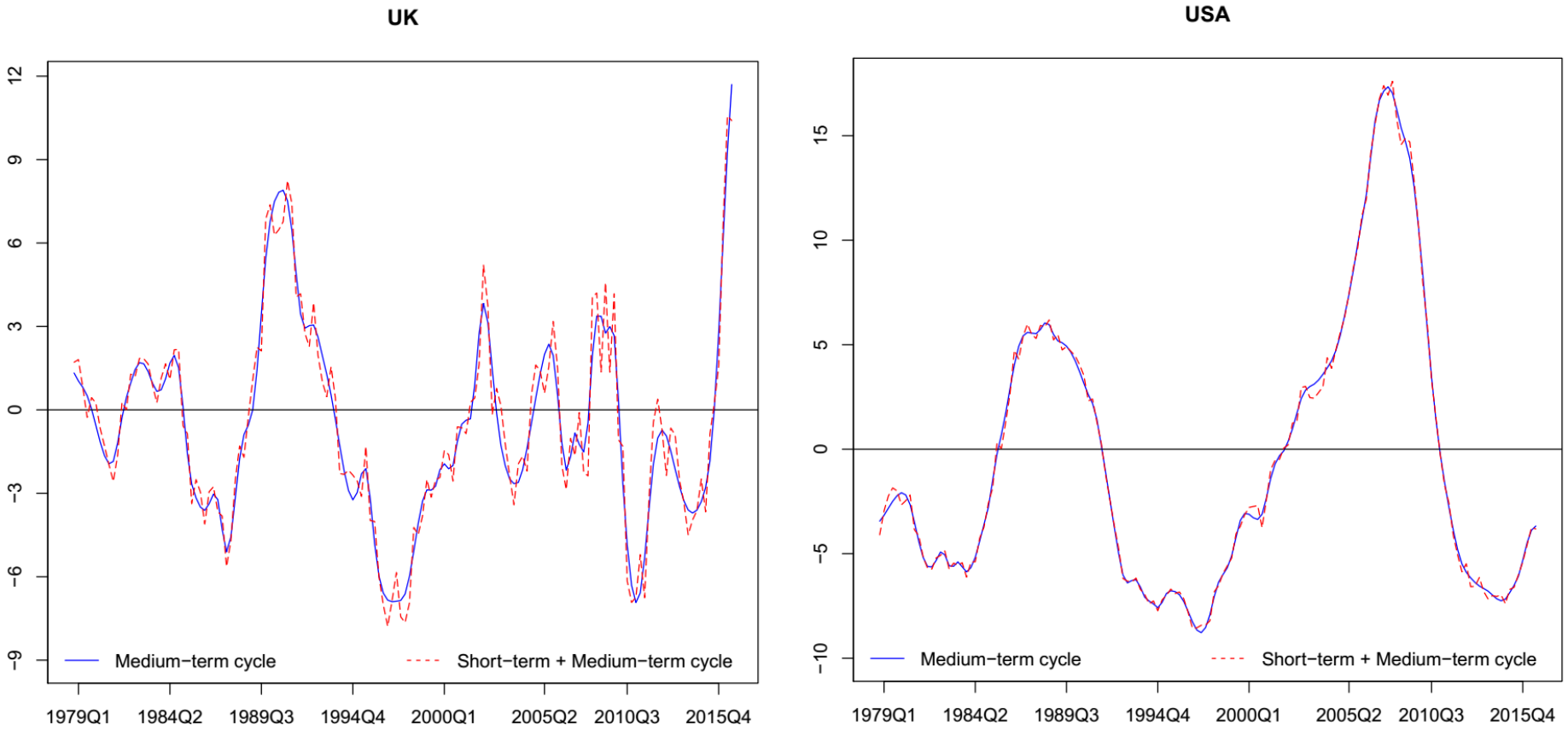
Source: Author's calculations.

Figure 1. Cycles in Credit-to-GDP: Germany and Japan



Note: The cycles are obtained according to the IMFs belonging to a particular frequency or period as reported in Table 1.
Source: Author's calculations.

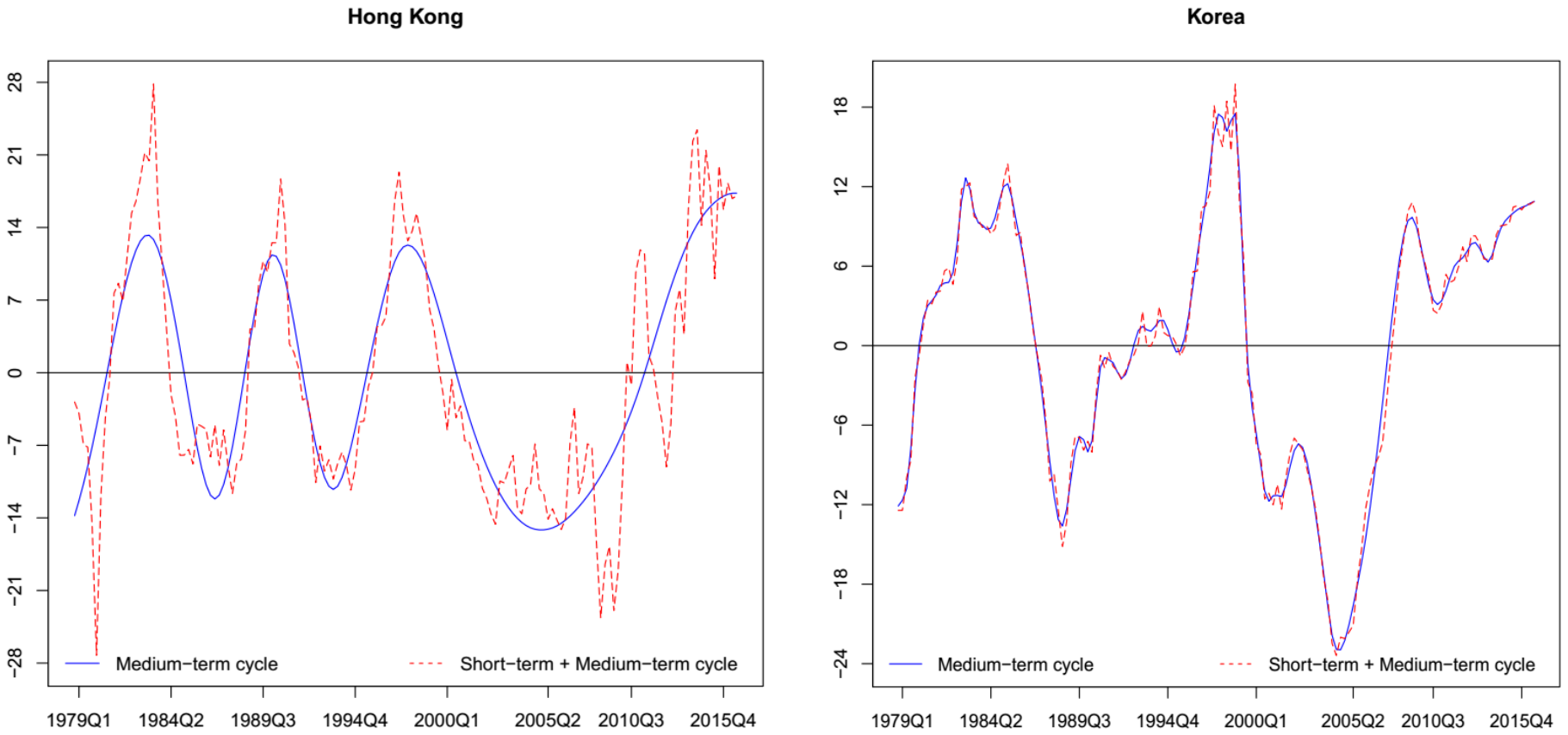
Figure 2. Cycles in Credit-to-GDP: UK and USA



Note: The cycles are obtained according to the IMFs belonging to a particular frequency or period as reported in Table 1.

