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Understanding the changing equilibrium real interest rates in Asia-Pacific[1]

Feng Zhu[2]

Abstract

This paper studies the evolution of the equilibrium real interest rate (ie natural or neutral interest rate) in Asia-Pacific. I take an empirical approach to estimate the rate, simple estimates suggest that except for China, and Thailand since 2005, the natural interest rate may have declined substantially in Asian-Pacific economies since the early or mid-1990s, by over 4 percentage points on average. In many economies the rate has turned negative. The tendency has become more accentuated in the 2000s, especially since the onset of the global financial crisis. Yet simple natural interest rate estimates are unreliable, which vary significantly over time and across the economies.

I use frequency-domain techniques to examine the relationship between the long-run component of real interest rate and those of population characteristics, globalisation, and a range of macroeconomic and financial variables (eg credit and asset prices). I estimate spectral and cospectral densities, coherency and the frequency-specific coefficients of correlation and regression proposed by Zhu (2005). the association seems to be broad and strong between the natural interest rate and the low-frequency trend components of demographic and global factors in Asia-Pacific, but weak between the natural interest rate and trends in asset prices, credit-to GDP ratio and trend growth in many economies in the region. In most cases, the natural interest rate seems to be correlated with broad measures of long-term financial sector development, and trends in saving rate and investment ratio.

Keywords: asset price, credit, demography, equilibrium real interest rates, frequency-domain methods, globalisation, natural interest rates, population ageing, trend growth.

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I. Introduction

Lower growth rates and slow global recovery, especially following the recent global financial crisis and the Great Recession, has raised concerns on whether the global economy has arrived at a "new normal" with lower trend growth and higher unemployment. The slower-than-expected trend growth has been accompanied by an extended period of very low or negative real interest rates, prompting questions on whether we also live now in a world of "new neutral" with lower equilibrium real interest rates.

IMF (2014) finds that "real interest rates worldwide have declined substantially since the 1980s". King and Low (2014) estimate a "world real interest rate" and find that the weighted rate has declined from a peak of 4.93% in the first quarter of 1992 to –0.48% in the second quarter of 2013. Bernanke (2015) observes the exceptionally low global interest rates, both short- and long-term, are not a "short-term aberration" but a long-term trend.

The downward trend in real interest rates has been accompanied by an apparent decline in the estimated equilibrium real interest rates, which have again been at the centre stage in recent policy debates. Barsky, Justiniano and Melosi (2014) find the natural rate negative in the last three recessions and "has remained persistently depressed since 2008". Williams (2015) identifies a "moderate secular decline (in the US natural rate) over the two decades preceding the Great Recession", and a "more substantial decline during the Great Recession". Yellen (2015) points out that some current external estimates of a close-to-zero equilibrium real federal funds rate fall well below the FOMC's assessment of longer-run levels. The recently updated Laubach-Williams (2003) estimate suggests a natural rate of –0.16% for the fourth quarter of 2014.

There are several competing theories behind the decline in equilibrium real interest rates. First, globalisation, especially trade and financial integration have helped forge a global market where domestic factors have begun to play a less prominent role. Financial integration implies that a larger share of global savings is channelled into cross-border financing of investment. In this vein, Bernanke (2005) proposes the "global savings glut" hypothesis, whereby the real interest rate falls to equilibrate the market for global saving as desired saving outstrips desired investment, and saving originating in China and other emerging economies holds down long-term interest rates. Caballero (2006) suggests the existence of a "safe asset shortage" due to rising global demand, as in emerging economies with rapid growth and high savings, there is limited availability of local safe assets in their undeveloped capital markets. Nevertheless, it is argued that these alone could not explain Greenspan's (2005) "conundrum" of anomalously low long-term interest rates. Although China's current account surplus has shrunk from over 10% in 2007 to 1.6% in 2013 and 2.1% in 2014, global interest rates have further declined (see Graph B.1.2, left-hand panel).

Second, many economists link the apparent decline in equilibrium real interest rates to a "new normal" world of lower potential output and trend growth, manifested in sluggish growth persisting in the major economies following the financial crisis. This has often been attributed to, among other factors, a secular deficiency in aggregate demand, significant financial frictions, unfavourable demographic trends, ebbing innovations, debt overhang, and insufficient structural policies.[3]

One notable thesis, that of "secular stagnation", was first proposed by Alvin Hansen (1934, 1939) and recently resurrected by Summers (2013, 2014a, 2014b) and Krugman (2013, 2014). The idea is that a low and declining rate of population growth and a slower pace of technological advance result in lower returns, less investment and consumer spending, creating a situation of persistently inadequate demand.[4] This leads to a declining natural rate of interest. Hansen (1939) considers that the *essence* of secular stagnation is the "sick recoveries which die in their infancy and depressions which feed on themselves and leave a hard and seemingly immovable core of unemployment," a scenario of slow jobless recoveries that the world has grown accustomed to in more recent times.

Related to this new-normal slow growth scenario is the "new neutral" thesis focussing on the exceedingly low real policy rates in many advanced and emerging economies alike. McCulley (2003) considers the US natural rate much lower than commonly assumed. In Clarida's (2014) view, central banks now operate in a world where average policy rates are set well below their pre-crisis levels, a direct consequence of the "global leverage overhang and moderate rates of potential trend growth". Clarida (2015) suggests that global factors have played a key role, with the lower US neutral policy rate driven by a slowdown in "global potential growth", and "a persistent excess of global saving relative to desired investment opportunities".

Other economists have cast doubts on the relevance of the hypothesis of secular stagnation and its inevitability. Eichengreen (2014) opines that the global economy is not predestined to suffer from secular stagnation, and "if the US experiences secular stagnation, the condition will be self-inflicted".[5] Eichengreen (2015) points out that based on the life cycle theory, slower population growth and greater life expectancy actually imply lower savings rates. Bernanke (2015a) criticises the proponents' lack of consideration of the international dimension and global factors affecting domestic spending, and he questions whether an economy's equilibrium real interest rate can stay negative for an extended period. Gordon (2014a, b) attributes the diminished long-run growth potential to a return of US technological progress to its low historical norm, besides the structural headwinds of stagnant population and average US education level, rising inequality, productivity slowdown and elevated public debt. Hamilton, Harris, Hatzius and West (2015) argue that the recent slow growth is likely due more to temporary "headwinds" which may be dissipating, as the balance sheet repair continues with the help of an easy monetary policy.

3 Lo and Rogoff (2014) survey alternative explanations for the sluggish economic growth persisting in many advanced economies after the onset of the financial crisis, and find it difficult to quantify and discern the effects of different long-term factors on economic growth until the post-financial-crisis debt overhang significantly abates.

4 According to Keynes (1937), "in an era of a declining population, … demand tends to be below what was expected and a state of over-supply is less easily corrected. Thus a pessimistic atmosphere may ensue".

5 According to Eichengreen (2014), a US secular stagnation would reflect the country's failure "to address its infrastructure, education and training needs", "to take steps to repair the damage caused by the Great Recession and support aggregate demand in an effort to bring the long-term unemployed back into the labour market." In his view, "these are concrete policy problems with concrete policy solutions".

There have been so far very few attempts to estimate and assess the equilibrium real interest rates for the emerging economies, even less for the emerging Asia.[6] This paper attempts to fill in the lacuna by providing some simple estimates, and to shed some light on the evolution of the equilibrium real interest rates in a number of Asian-Pacific economies. In particular, I examine the roles of demographic trends, globalisation, financial intermediation and trend growth in the evolution of the natural interest rates in the region to determine whether these factors may account for the changes over time and differences across countries in the natural rate estimates.

Several results emerge. First, simple estimates suggest that except for China, and also Thailand since 2005, the natural interest rate has declined substantially in Asian-Pacific economies since the early or mid-1990s, by over 4 percentage points on average. In many economies the rate has turned negative. The tendency has become more accentuated in the 2000s, especially since the onset of the global financial crisis and the Great Recession. Second, the natural interest rate estimates vary significantly over time and across the economies. Third, the association seems to be broad and strong between the natural interest rate and the low-frequency trend components of demographic and global factors in Asia-Pacific, but it appears to be weak between the natural interest rate and trends in asset prices, credit-to GDP ratio and trend growth in many economies in the region. In most cases, the natural interest rate does seem to be correlated with broadly measured long-term financial sector development, and trends in saving rate and investment ratio.

The rest of the paper is structured as follows. In the next section, I give a detailed account of data and the empirical methodology, namely the estimation of frequency-domain indicators. Section III presents results on the equilibrium real interest rate estimates in Asia-Pacific, and on the relationship between the long-run component of real interest rate and those of population characteristics, globalisation, and macroeconomic and financial variables (eg credit and asset prices), based on spectral time series analyses. Section IV concludes.

II. Methodology and data

This section illustrates two empirical approaches I use to estimate the time-varying natural interest rates in Asia-Pacific, and to assess their relationship with trend growth rates, demographic trends, financial developments and an index of globalisation.

The equilibrium real interest rate is unknown and has to be estimated. There are four broad approaches to its estimation. In the first, purely statistical approach, the equilibrium real interest rate measures are model-independent and rely on time-series techniques trend-cycle decomposition. Hamilton, Harris, Hatzius and West's (2015) follow this approach. A second financial-market based approach extracts information about the equilibrium real interest rate from the yield curve (see, eg Bomfim 2001). A third, hybrid method is to align a carefully chosen econometric method with economic theory to identify and estimate the natural interest rate as an unobserved component in time-series models. Laubach and Williams (2003) evaluate the natural rate using the Kalman filter. Specifically, they analyse US inflation and

[6] There are exceptions, see, for example, Goyal (2008) and Goyal and Arora (2013).

output dynamics in a restricted VAR model, jointly estimating the time-varying natural interest rate, potential output, and trend growth rate.

A fourth approach relies on structural models to better identify an economy's unobservable natural interest rate, in which the structural shocks likely to drive the evolution of the natural rate are well specified. Bomfim (1997) uses the MIT-Penn-SSRC (MPS) Keynesian model of the US economy to obtain an equilibrium federal funds rate series. Edge, Kiley and Laforte (2008) rely on the evolution of natural rates of output and interest estimated from a DSGE model for the US economy to explain macroeconomic fluctuations. The structural general equilibrium approach has the advantage of allowing for the accounting of the sources of fluctuations in the equilibrium real interest rate. One significant drawback, more so in the aftermath of the global financial crisis, is that the DSGE models have yet to better account for nonlinearities and provide a convincing and realistic description of the functioning of financial intermediation in the economy. I take the first, statistical approach and estimate the natural interest rate for a number of Asian-Pacific economies by identifying a time-varying trend in the short-term policy rates, isolating the long-run component in the time series. The paper acknowledges the time-varying nature of the natural interest rate and treats it as such in the estimation.

I first apply the well-known time-domain Hodrick-Prescott (1980, 1997) filter to these series to obtain the trend components for these variables and examine their correlations; I then use various different tools of spectral analysis of time series in the frequency domain to evaluate the relationship between natural interest rate estimates and the above-mentioned potential drivers.

II.1. Data and variables[7]

The empirical analysis is based on annual and quarterly data for 13 Asian-Pacific economies: Australia, China, Hong Kong SAR, India, Indonesia, Japan, Korea, Malaysia, New Zealand, the Philippines, Singapore, Thailand and the United States, spanning the period 1950Q1-2014Q4. To get the data as early in time as possible, the empirical analysis focuses on annual data, with the downside of having less data points available.