Source: Author's calculations.

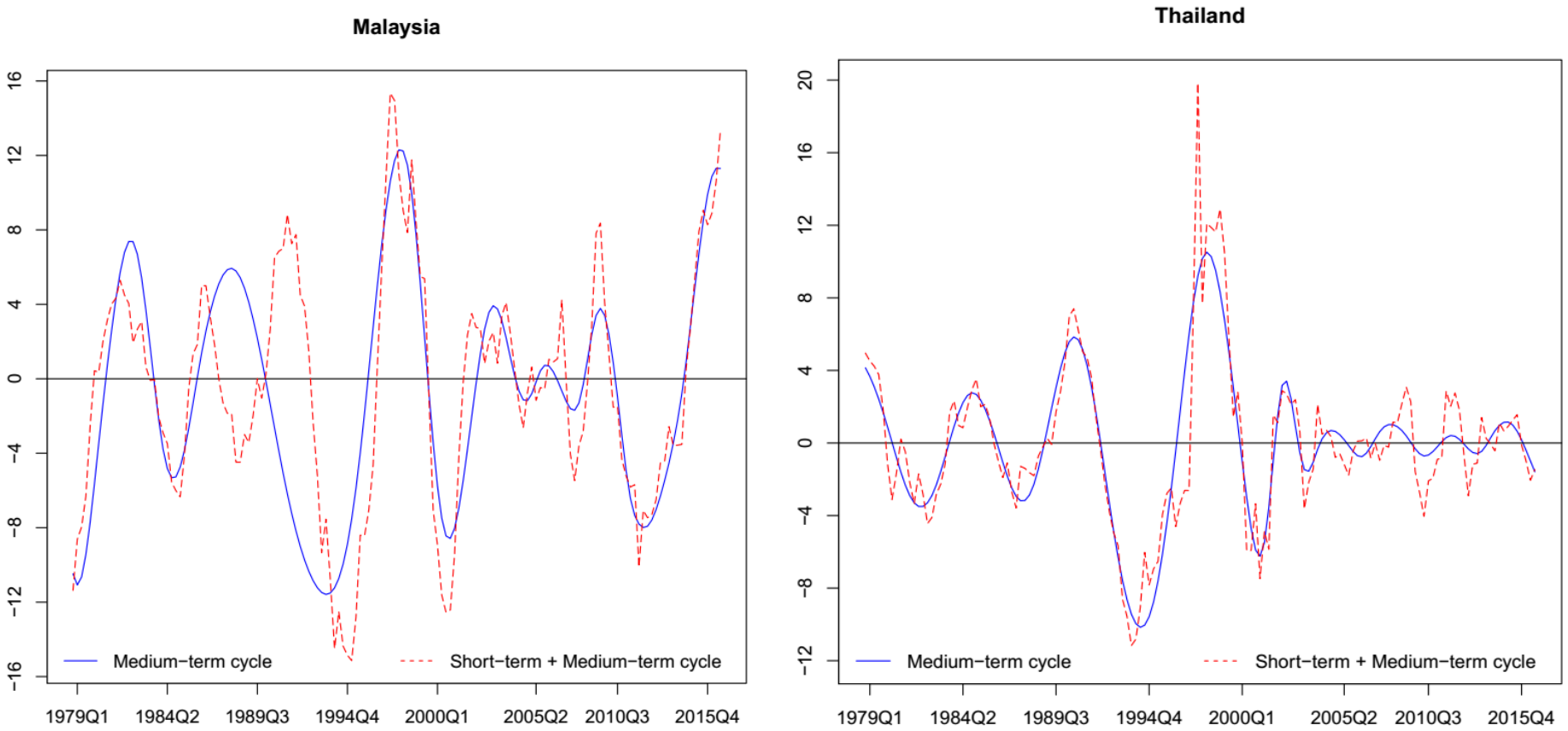
Figure 3. Cycles in Credit-to-GDP: Hong Kong and Korea



Note: The cycles are obtained according to the IMFs belonging to a particular frequency or period as reported in Table 1.

Source: Author's calculations.

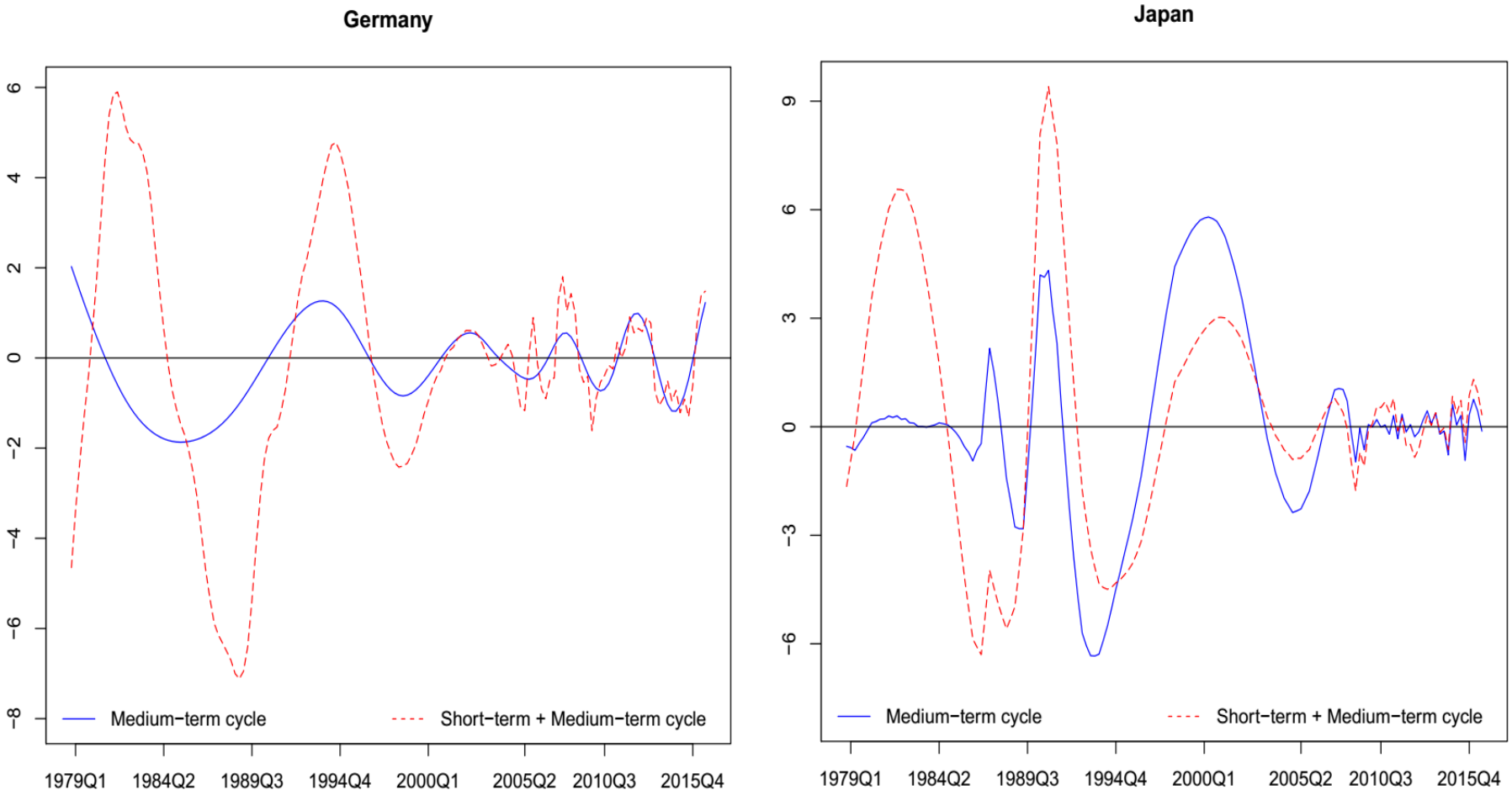
Figure 4. Cycles in Credit-to-GDP: Malaysia and Thailand