The set of data series comprises macroeconomic real and price variables (real GDP, real private consumption, employment, unemployment rate, consumer price index or CPI, GDP deflator, Consensus Economics © CPI forecasts and real effective exchange rate or REER), demographic variables (growth in total and working age population, shares of those aged between 39 and 64 years and of those aged above 64 years in total population, total and old age dependency ratios, and life expectancy), financial variables (real equity and housing prices, total bank lending, total credit to the private sector, financial development index of Sahay et al (2015) which measures the depth, access and efficiency of financial institutions and financial markets), and external or global variables (KOF globalisation indices of Dreher (2006) and Dreher, Gaston and Martens (2008); King-Low (2014) world real interest rate, global official liquidity, G7 and G20 aggregate policy rate).

The key variable is the real interest rate, which is obtained by deflating a nominal interest rate by a suitable measure of inflation or its expectations. The choice of the

[7] Annex C provides details on the definition, construction and sources of data used in this paper.

type and maturity of the nominal interest rate is relatively straightforward: central banks are most interested in a natural rate benchmark towards which the policymakers can adjust the policy rates. Therefore I focus on short-term nominal interest rates which are either policy rates or their closest market counterparts. For most economies, this means an interbank overnight rate. In China's case, I use an average of interbank overnight, 7-day repo and 3-month deposit rates. For Hong Kong SAR and New Zealand, the 1-month HIBOR rate and 30-day Bank Bill rate are used, respectively. To obtain longer historical series, I supplement the series with less appealing alternatives, such as discount rates.

To compute *ex ante* real interest rate, it is important to have an appropriate measure of inflation expectations. One measure is the difference between the interest rates on nominal US Treasuries and on US Treasury's inflation-indexed securities, yet inflation-indexed bonds are uncommon in the region. Another measure is private-sector forecasts, which are scarce for most economies in our sample. While Consensus Economics © forecasts are available, they only start in the last quarter of 1989 or later for the economies in the region. A more practical alternative is to use the forecasts from a simple autoregressive model of actual inflation to proxy the expected inflation, as in Blanchard and Summers (1984) and Hamilton, Harris, Hatzius and West (2015). I take a similar approach. I first use the Hodrick-Prescott filter and other spectral methods to decompose the inflation rate into the trend and cyclical components, I then use the trend component as the expected inflation to obtain the *ex ante* real interest rate. The approach has the advantage that trend inflation can be seen as a proxy for the long-run equilibrium inflation rate, a target for central banks pursuing price stability.

II.2. Empirical methods

Spectral analysis of time series is appealing as covariance stationary processes can be uniquely decomposed into mutually uncorrelated components, each associated with a specific frequency (band). Spectral or frequency-domain methods have a long tradition in the economic analysis of time series. Granger (1966) provides evidence that macroeconomic time series tend to be persistent and have a "typical spectral shape" with much of the power of the time series concentrating in the very low frequencies, ie, long run. Granger and Rees (1968) apply spectral methods to analyse the term structure of interest rates. Hannan (1963a, 1963b) pioneered spectral regression analysis, which was introduced to economics by Engle (1974, 1978, 1980). Phillips (1991) applies it to integrated time series to obtain asymptotically median unbiased estimates of cointegrating coefficients. Spectral regression allows us to focus on specific frequency bands, and permit a nonparametric treatment of regression errors.

Instead of working directly in the frequency domain, economists often rely on linear filters which decompose data into trend and cycle components converted back into the time domain. These include the Lucas (1980) exponential smoothing filter, the Hodrick-Prescott (1980, 1997) and the Baxter-King (1999) band-pass filter. Due to finite data length, these filters are only approximations to the ideal filters, and filter leakage, compression and exacerbation are inevitable. Moreover, simple correlation and regression analyses average relationships within each frequency band, this could mask possibly large variations within any pre-specified band.

We use frequency-domain methods to study how the estimated long-run component of real interest rates may behave in Asian-Pacific economies, and how they relate to potential natural rate drivers such as demographics, globalisation, financial developments and growth at different frequencies in different economies. Engle (1974) points out that "there is little discussion of whether the same model applies to all frequencies. It may be too much to ask of a model that it explain both slow and rapid shifts in the variables, or both seasonal and non-seasonal behaviour. It is at least reasonable to test the hypothesis that the same model applies at various frequencies." Zhu (2005) uncovers significant difference in the inflation-output trade-offs across the spectrum, from the short to the long run. Zhu (2012) finds that the credit and output relationship varies greatly from the short to the long run, being strong in the very low frequencies but rather weak in business-cycle and higher frequencies.

Significant cross-frequency differences in how the natural rates relate to the potential drivers may have important implications for policy-making. In this paper, I take a more direct approach and examine such linkages in the entire spectrum. I first estimate conventional spectral indicators including spectral and cross-spectral densities, coherency, transfer function, gain and phase-to-frequency ratio. I then assess the natural interest rate linkages estimating frequency-specific coefficients of correlation (FSCC) and regression (FSCR) proposed by Zhu (2005).[8] To obtain the coefficient estimates, I apply a data extraction procedure based on Fourier and inverse Fourier transforms. I convert the data back into the time domain, where conventional statistics can be calculated.

The FSCC is superior to traditional indicators, such as coherence and cospectrum, by providing a real-valued, normalised and signed measure of the strength of multiple correlation. Unlike coherence, the FSCC is signed. Compared to cospectrum, it is standardised taking values in the [-1,1] range, providing a clear indication of the strength of correlation independent of data scale. The FSCR has the advantage of being easily applied to any specific frequency, and the statistical inference with both FSCC and FSCR estimates is straightforward.

III. What factors may influence equilibrium real interest rates?

This section presents simple estimates of equilibrium real interest rates for the Asian-Pacific economies in the sample using the Hodrick-Prescott (1980, 1997) filter. Then I discuss results, based on frequency-domain analyses, on the likely factors behind the secular decline in equilibrium real interest rates, namely, changing demographic trends, rising globalisation, financial sector developments and slowing trend growth.

III.1. Simples estimates of equilibrium real interest rates

A visual inspection of the equilibrium real interest rates, estimated based on the Hodrick-Prescott (1981) filtering technique, suggests both commonality and diversity

[8] Annex A provides an exposition of frequency-domain analysis used in this paper. For further details, see Zhu (2005, 2012).

(Graphs B.1.1 and B.1.2 in Annex B.1). First, the estimated natural interest rates have fallen significantly since the early and mid-1990s. In most cases, the decline has been sizeable, above four percentage points. In some economies, the decline started earlier, eg Singapore and Thailand in the early 1980s and the United States in late 1980s. In addition, the fall has apparently accentuated in the aftermath of the 2007-2009 global financial crisis. In contrast, the estimated equilibrium real interest rate has been on an upward trend in China since 1993, when data became available. In Thailand's case, the natural rate apparently started to rebound from a low of 0.61% in 2005 to reach 1.60% in 2014.

Second, natural rate estimates in the Asian-Pacific economies show different patterns of evolution, and the rates can differ substantially from each other at any single point of time. In particular, Japan's natural interest rate has evolved in a notably different way. It rose significantly from the low, negative levels in the first years of the 1970s to a peak in the early 1980s, but has experienced a long, secular decline since then.

Notably, while negative equilibrium real interest rates were less common in the past, they have become a more common feature in many regional economies in the aftermath of the global financial crisis. Except in Australia, China, Malaysia and Thailand, the natural rates are now at historically low levels. While the natural rates in New Zealand, Singapore and Thailand have stayed positive throughout the sample period, all other economies have experienced negative natural interest rates in the past.

Our analysis suggests that the estimates of the equilibrium interest rates in Asia Pacific in general vary substantially over time and across economies. The perceived degree of imprecision and uncertainty is sizeable. For instance, the HP-filtered estimates of the natural interest rate in all economies vary significantly depending on the value of the smoothing parameter λ (Graph B.1.1). Indeed, for annual data, while Hodrick and Prescott (1981) propose a value of 100 for the smoothing parameter λ, Ravn and Ulhig (2002) suggest that $\lambda = 6.25$ is more appropriate. I experimented different values for the smoothing parameter, namely, $\lambda = \{6.25, 100, 400, 800, 1600, 6400, 25600, 129600\}$, the resulting equilibrium real interest rate estimates turn out to be very different, with the difference going well above two percentage points. In the case of Thailand, for example, the difference in the 2014 estimates with $\lambda = 6.25$ and $\lambda = 6400$ is almost four percentage points; and more seriously, when one estimate points to a strong recent upward trend, the other estimate suggests a secular decline in Thailand's natural interest rate. Indeed this is a common issue with many filters where the choice of the degree of smoothing belongs to the researcher.

III.2. What may explain changes in equilibrium real interest rates?

The frequency-domain analysis focuses on the likely factors behind the secular decline in equilibrium real interest rates, namely, changing demographic trends, rising globalisation, financial sector developments and slowing trend growth. The analysis is based on the estimates of a set of traditional frequency-domain indicators: spectral density, or power spectrum, estimated using Welch's method, which records the contribution of the component(s) belonging to a specific frequency or frequency band to the total variance of a stochastic process; cospectral density, also known as cross power spectral density or cospectrum, estimated using Welch's averaged modified periodogram method, which represents the covariance between the in-phase components of two stochastic processes at a specific frequency or frequency band; squared coherence, or coherency, estimated using Welch's averaged periodogram method, which, like the coefficient of determination R^2, measures the strength of linear association between two stochastic processes at a specific frequency or frequency band; gain or transfer is analogous to a standardised regression coefficient at a given frequency; and the phase measures the timing or average phase lead of one series over another at different frequencies, which incorporates all relevant information about leads and lags.

The estimates of traditional spectral indicators are presented in Annex B.2, along with the estimates of Zhu's (2005) frequency-specific coefficients of correlation and regression. In all graphs, the shaded grey area indicates the business-cycle frequency range of between six quarters (marked by "H") and 32 quarters (marked by "L"). The area between 0 and L is the low frequency range which contains the trend component, which is of primary interests to the analysis when low-frequency, long-run relationships are examined in comparison with their business-cycle- and high-frequency counterparts.

Spectral density estimates indicate that almost all demographic, global, macroeconomic and financial variables under study have the "typical spectral shape" of Granger (1966). The spectral density estimates indicate that most of these variables are very persistent in Asian-Pacific economies, with much of the power of their spectral density concentrating in the very low frequencies, ie, the long run of beyond 32 quarters. This suggests that understanding trends are crucial to the analysis. However, one major exception is the asset prices, of which the power is more evenly distributed across the frequency range, or more heavily concentrated in higher frequencies. This is the case for real housing price inflation in Australia, and for real equity price inflation in China, India, Indonesia and Japan. In a number of cases, eg real housing price inflation in Korea and real equity price inflation in Malaysia, asset prices actually have more power in the business-cycle (six to 32 quarters) or higher frequencies. This implies that cycles in equity or housing prices may carry more power than trends. It is no wonder that trend equity or housing price inflation turn out to have a relatively weak association with the equilibrium real interest rate in the analysis.

Similarly, estimates of cross-spectral density, coherency, gain and frequency-specific coefficients of correlation and regression suggest that association between real interest rates and many of the demographic, global, macroeconomic and financial variables I examine is often strongest in the very low frequencies (ie long run) in Asia-Pacific, but such association is not always strong in absolute terms. In particular, real interest rates seem to be more associated with many financial variables in higher frequencies, implying that real GDP growth and asset market or credit market developments are not as crucial to the understanding of evolution of the equilibrium real interest rate as many of us have assumed, and other factors, especially globalisation and demographic trends may matter more.

The following sub-sections give a detailed account of the correlations of these factors with the estimates of equilibrium real interest rates in the Asian-Pacific economies.

III.2.1. Demographic trends

I use several variables to describe population dynamics. First, the shares of those aged between 39 and 64 years and of those aged above 64 years in total population, which correspond to the population groups that save most for retirement or dissave in retirement, respectively. The patterns of their saving and consumption have a direct impact on an economy's saving-investment dynamics, and hence the equilibrium real interest rate. Second, the total and old age dependency ratios indicate an economy's ability to sustain non-working age population. Third, rising life expectancy may influence one's decision on work, consumption and saving. As life expectancy rises, retirement gets delayed and periods of retirement lengthen. Savings can rise in the aggregate as workers save more or fall due to the dissaving of retirees. Fourth, growth in the working age population has slowed or turned negative in many advanced economies, and the secular trend has started to affect some emerging economies. This reduces an economy's long-term growth potential and its natural interest rate.

Spectral analysis provides further interesting details on the relationship between real interest rate and population dynamics in Asia-Pacific (Graphs in Annex B.2). First, while spectral density estimates indicate that trend is the most important component in the share of people aged 39-64 in total population and old age dependency ratio, there are clear four distinct cycles in higher frequencies of less than six quarters, for all economies in the sample. The demographic trend and cycles may then be translated into their relationships with the real interest rate, as indicated by the cospectral density estimates.

Second, strong association between demographic trends and the equilibrium real interest rate is seen in most spectral indicators in many economies. This is most apparent in the cospectral density and coherency estimates. However, correlation patterns can differ, and in some cases, the sign of correlation, raising important issues regarding economic reasoning behand the relationship between demographic trends and the natural interest rate. Important exceptions may be China and Korea, where correlation coefficient estimates at around 32 quarters point to statistically insignificant correlations between the equilibrium real interest rate and the population share of those aged 39-64 and the old aged dependency ratio; but they indicate a statistically significant, strong and negative correlation of −0.75 with working age population growth in China, but large positive correlation in Korea. Old age dependency ratio correlates negatively with the natural interest rate in Japan but positively in the United States, while working age population growth has a strong positive correlation with the natural interest rate in both countries. Hence population ageing and shrinking working age population lower the equilibrium real interest rate in Japan, but the more complex US population dynamics, much due to immigration, may imply a different rapport.

III.2.2. Globalisation

Another potential driver of the decline in equilibrium real interest rates is globalisation. I use the KOF overall globalisation index developed by Dreher (2006) and Dreher, Gaston and Martens (2008), which summarises the economic, social and political dimensions; and the KOF index of economic globalisation, and sub-indices of the actual trade and capital flows, and of trade and capital account restrictions. I also use an indicator of global official liquidity, which is the sum of the total assets of the central banks in the advanced economies and the foreign reserves of the major emerging economies. Other global liquidity indicators such as G7 and G20 aggregate (weighted average) policy rate are considered, and it is well-known that domestic interest rates have over time become more strongly correlated with the interest rates in the advanced economies.

Spectral density estimates indicate large persistence in KOF globalisation indices (Graphs in Annex B.2). Estimates of cospectral density, squared coherence and frequency-specific correlation coefficient suggest that globalisation, overall or economic, is more strongly associated with the equilibrium real interest rate than many other variables in most economies in the region. There is again sizeable heterogeneity: while the evidence is strong in Australia, Malaysia, Japan and the United States, the case is weaker among some emerging Asian economies. In particular, estimates of frequency-specific correlation coefficient indicate that the correlation of KOF overall and economic globalisation indices with equilibrium real interest rate is not significantly different from zero in China, Indonesia, the Philippines and Thailand, in some cases contradicting evidence provided by other spectral indicators such as cospectral density and coherency. One possibility is that the emerging economies, albeit more globalised than before, are still some distance away from the level of globalisation achieved by the advanced economies, and their interest rates may be more prone to various domestic factors or controls, leading to a weaker association.

III.2.3. Financial sector developments

A third driver may be changes in the functioning of financial intermediation due to sizeable financial frictions in the wake of the crisis. There is evidence that recessions and financial crises may cause permanent damages to an economy and dislocate their equilibrium real interest rates.[9] I use a number of financial variables, namely, the financial development index of Sahay et al (2015), real credit growth and the growth rates in real housing and equity prices to examine how they correlate with equilibrium real interest rates in the long run. The financial development index developed by Sahay et al (2015) measures the depth, access and efficiency of financial institutions and financial markets.

Estimates of spectral indicators provide a number of interesting findings (Graphs in annex B.2). First, growth in real equity or housing prices is generally uncorrelated with the estimated equilibrium real interest rate, and much of the correlation between asset prices and the real interest rate occur in high or very high frequencies, well below four quarters. One exception may be Japan, where the estimated frequency-specific coefficients of correlation point to a positive correlation of close to 0.6 in the low frequency range, which was contradicted by a very low reading in the squared coherence estimate. Second, compared to real equity and housing prices, the credit-to-GDP ratio tends to have a stronger association with the equilibrium real interest rate estimate in very low frequencies, eg in Australia, India, Indonesia, Malaysia and the Philippines, but the association is generally weak. Long-term credit market developments may therefore have a mild relationship with the evolution of equilibrium real interest rate.

Consistent with earlier observations, broad financial sector development as measured by the financial development index developed by Sahay et al (2015), in the

9 Cerra and Saxena (2008) and Reinhart and Rogoff (2009) find highly persistent output effects from deep recessions around the world. Cecchetti and Zhu (2009) suggest that most often, output level falls permanently and growth rate rises after financial crises. Ball (2014) examine 23 OECD countries and find that the potential output loss from the Great Recession varies greatly across countries, but is large in most cases of. The long-term effects of recessions seem to be consistent with the hysteresis hypothesis of Blanchard and Summers (1986). Reifschneider, Wascher and Wilcox (2013) argue that a recession reduces an economy's potential output.

very low frequencies (long run), is indeed more strongly associated with the equilibrium real interest rate estimate in most economies in the region. Again there are exceptions, eg India, Indonesia and Thailand. And in several cases, while cospectral density and coherency estimates indicate the existence of association, this is contradicted by evidence provided in the estimates of frequency-specific correlation coefficients.

To sum up, long-term developments in the financial sector, especially when defined broadly, may be associated with the evolution of equilibrium real interest rate, but credit market per se, and asset prices in particular, are estimated to have rather weak association with the natural interest rate. Improvement in a country's financial infrastructure could play a role in the evolution of the equilibrium real interest rate.

III.2.4. Trend growth

One issue which has recently attracted much attention is how closely trend growth is associated with the equilibrium real interest rate. Estimation of the natural rates, eg, Laubach and Williams (2003), often embodies a close relationship between the two, with the estimation becoming predicated on this relationship. Yet Bosworth (2014) identifies only a weak relationship between real interest rates and economic growth.

Evidence from the spectral analysis is mixed, and several messages emerge (Graphs in Annex B.2). First, in a number of economies, the estimated correlation between the equilibrium real interest rate and trend growth is not statistically significant: this is the case in Australia, China, Indonesia, and the Philippines. Indeed a stronger relationship between real interest rate and real GDP growth tends to happen in the high-frequency range of less than four quarters, eg in Australia, India, Korea, Malaysia, the Philippines and the United States, as indicated by coherency estimates. In some other economies like Japan, Korea and Thailand and the United States, the estimated correlation between the equilibrium real interest rate and trend growth is strong. The overall evidence is rather mixed, with significant cross-economy heterogeneity. Second, many economies observe a statistically significant correlation of their saving rate and investment ratio with the equilibrium real interest rate, notable exception are China and India, and in terms of investment ration in Indonesia and saving rate in Thailand. The correlation is estimated to be stronger in Japan, Korea and Malaysia.

The results suggest that the relationships between the equilibrium real interest rate and trend growth and other macroeconomic variables are more complex than what we have once assumed, and large disparity in the estimated relationships across the Asian-Pacific economies suggest that more work needs to be done to update economic theory so as to improve our understanding of the equilibrium real interest rate and provide a sound foundation for monetary policymaking.

IV. Conclusion

This paper estimates the equilibrium real interest rate for a number of Asian-Pacific economies, and studies the relationship between the long-run component of real interest rate and those of demographics, the process of globalisation, indicators of financial sector developments, and macroeconomic variables such as trend growth. I take a purely statistical approach and focus on the empirics, applying the time-domain Hodrick-Prescott (1981, 1997) filter and frequency-domain tools, including both traditional spectral indicators and the frequency-specific correlation and regression techniques proposed by Zhu (2005).

The spectral analysis uncovers a number of interesting empirical facts for the Asian-Pacific economies. First, the estimated natural interest rates have started to trend down in some economies in the region as early as the 1980s, and the tendency has become more accentuated in the 2000s, especially since the onset of the global financial crisis and the Great Recession. Second, the natural interest rate estimates vary significantly over time and across the economies, ranging from −1.32%, −0.47% and −0.37% to 4.20%, 5.27% and 5.96% in Indonesia, Japan and Korea, respectively. Third, the association seems to be broad and strong between the natural interest rate and the low-frequency trend components of demographic and global factors in Asia-Pacific, but it appears to be weak between the natural interest rate and trends in asset prices, credit-to GDP ratio and trend growth in many economies in the region. In most cases, the natural interest rate does seem to be correlated with broadly measured long-term financial sector development, and trends in saving rate and investment ratio.

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Annex A: Frequency domain analysis

In this annex, we illustrate the method we use to estimate frequency-wise correlation and regression estimates, which is based on a simple frequency-specific data extraction procedure.

A.1. A frequency-specific data extraction procedure

Consider a time series vector $x = [x_1, x_2, ..., x_T]^T$. For $s = 1,...,T$, define the fundamental frequencies as $\omega_s = 2\pi s/T$. The discrete Fourier transform of x at frequency ω_s is

$$w_s x = T^{-1/2} \sum_{t=1}^{T} x_t e^{(t-1)i\omega_s}$$

where

$$w_s = T^{-1/2} \begin{bmatrix} 1 & e^{i\omega_s} & \cdots & e^{(T-1)i\omega_s} \end{bmatrix}$$

Define

$$W = \begin{bmatrix} w_0 \\ w_1 \\ \vdots \\ w_{T-1} \end{bmatrix}$$

W is a unitary matrix such that $W^* W = WW^* = I$, where $*$ indicates the Hermitian conjugate (ie, transpose of the complex conjugate). Then $\tilde{x} = Wx$ is the vector of discrete Fourier transform of time series x at all fundamental frequencies ω_s, $s = 1,...,T-1$.