Note: The cycles are obtained according to the IMFs belonging to a particular frequency or period as reported in Table 1.

Source: Author's calculations.

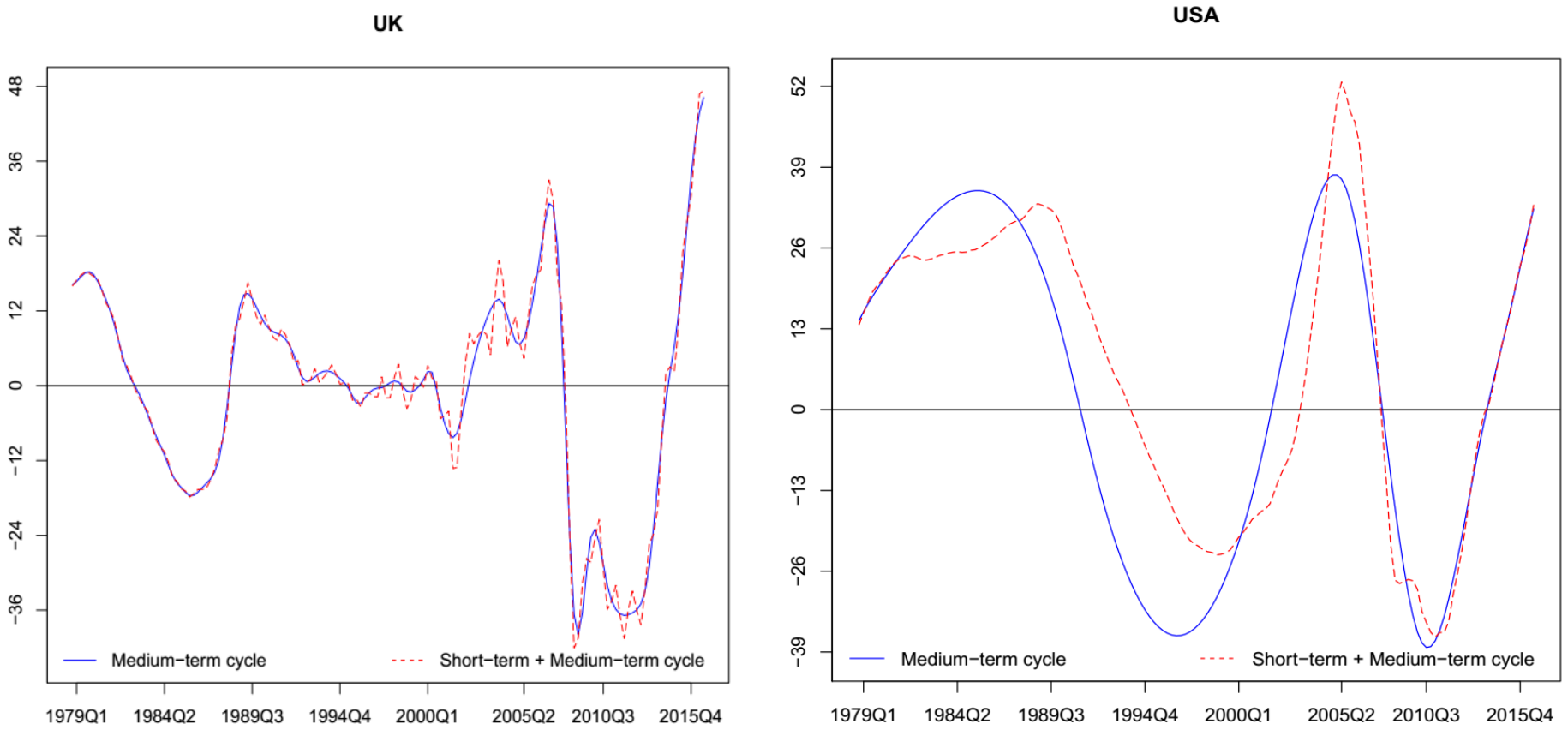
Figure 5. Housing Cycles: Germany and Japan



Note: The cycles are obtained according to the IMFs belonging to a particular frequency or period as reported in Table 1.