Define A_s as a $T \times T$ selection matrix which selects the s -th element or row from any data vector or matrix, respectively. It has 1 as the s,s -th element and zeros elsewhere.[10] The data vector of the discrete Fourier transform of time series x at the s -th frequency ω_s is

$$A_s \tilde{x} = A_s W x$$

So there are T data vectors $A_s \tilde{x}$, extracted from the original time series x, each of length T. All but the s -th elements of the s -th data vector $A_s \tilde{x}$ are zero. We then use inverse Fourier transform to convert the complex data vector $A_s \tilde{x}$ back into the time domain. Write the frequency-ω_s inverse Fourier transform of the time series x as

$$\tilde{x}(\omega_s) = L_s x = W^* A_s W x$$

[10] To select a frequency band $[\omega_s, \omega_t]$, let the s -th to t -th diagonal elements of A be one.

where $L_s = W^* A_s W$ is a linear operator. Using Fourier and inverse Fourier transforms and the selection matrix A_s, from any data vector x, we can extract T time series $x(\omega_s) = [x_1(\omega_s), x_2(\omega_s), \ldots, x_T(\omega_s)]^T$, each corresponding to a specific frequency ω_s, where $s = 1, \ldots, T$. Based on these frequency-specific data, we can then design frequency-wise correlation and regression coefficients in a conventional way.

A.2. Correlation analysis

For bivariate stochastic processes $z_t = [x_t \quad y_t]^T$, which are assumed to be jointly weakly stationary with continuous spectra, we write the corresponding spectral density matrix as[11]

$$f_{zz}(\omega) = \begin{bmatrix} f_{xx}(\omega) & f_{xy}(\omega) \\ f_{yx}(\omega) & f_{yy}(\omega) \end{bmatrix}$$

where the spectral densities $f_{xx}(\omega)$, $f_{yy}(\omega)$ and the cross-spectral density $f_{xy}(\omega)$ determine the relationship between x_t and y_t at frequency ω. In Cartesian form, the cross-spectral density $f_{xy}(\omega)$ can be written as

$$f_{xy}(\omega) = c_{xy}(\omega) - i q_{xy}(\omega)$$

where $c_{xy}(\omega)$ and $q_{xy}(\omega)$ are real-valued functions known as ***cospectrum*** (or ***cospectral density***) and ***quadspectrum*** (or ***quadrature spectral density***), respectively. The cospectrum $c_{xy}(\omega)$ represents the covariance between coefficients of the in-phase components of two time series, while the quadspectrum $q_{xy}(\omega)$ represents the covariance between coefficients of the out-of-phase components. Cospectrum estimation is equivalent to studying the off-diagonal elements of the variance-covariance matrix between two time series, which are uniquely related to cospectra by Fourier and inverse Fourier transforms.

In polar form,

$$f_{xy}(\omega) = |f_{xy}(\omega)| \exp(i \varphi_{xy}(\omega))$$

where

$$\varphi_{xy}(\omega) = -\arctan\left(\frac{q_{xy}(\omega)}{c_{xy}(\omega)}\right)$$

The ***phase*** $\varphi_{xy}(\omega)$ measures the average phase lead of x_t over y_t, and $\varphi_{xy}(\omega)/\omega$ indicates the extent of time lag. The ***gain*** $G_{xy}(\omega)$ is defined as

11 All concepts described in the Annex for bivariate time series can be easily generalised to multivariate stochastic processes, where exogenous variables can also be introduced.

$$G_{xy}(\omega)=\frac{\left|f_{xy}(\omega)\right|}{f_x(\omega)}$$

This is a standardized version of the regression coefficient of y on x at frequency ω. A small $G_{xy}(\omega)$ indicates that x has little effect on y at frequency ω.

Define the ***complex coherence*** $ccoh_{xy}(\omega)$ at frequency ω as

$$ccoh_{xy}(\omega)=\frac{f_{xy}(\omega)}{\left[f_{xx}(\omega)f_{yy}(\omega)\right]^{1/2}}$$

The complex coherence $ccoh_{xy}$ is the frequency domain analogue of the coefficient of correlation, but since f_{xy} and $ccoh_{xy}$ are complex, it is hard to interpret this indicator in terms of the overall strength of linear correlation between x and y. ***Real coherence*** $rcoh_{xy}$, which we define as the real part of $ccoh_{xy}$, is the cospectrum c_{xy} standardized by the square root of the product of f_{xx} and f_{xy}. It is the coefficient of correlation between coefficients of the in-phase components of two time series x and y. However, a true frequency-specific correlation coefficient needs to account for both the real and complex parts of the complex coherence $ccoh_{xy}$.

One alternative is the ***coefficient of coherence*** of x_t over y_t at frequency ω, defined as $cohe_{xy}(\omega)=\left|ccoh_{xy}(\omega)\right|$.[12] But although it delivers a real number, it fails to reveal the sign of linear correlation at frequency ω. The ***coherency*** $ccoh_{xy}(\omega)$ of x_t over y_t at frequency ω is

$$coh_{xy}(\omega)=cohe_{xy}(\omega)^2=\left|ccoh_{xy}(\omega)\right|^2$$

Analogous to the coefficient of determination (ie R^2) in the time domain, the coherency coh_{xy} is the standardized modulus of cross spectral density. It measures the strength of linear association between two or more variables of interest across frequencies. By Schwarz Inequality, $\forall\omega$, $coh_{xy}(\omega)\in[0,1]$. At frequencies for which $f_{xx}(\omega)f_{yy}(\omega)=0$, we define $coh_{xy}(\omega)=0$, so the two series x_t and y_t are completely unrelated at frequency ω. If $coh_{xy}(\omega)=1$, then one series is an exactly linearly filtered version of the other at frequency ω. In general, coh_{xy} varies with the frequency ω, indicating the changing pattern of linear association across frequencies. Regions of high coherence are of particular interest.

What we need is a frequency-domain analogue of the time-domain coefficient of correlation, corresponding either to a specific frequency ω, or to a frequency band $[\omega_l,\omega_m]$, where $0\le\omega_l\le\omega_m\le 2\pi$. One natural choice would be the complex

12 Extending the conceptual construct of bivariate coherence to multiple time series, we have multiple and partial coherences.

coherence $ccoh_{xy}$. But although $ccoh_{xy}$ is signed and normalized, since in general f_{xy} is complex-valued, so is $ccoh_{xy}$. There is no easy way to graphically illustrate, and to interpret the interplay between the real and complex parts of the complex coherence, even if we are able to represent the indicator in a three-dimensional diagram. Our solution is to take advantage of the proposed simple frequency-domain data recovery procedure, and we define $\rho(\omega)$, the ***frequency-specific coefficient of correlation*** (FSCC) at frequency ω , as follows

$$\rho(\omega) = \frac{Cov(\hat{x}(\omega), \hat{y}(\omega))}{\sqrt{Var(\hat{x}(\omega))}\sqrt{Var(\hat{y}(\omega))}}$$

where $\hat{x}(\omega)$ and $\hat{y}(\omega)$ are frequency-specific time series extracted from data vectors x and y, and $Cov(\bullet)$ and $Var(\bullet)$ stand for covariance and variance, respectively. The confidence interval for $\rho(\omega)$ can be computed in the conventional way.

The frequency-specific coefficient of correlation is normalized to take values in the [-1,1] interval. Unlike cospectral density c_{xy}, the FSCC ρ is free from data scale, hence a true measure of the strength of frequency-ω correlation between x and y. Comparing to coherence coh_{xy}, the FSCC ρ signs the direction of correlation existing in the data. The FSCC estimate is a clear improvement upon cospectrum and coherence estimates, and we use it as the main indicator of strength of bivariate correlation for Phillips relations. When the distribution theories for the cospectral density c_{xy} and the coherence coh_{xy} are complicated, p -values and confidence intervals for the FSCC estimates $\hat{\rho}$'s can be provided in the usual way. In fact, these are often supplied automatically in an econometric or statistical software package.

A.3. Frequency-Specific Spectral Regression

Consider a simple model for two time series $y = [y_1, y_2, \dots, y_T]^T$ and $x = [x_1, x_2, \dots, x_T]^T$

$$y = \beta x + \varepsilon$$

where $\varepsilon \sim iid\left(0, \sigma^2 I\right)$ and x is uncorrelated with ε. The ***periodogram*** of x and the ***cross-periodogram*** between x and y at frequency ω_s are, respectively

$$I_x(\omega_s) = |w_s x|^2$$

$$I_{xy}(\omega_s) = (w_s x)^* (w_s y)$$

where w_s is defined as before. The s -th frequency spectral regression is

$$A_s \tilde{y} = \beta_s A_s \tilde{x} + A_s \tilde{\varepsilon}$$

where $\tilde{q} = Wq$, for any q, and W is defined as before. The s -th frequency spectral regression coefficient is

$$\tilde{\beta}_s = \left(\tilde{x}^* A_s \tilde{x}\right)^{-1} \tilde{x}^* A_s \tilde{\varepsilon} = I_x(\omega_s)^{-1} I_{xy}(\omega_s)$$

Since the unsmoothed periodogram I_x and the cross-periodogram I_{xy} are not consistent estimators of the spectral and cross-spectral densities, and we are interested in frequency-specific regression coefficients that do not involve averaging over a frequency band to obtain consistent estimates of the sums of periodogram and cross-periodogram ordinates, we may instead use smoothed spectral estimates to estimate β_s:

$$\hat{\beta}_s = \hat{f}_x(\omega_s)^{-1} \hat{f}_{xy}(\omega_s)$$

In general, the estimator $\hat{\beta}_s$ will be complex-valued. To obtain a real-valued estimate, one can take the real part of $\hat{\beta}_s$, but typically, both the real and complex parts of $\hat{\beta}_s$ matter. Or we may simply use the gain, ie, the modulus $\left|\hat{\beta}_s\right|$, which has the drawback of not allowing us to discern the sign of spectral regressions. We take advantage of the proposed data extraction procedure and run OLS regressions with frequency-specific data. Since the Fourier transform and inverse Fourier transform are linear operations, conventional asymptotic theory continues to apply, and the confidence interval for $\hat{\beta}_s$ can be computed in the usual way (except at the zero frequency). Write the inverse Fourier transform as

$$L_s y = \beta_s L_s x + L_s \varepsilon$$

Simple OLS spectral regressions lead to the ***frequency-specific coefficient of regression*** (FSCR) $\hat{\beta}_s$ corresponding to frequency ω_s

$$\hat{\beta}_s = \left(x^T L_s^T L_s x\right)^{-1} x^T L_s^T L_s y = \left(\hat{x}_s^T \hat{x}_s\right)^{-1} \hat{x}_s \hat{y}_s$$

The great advantage of the data extraction procedure is that it is linear in nature, therefore all inferential apparatus in the conventional OLS regression theory can still be used as usual.