Source: Author's calculations

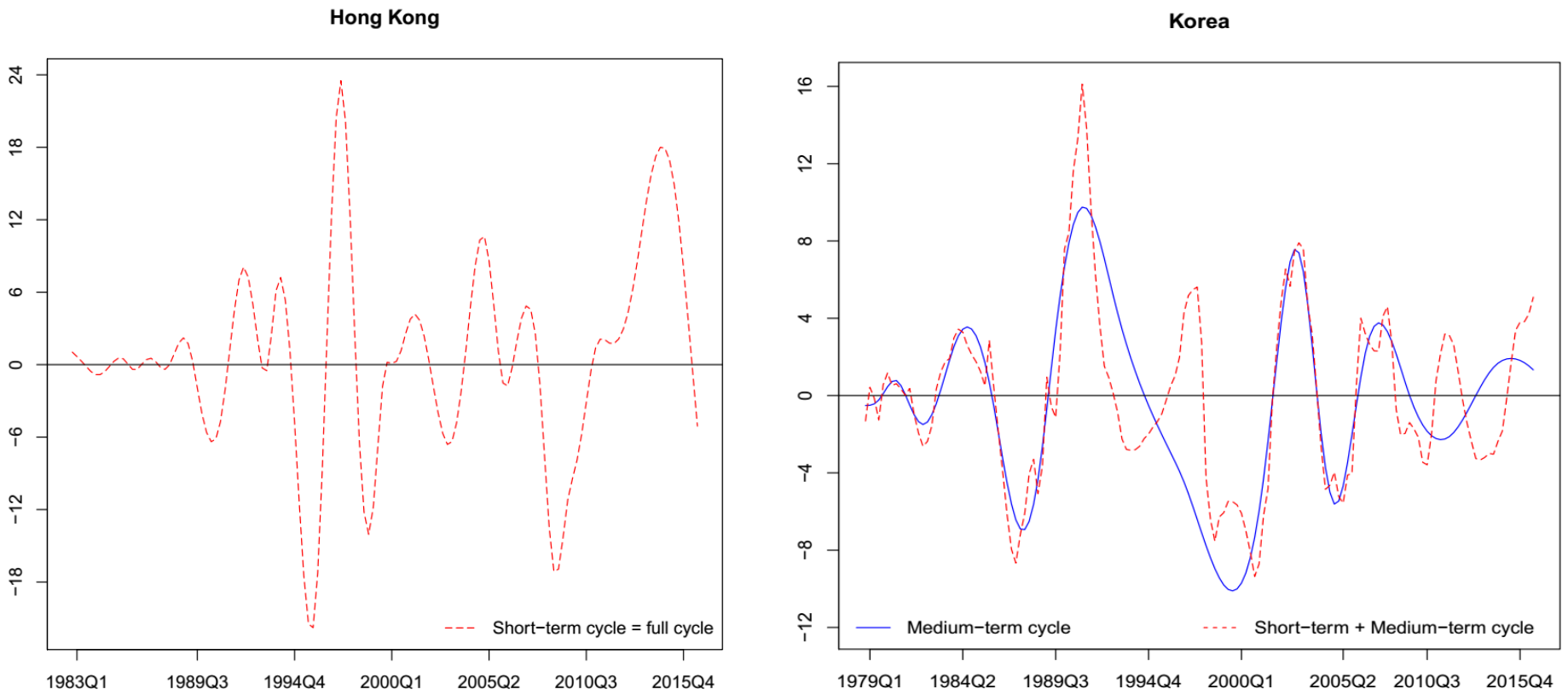
Figure 6. Housing Cycles: UK and USA



Note: The cycles are obtained according to the IMFs belonging to a particular frequency or period as reported in Table 1.

Source: Author's calculations.

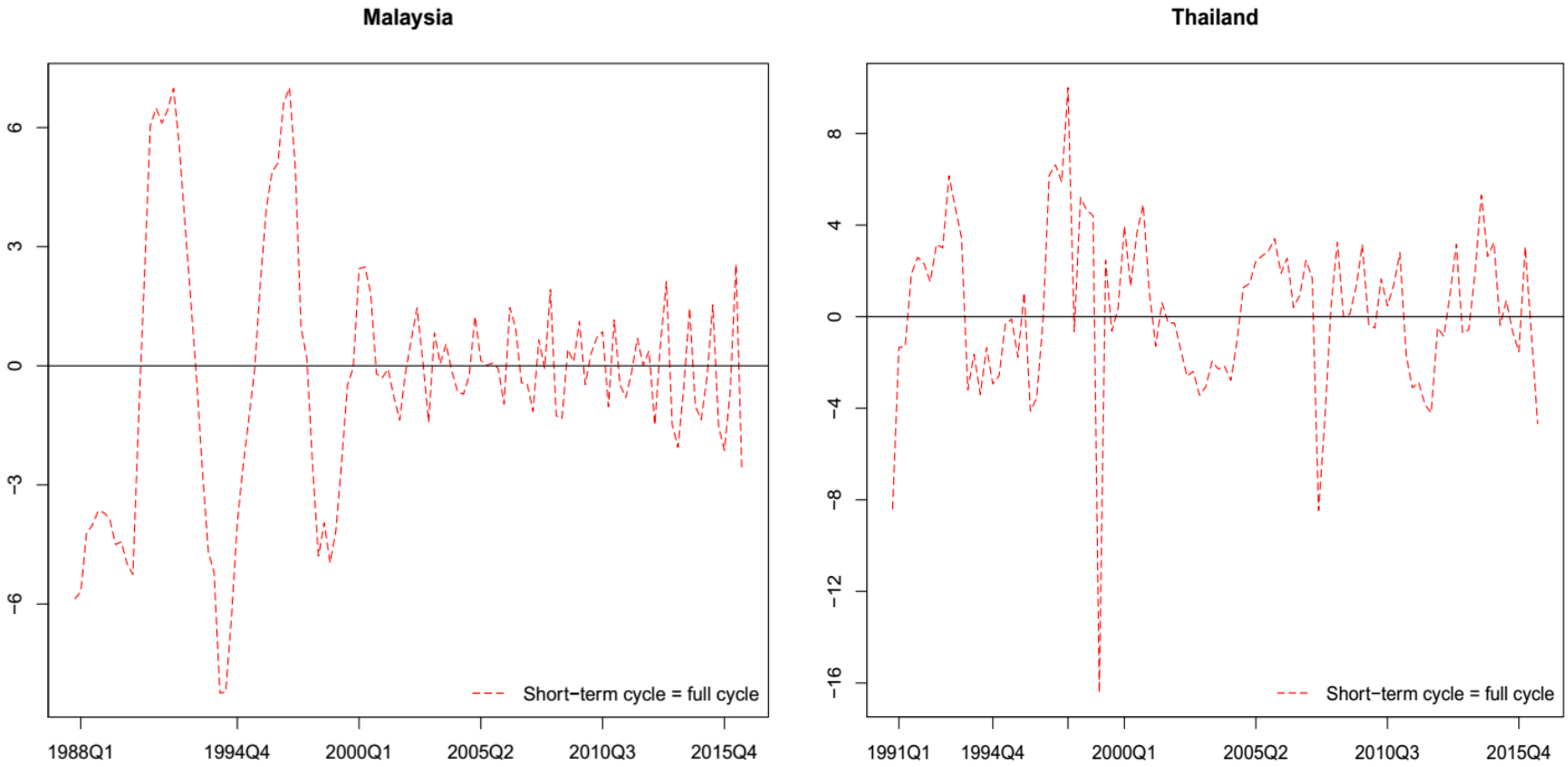
Figure 7. Housing Cycles: Hong Kong and Korea



Note: The cycles are obtained according to the IMFs belonging to a particular frequency or period as reported in Table 1.