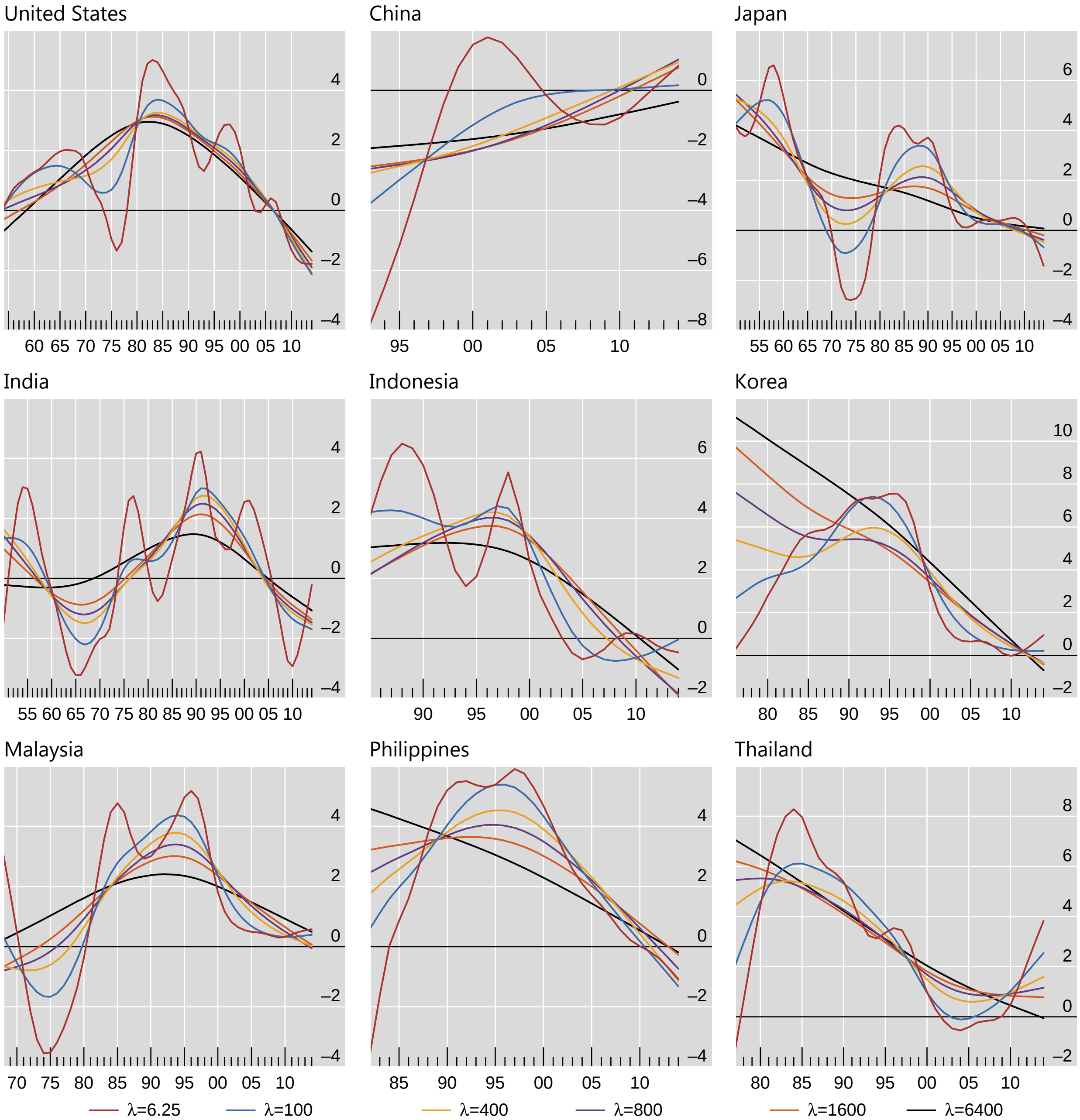
Annex B: Graphs

This annex contains graphs of estimates of the equilibrium real interest rate based on the Hodrick-Prescott (1981) filter.

B.1. Equilibrium real interest rate estimates

Real overnight interest rate

Sensitivity of equilibrium real interest rate estimates,[1] in per cent — Graph B.1.1



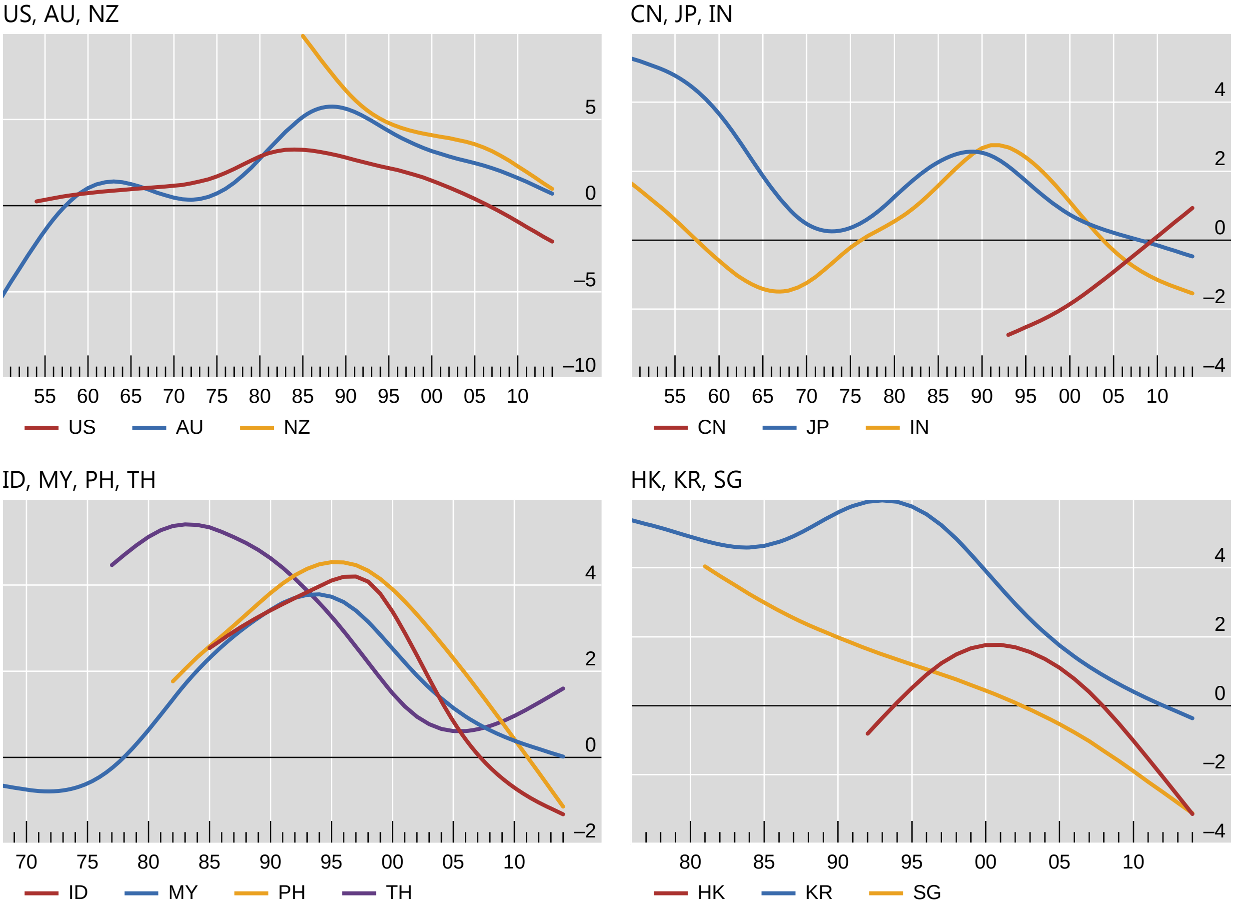
[1] Equilibrium real interest rate estimates are based on the Hodrick-Prescott (1981) filtering technique. The trend component is extracted with the smoothing parameter λ set at 6.25, 100, 400, 800, 1600 and 6400.

Source: author's calculations.

Estimates of equilibrium real interest rate in Asia-Pacific

Trend in real overnight interest rate,[1] in per cent

Graph B.1.2



AU = Australia; CN = China; HK = Hong Kong; ID = Indonesia; IN = India; JP = Japan; KR = Korea; MY = Malaysia; NZ = New Zealand; PH = Philippines; SG = Singapore; TH = Thailand; US = United States.

[1] Equilibrium real interest rate estimates are based on the Hodrick-Prescott (1981) filtering technique. The trend component is extracted with the smoothing parameter λ set at 400.

Source: author's calculations.

B.2. Spectral analysis of equilibrium real interest rate

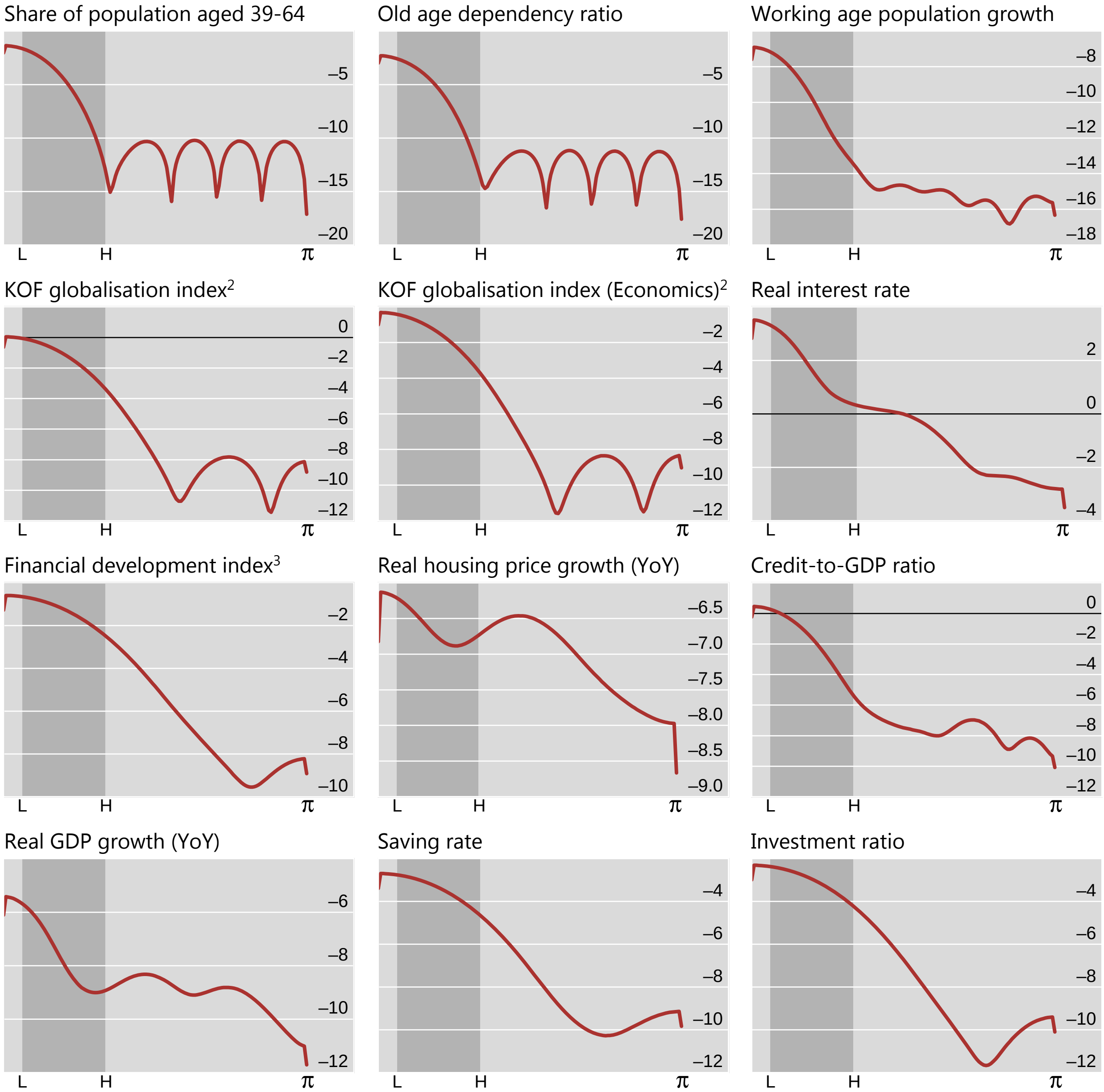
This annex contains estimates of the frequency domain indicators.