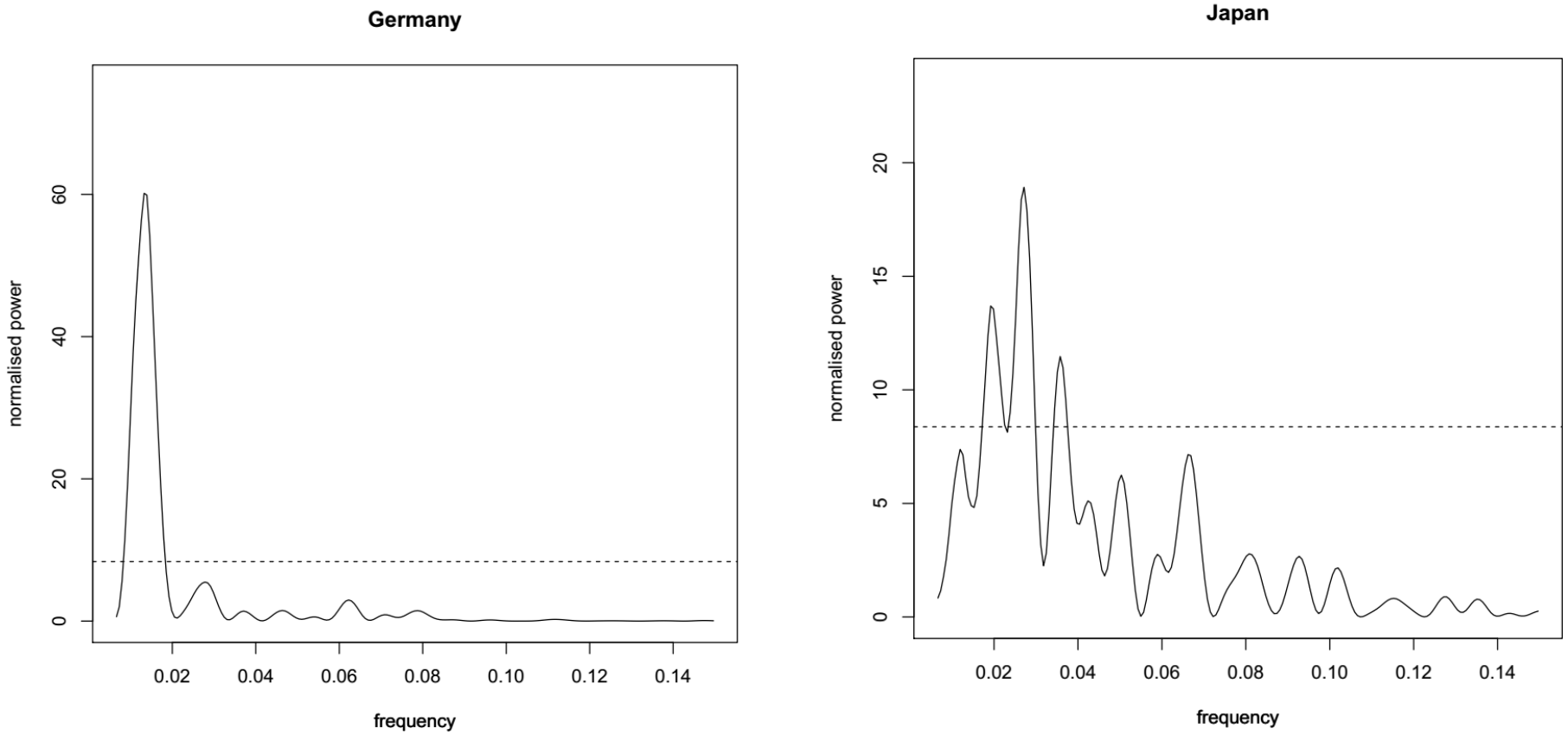
Source: Author's calculations.

Figure 8. Housing Cycles: Malaysia and Thailand



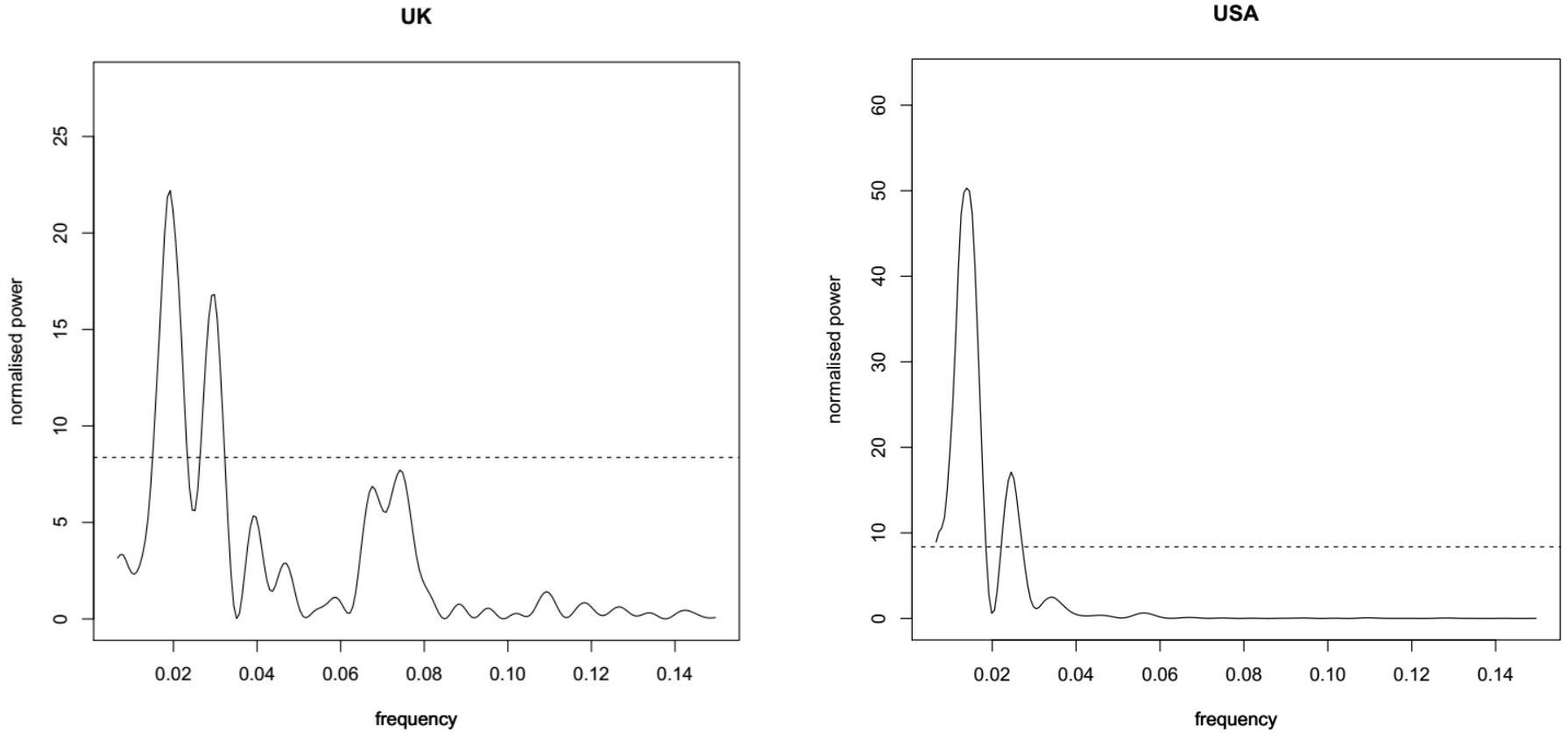
Note: The cycles are obtained according to the IMFs belonging to a particular frequency or period as reported in Table 1.
Source: Author's calculations.

Figure 9. Lamb-Scargle Normalized Periodograms: Credit Cycles (Germany and Japan)