B.2.1. Australia

Spectral density estimates: Australia[1]

In logarithm

Graph B.2.1.1



Horizontal axis indicates frequency ranging from 0 to π; vertical axis indicates spectral density. The shaded area indicates the business-cycle frequency, ranging from six quarters (marked by "H") to 32 quarters (marked by "L"). The area between 0 and L corresponds to the low frequency range which contains the trend component.

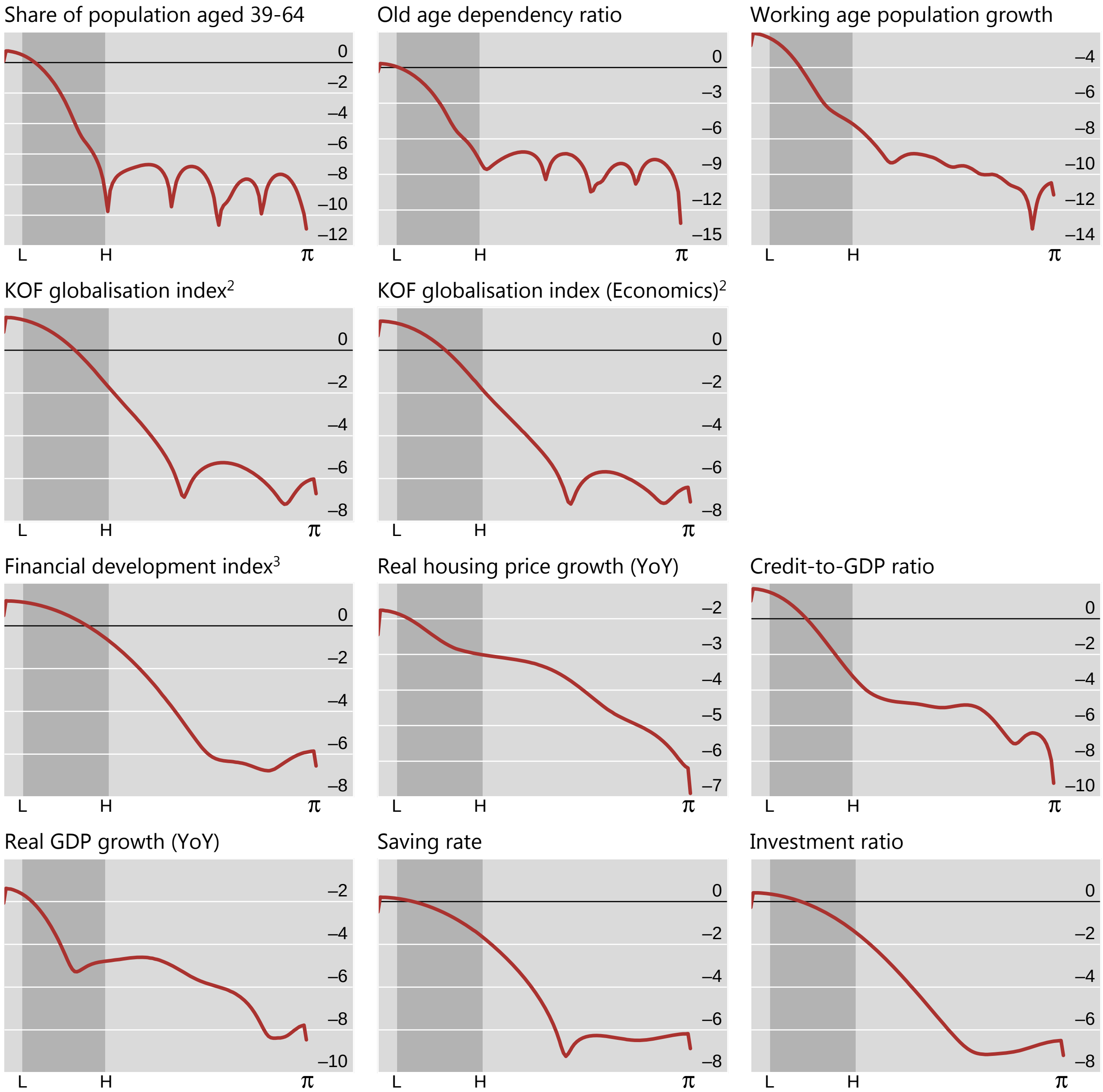
[1] Spectral density, or power spectrum, is estimated using Welch's method. It records the contribution of the component(s) belonging to a specific frequency or frequency band to the total variance of a stochastic process. [2] The overall KOF Index of Globalisation covers the economic, social and political dimensions of globalisation. For details on the Index and the Economics sub-index, see Dreher (2006) and Dreher, Gaston and Martens (2008). [3] For details on the financial development index, see Sahay et al (2015).

Source: author's calculations.

Cospectral density estimates: Australia[1]

In logarithm, with real interest rate

Graph B.2.1.2



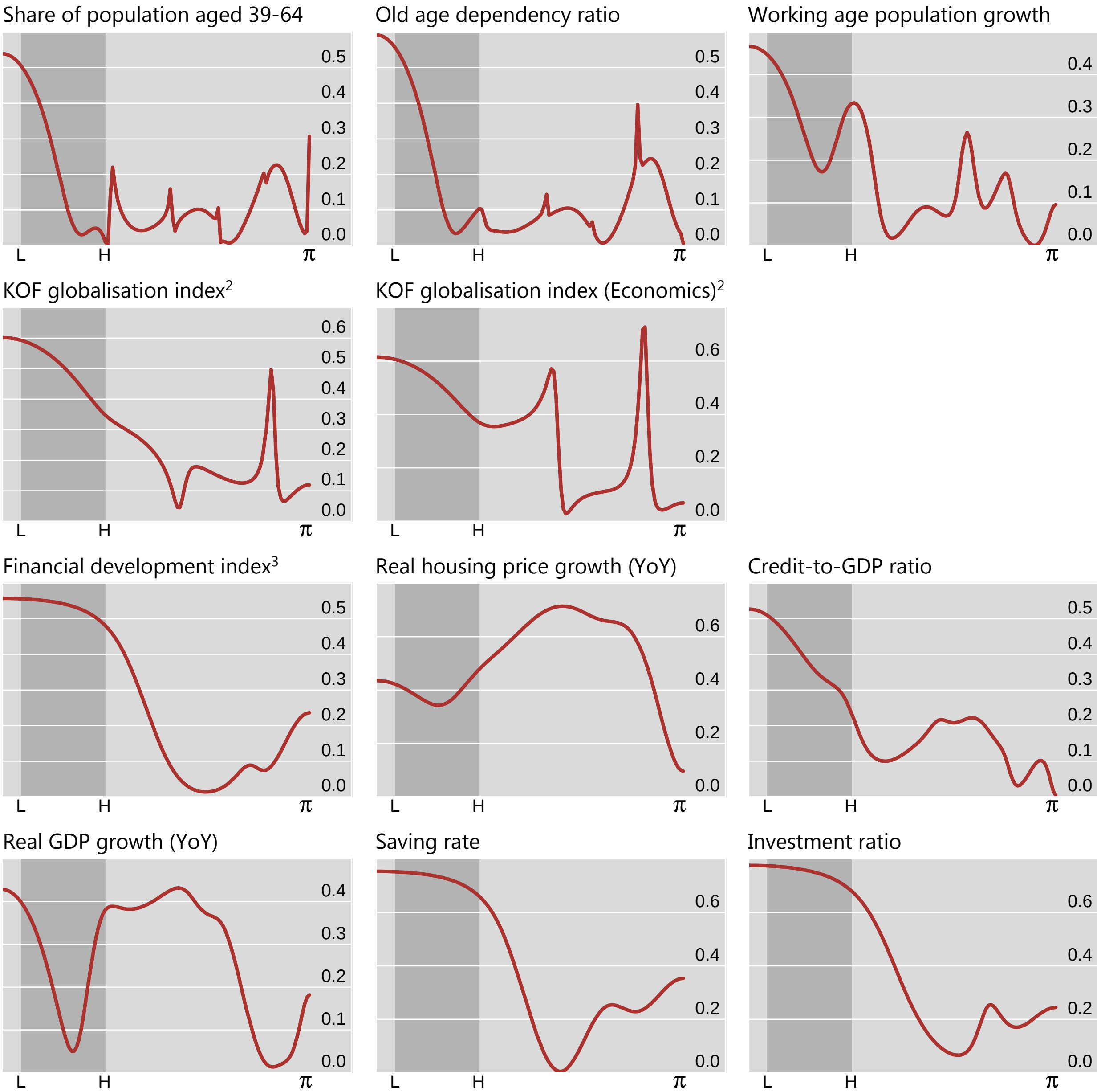
Horizontal axis indicates frequency ranging from 0 to π; vertical axis indicates spectral density. The shaded area indicates the business-cycle frequency, ranging from six quarters (marked by "H") to 32 quarters (marked by "L"). The area between 0 and L corresponds to the low frequency range which contains the trend component.

[1] Cospectral density, also known as cross power spectral density or cospectrum, is estimated using Welch's averaged, modified periodogram method. It represents the covariance between the in-phase components of two stochastic processes at a specific frequency or frequency band. [2] The overall KOF Index of Globalisation covers the economic, social and political dimensions of globalisation. For details on the Index and the Economics sub-index, see Dreher (2006) and Dreher, Gaston and Martens (2008). [3] For details on the financial development index, see Sahay et al (2015).

Source: author's calculations.

Squared coherence estimates: Australia[1]

With real interest rate | Graph B.2.1.3



Horizontal axis indicates frequency ranging from 0 to π; vertical axis indicates spectral density. The shaded area indicates the business-cycle frequency, ranging from six quarters (marked by "H") to 32 quarters (marked by "L"). The area between 0 and L corresponds to the low frequency range which contains the trend component.

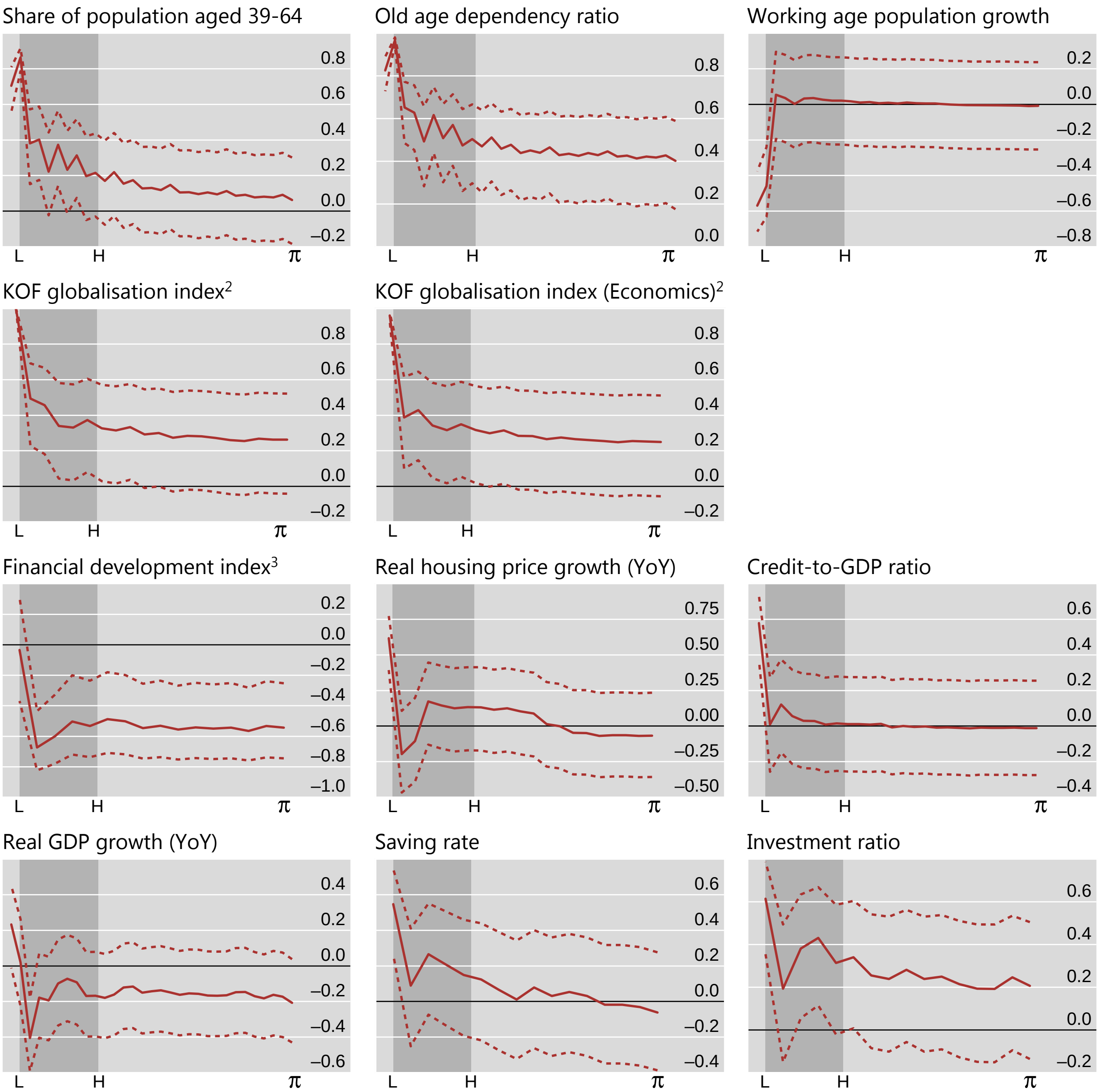
[1] Squared coherence, known as coherency, is estimated using Welch's averaged periodogram method. It is similar to the coefficient of determination R^2, and measures the strength of linear association between two stochastic processes at a specific frequency or frequency band. [2] The overall KOF Index of Globalisation covers the economic, social and political dimensions of globalisation. For details on the Index and the Economics sub-index, see Dreher (2006) and Dreher, Gaston and Martens (2008). [3] For details on the financial development index, see Sahay et al (2015).

Source: author's calculations.

Frequency-specific correlation coefficient estimates: Australia[1]

With real interest rate

Graph B.2.1.4



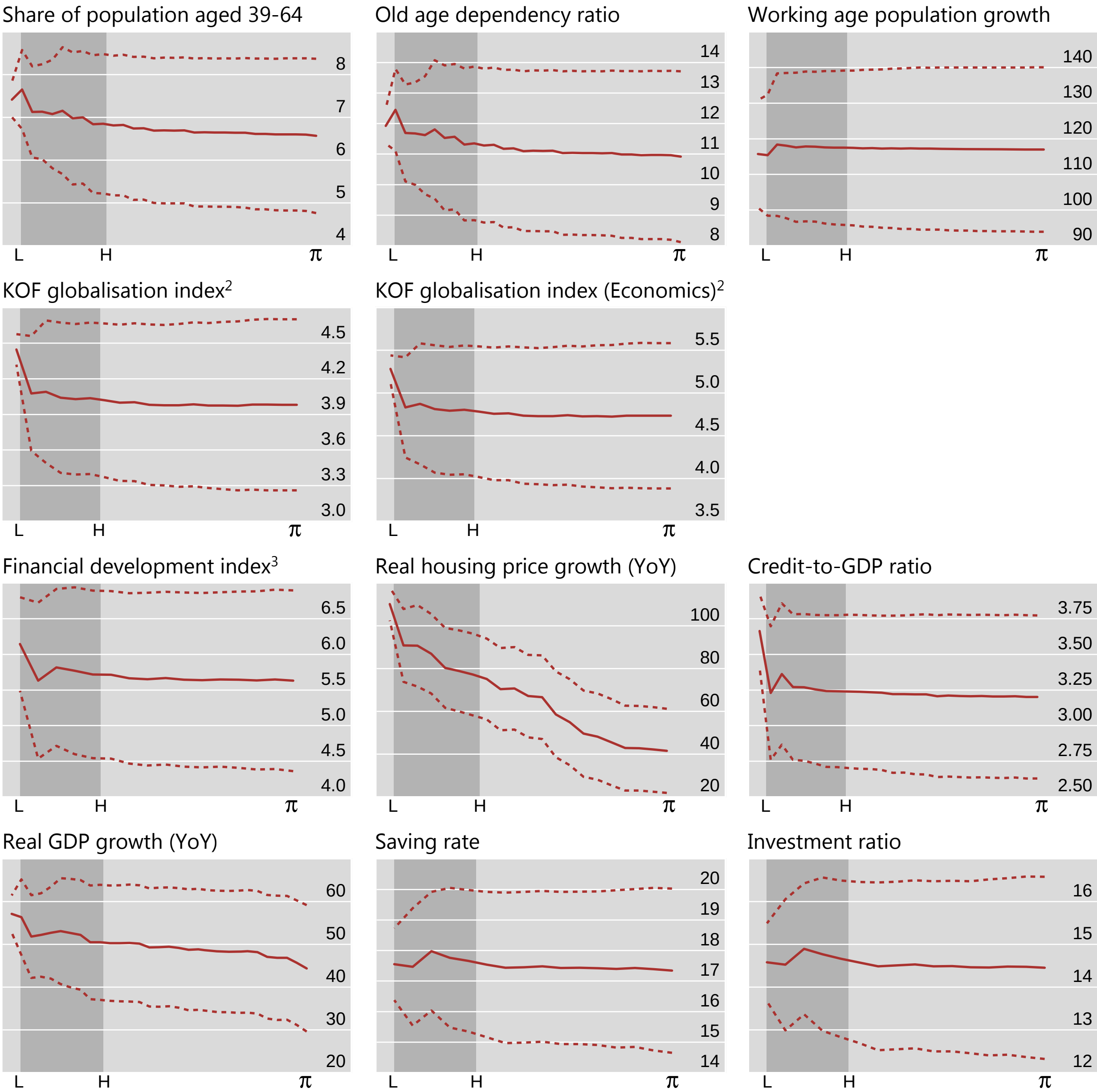
Horizontal axis indicates frequency ranging from 0 to π; vertical axis indicates spectral density. The shaded area indicates the business-cycle frequency, ranging from six quarters (marked by "H") to 32 quarters (marked by "L"). The area between 0 and L corresponds to the low frequency range which contains the trend component.

[1] The frequency-specific coefficient of correlation measures the strength of correlation between two stochastic processes at a specific frequency or frequency band. See Zhu (2005). [2] The overall KOF Index of Globalisation covers the economic, social and political dimensions of globalisation. For details on the Index and the Economics sub-index, see Dreher (2006) and Dreher, Gaston and Martens (2008). [3] For details on the financial development index, see Sahay et al (2015).

Source: author's calculations.

Frequency-specific regression coefficient estimates: Australia[1]

Real interest rate as regressand | Graph B.2.1.5



Horizontal axis indicates frequency ranging from 0 to π; vertical axis indicates spectral density. The shaded area indicates the business-cycle frequency, ranging from six quarters (marked by "H") to 32 quarters (marked by "L"). The area between 0 and L corresponds to the low frequency range which contains the trend component.

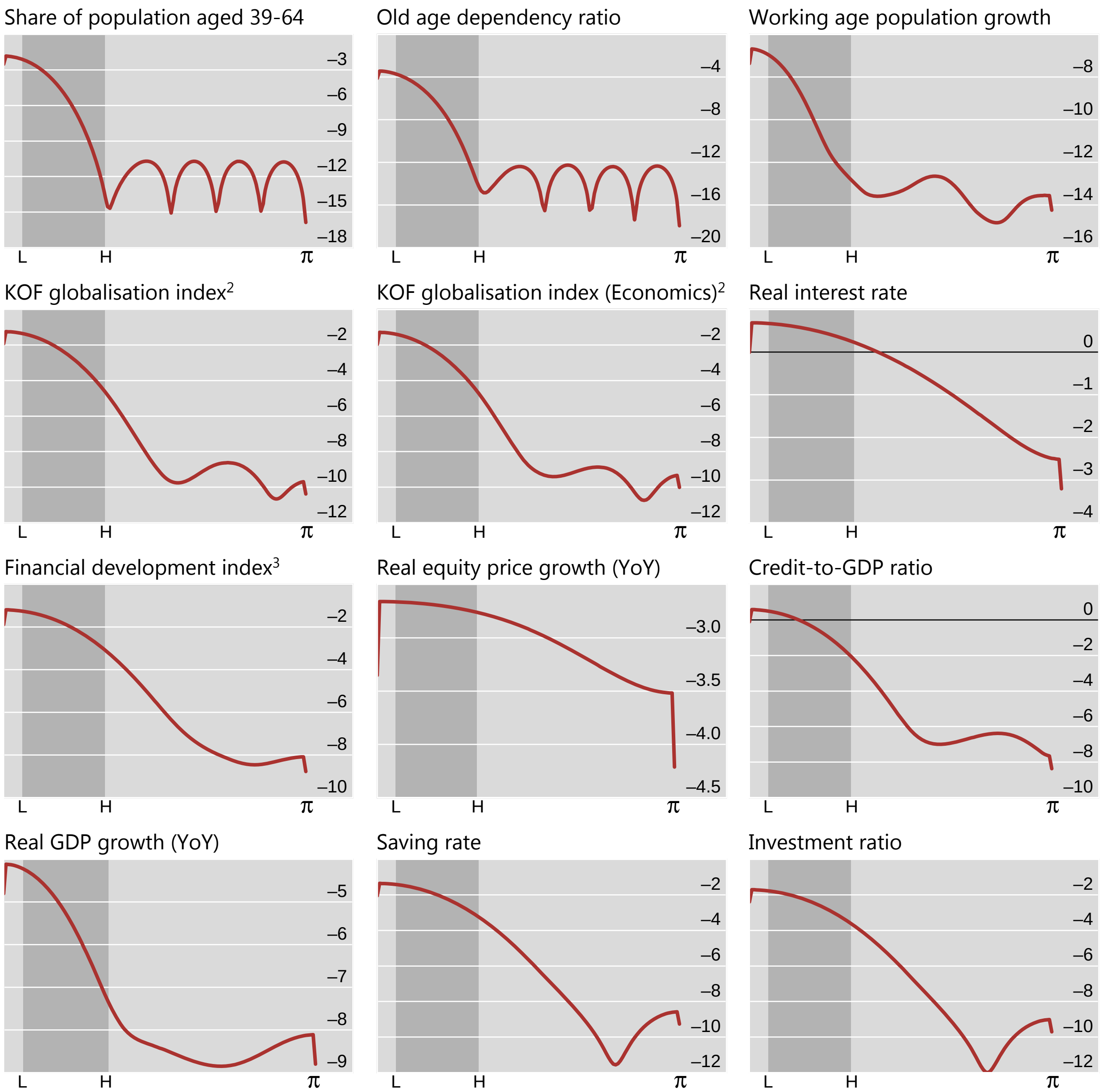
[1] The frequency-specific coefficient of regression indicates the degree of linear association between two stochastic processes at a specific frequency or frequency band. See Zhu (2005). [2] The overall KOF Index of Globalisation covers the economic, social and political dimensions of globalisation. For details on the Index and the Economics sub-index, see Dreher (2006) and Dreher, Gaston and Martens (2008). [3] For details on the financial development index, see Sahay et al (2015).