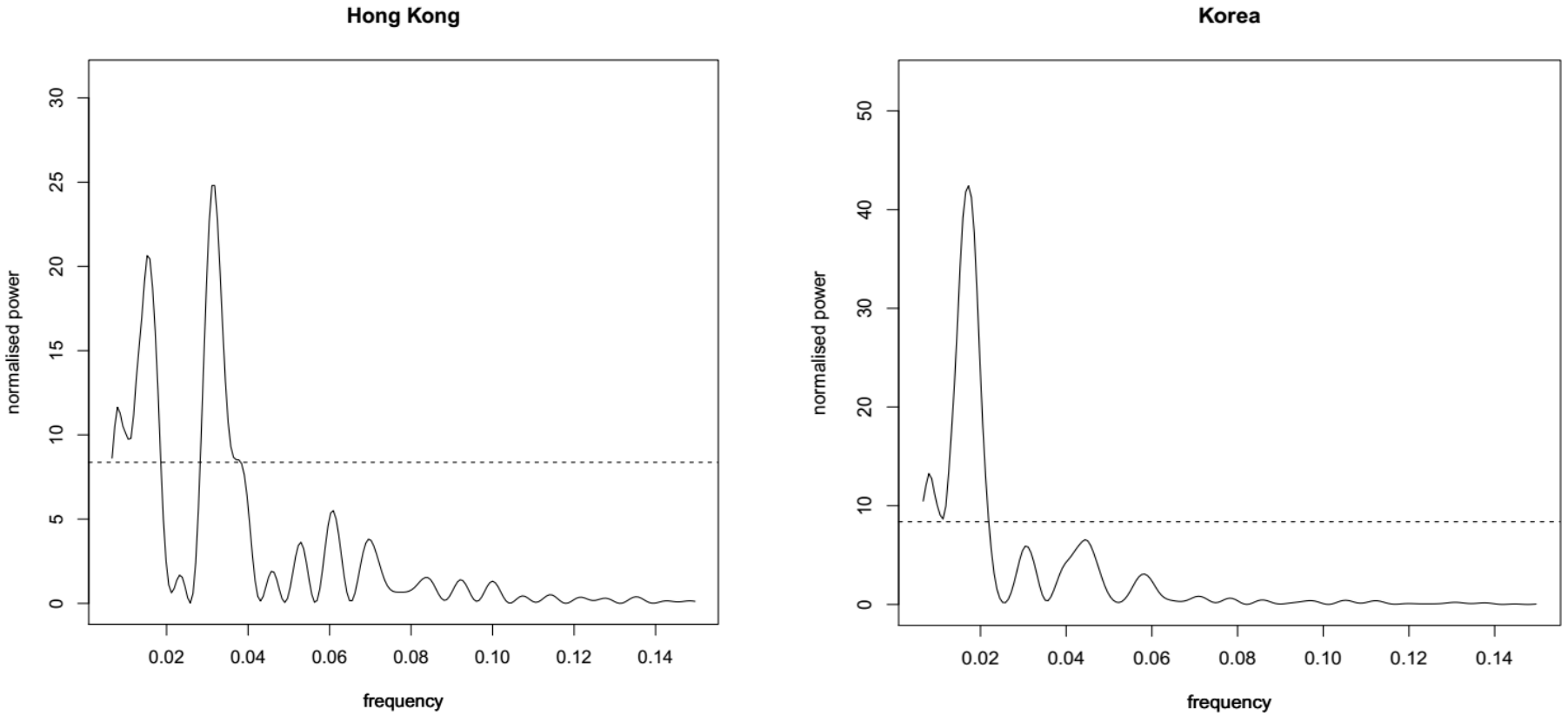
Note: The horizontal dashed line is the 1 percent significance level cut-off.
Source: Author's calculations.

Figure 10. Lamb-Scargle Normalized Periodograms: Credit Cycles (UK and USA)



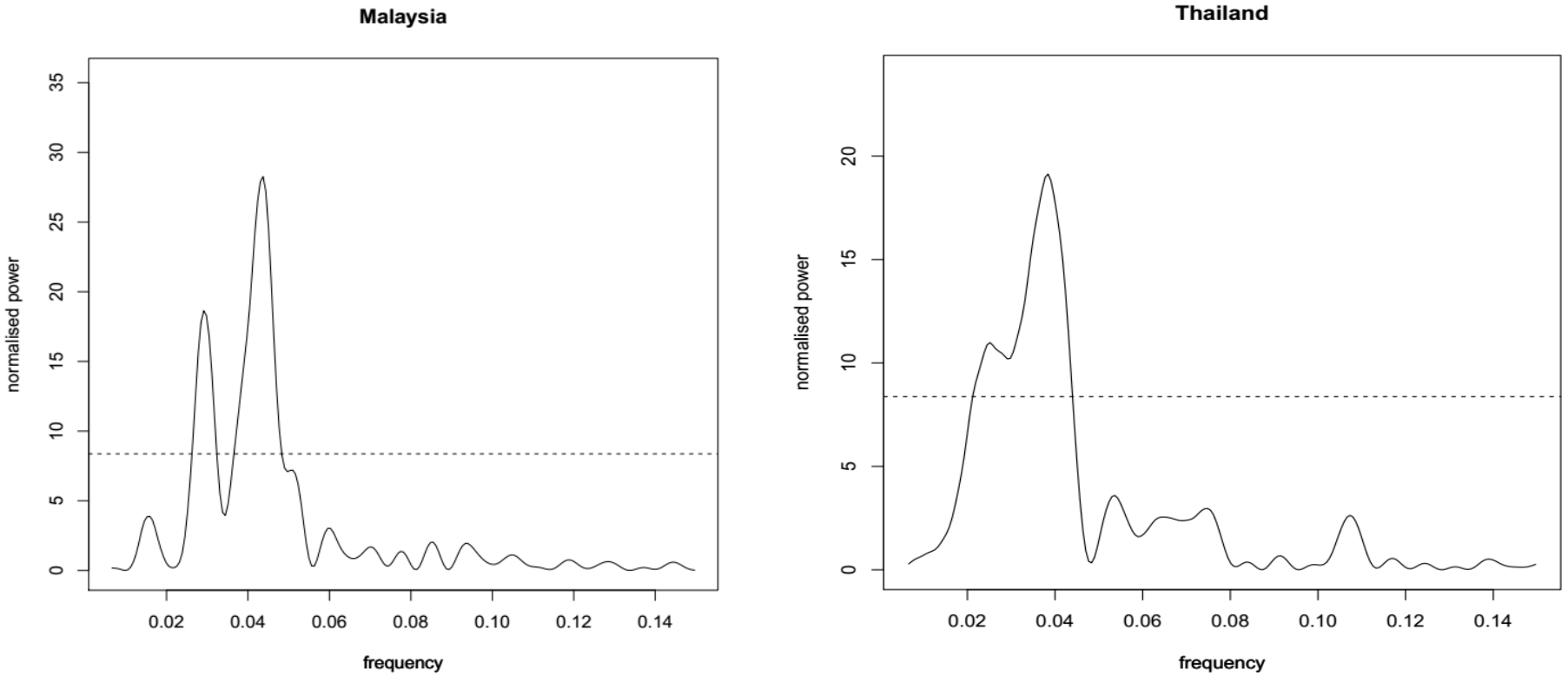
Note: The horizontal dashed line is the 1 percent significance level cut-off.
Source: Author's calculations.

Figure 11. Lamb-Scargle Normalized Periodograms: Credit Cycles (Hong Kong and Korea)



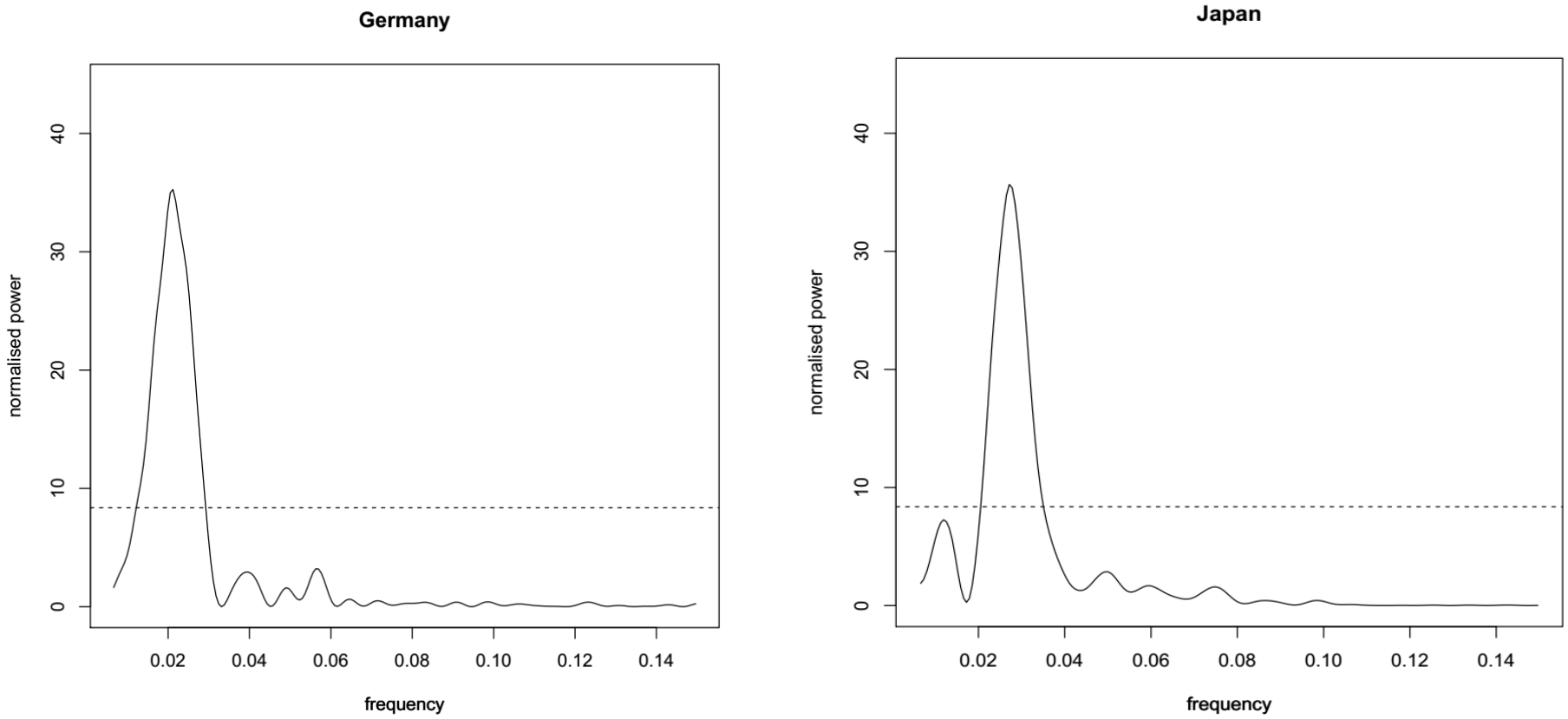
Note: The horizontal dashed line is the 1 percent significance level cut-off.
Source: Author's calculations.

Figure 12. Lamb-Scargle Normalized Periodograms: Credit Cycles (Malaysia and Thailand)



Note: The horizontal dashed line is the 1 percent significance level cut-off.
Source: Author's calculations.

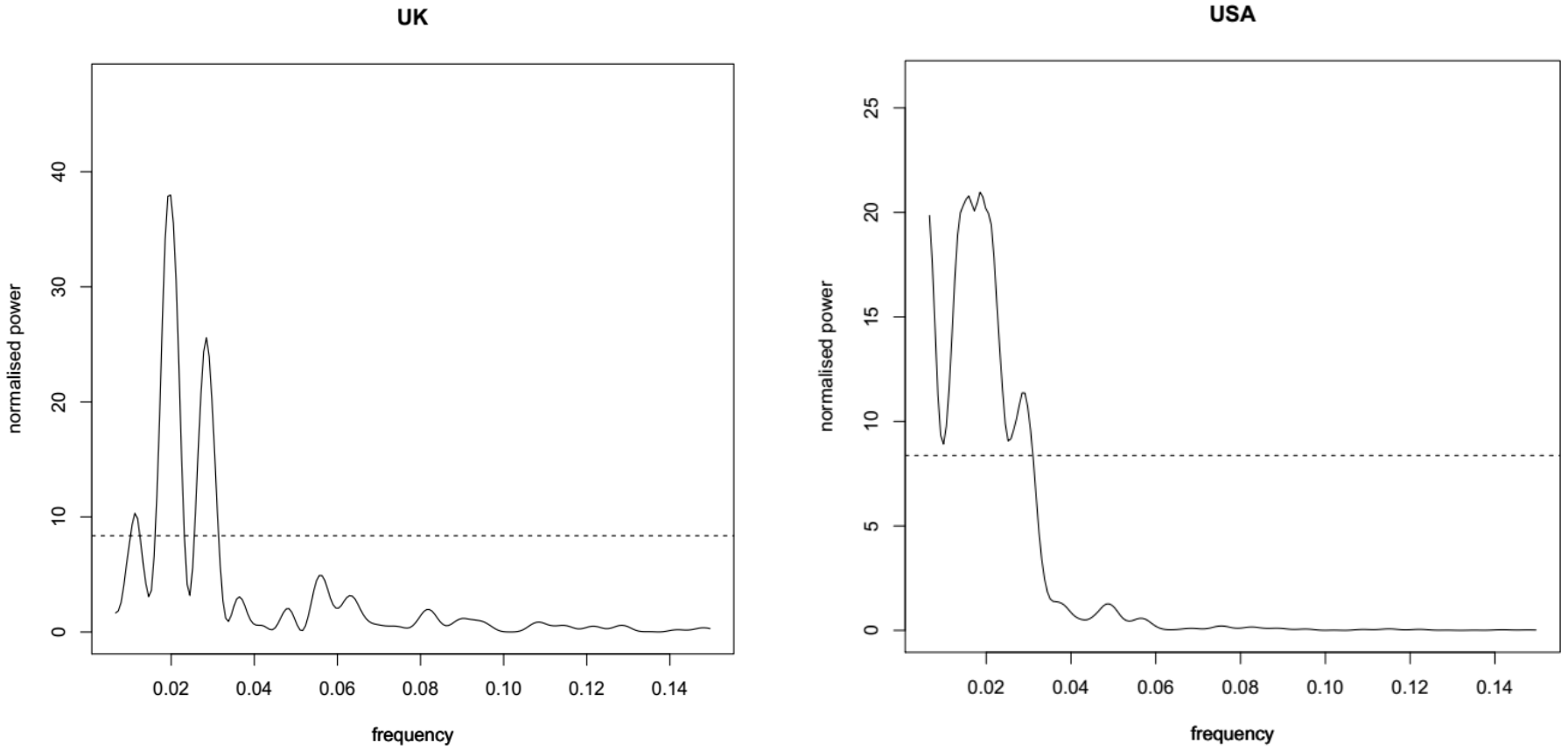
Figure 13. Lamb-Scargle Normalized Periodograms: Housing Cycles (Germany and Japan)



Note: The horizontal dashed line is the 1 percent significance level cut-off.

Source: Author's calculations.

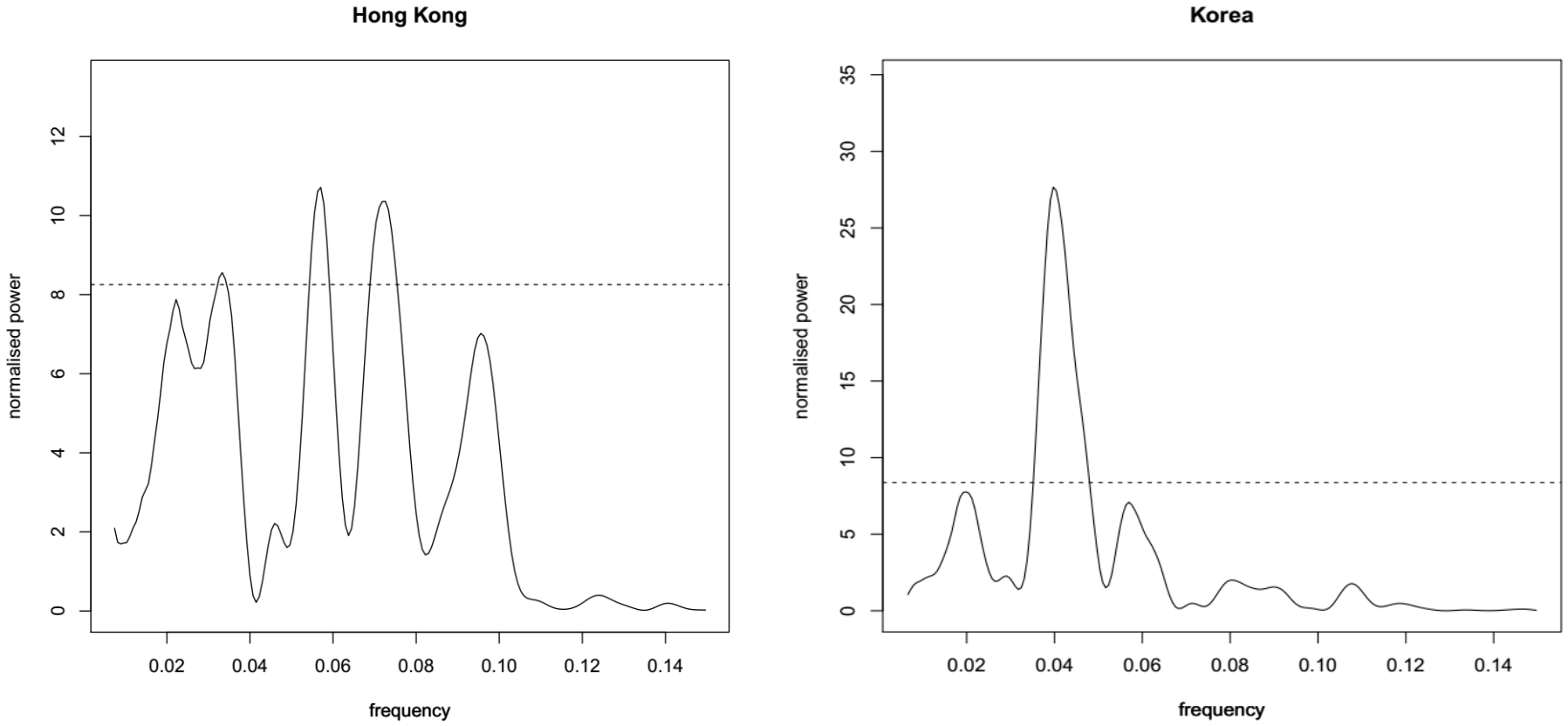
Figure 14. Lamb-Scargle Normalized Periodograms: Housing Cycles (UK and USA)



Note: The horizontal dashed line is the 1 percent significance level cut-off.

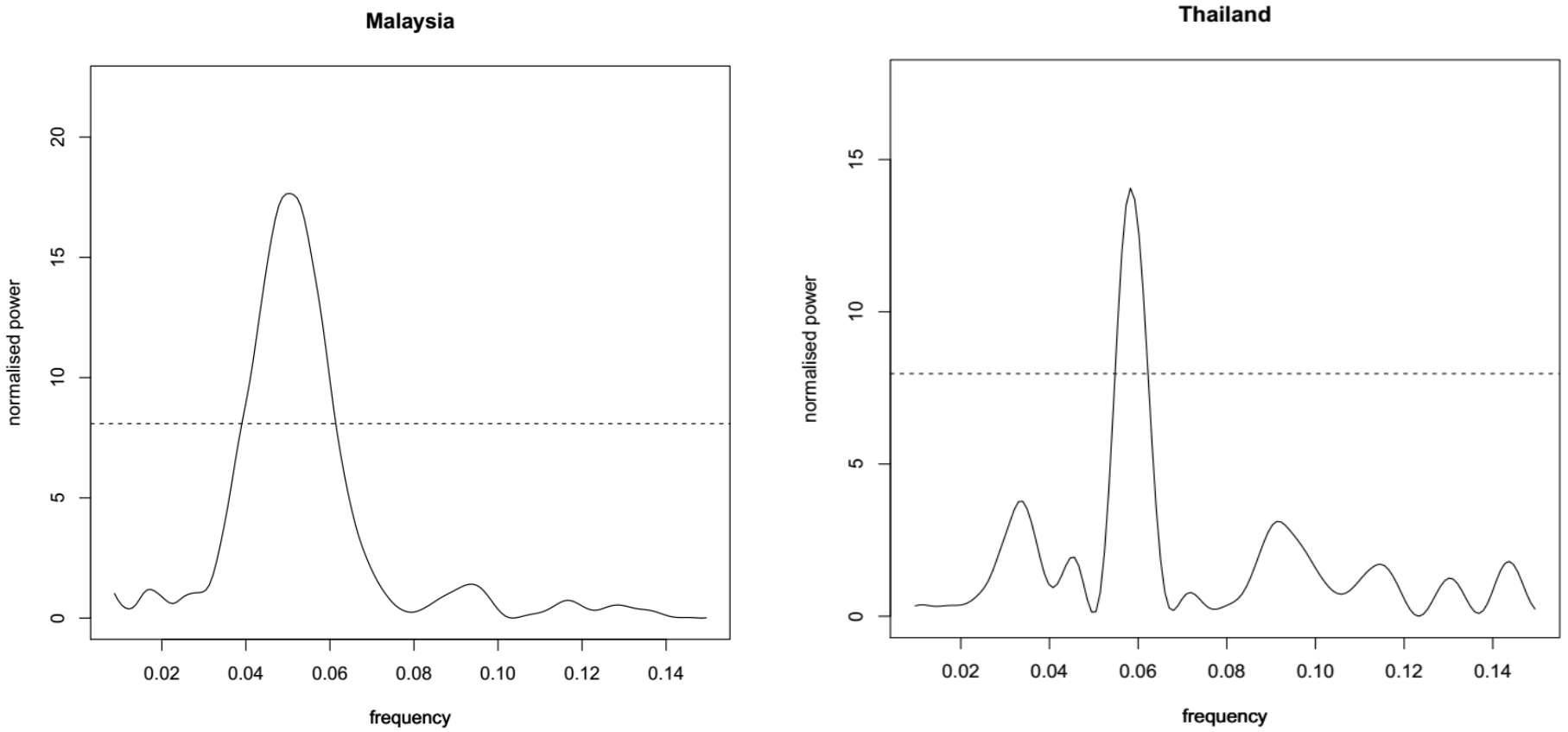
Source: Author's calculations.

Figure 15. Lamb-Scargle Normalized Periodograms: Housing Cycles (Hong Kong and Korea)



Note: The horizontal dashed line is the 1 percent significance level cut-off.
Source: Author's calculations.

Figure 16. Lamb-Scargle Normalized Periodograms: Housing Cycles (Malaysia and Thailand)



Note: The horizontal dashed line is the 1 percent significance level cut-off.
Source: Author's calculations.