Source: author's calculations.

B.2.2. China

Spectral density estimates: China[1]

In logarithm — Graph B.2.2.1



Horizontal axis indicates frequency ranging from 0 to π; vertical axis indicates spectral density. The shaded area indicates the business-cycle frequency, ranging from six quarters (marked by "H") to 32 quarters (marked by "L"). The area between 0 and L corresponds to the low frequency range which contains the trend component.

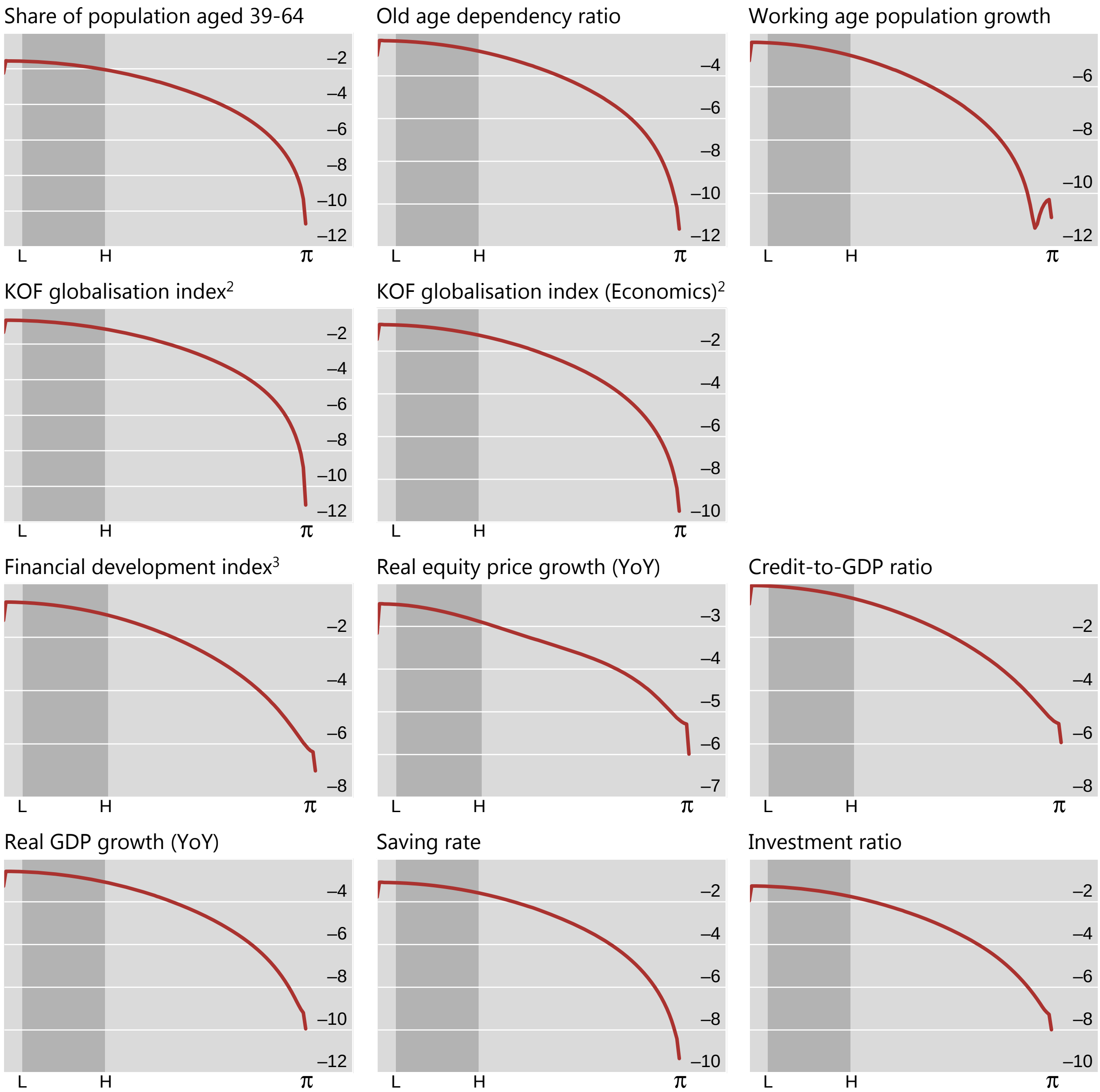
[1] Spectral density, or power spectrum, is estimated using Welch's method. It records the contribution of the component(s) belonging to a specific frequency or frequency band to the total variance of a stochastic process. [2] The overall KOF Index of Globalisation covers the economic, social and political dimensions of globalisation. For details on the Index and the Economics sub-index, see Dreher (2006) and Dreher, Gaston and Martens (2008). [3] For details on the financial development index, see Sahay et al (2015).

Source: author's calculations.

Cospectral density estimates: China[1]

In logarithm, with real interest rate

Graph B.2.2.2



Horizontal axis indicates frequency ranging from 0 to π; vertical axis indicates spectral density. The shaded area indicates the business-cycle frequency, ranging from six quarters (marked by "H") to 32 quarters (marked by "L"). The area between 0 and L corresponds to the low frequency range which contains the trend component.

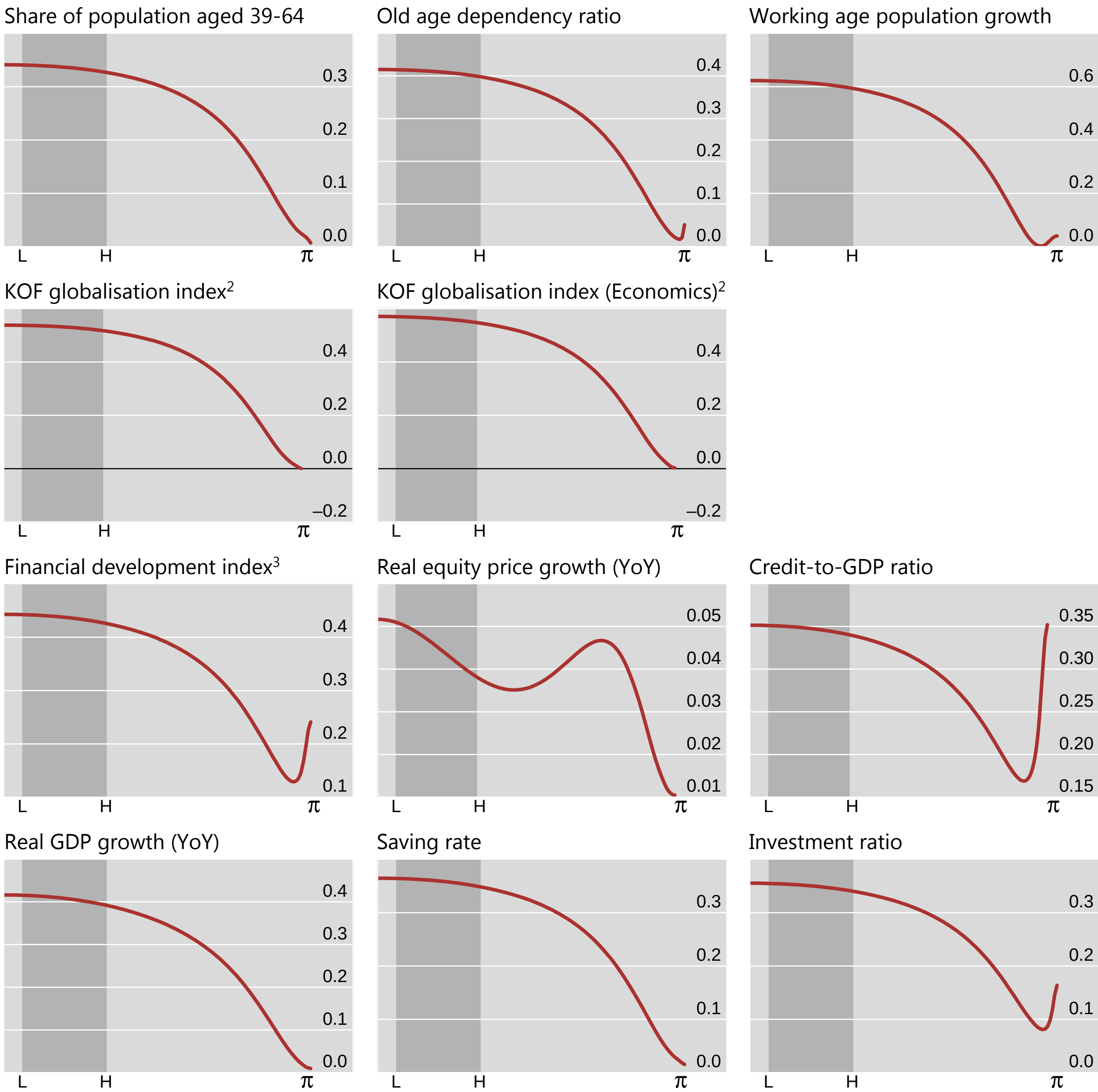
[1] Cospectral density, also known as cross power spectral density or cospectrum, is estimated using Welch's averaged, modified periodogram method. It represents the covariance between the in-phase components of two stochastic processes at a specific frequency or frequency band. [2] The overall KOF Index of Globalisation covers the economic, social and political dimensions of globalisation. For details on the Index and the Economics sub-index, see Dreher (2006) and Dreher, Gaston and Martens (2008). [3] For details on the financial development index, see Sahay et al (2015).

Source: author's calculations.

Squared coherence estimates: China[1]

With real interest rate

Graph B.2.2.3



Horizontal axis indicates frequency ranging from 0 to π; vertical axis indicates spectral density. The shaded area indicates the business-cycle frequency, ranging from six quarters (marked by "H") to 32 quarters (marked by "L"). The area between 0 and L corresponds to the low frequency range which contains the trend component.

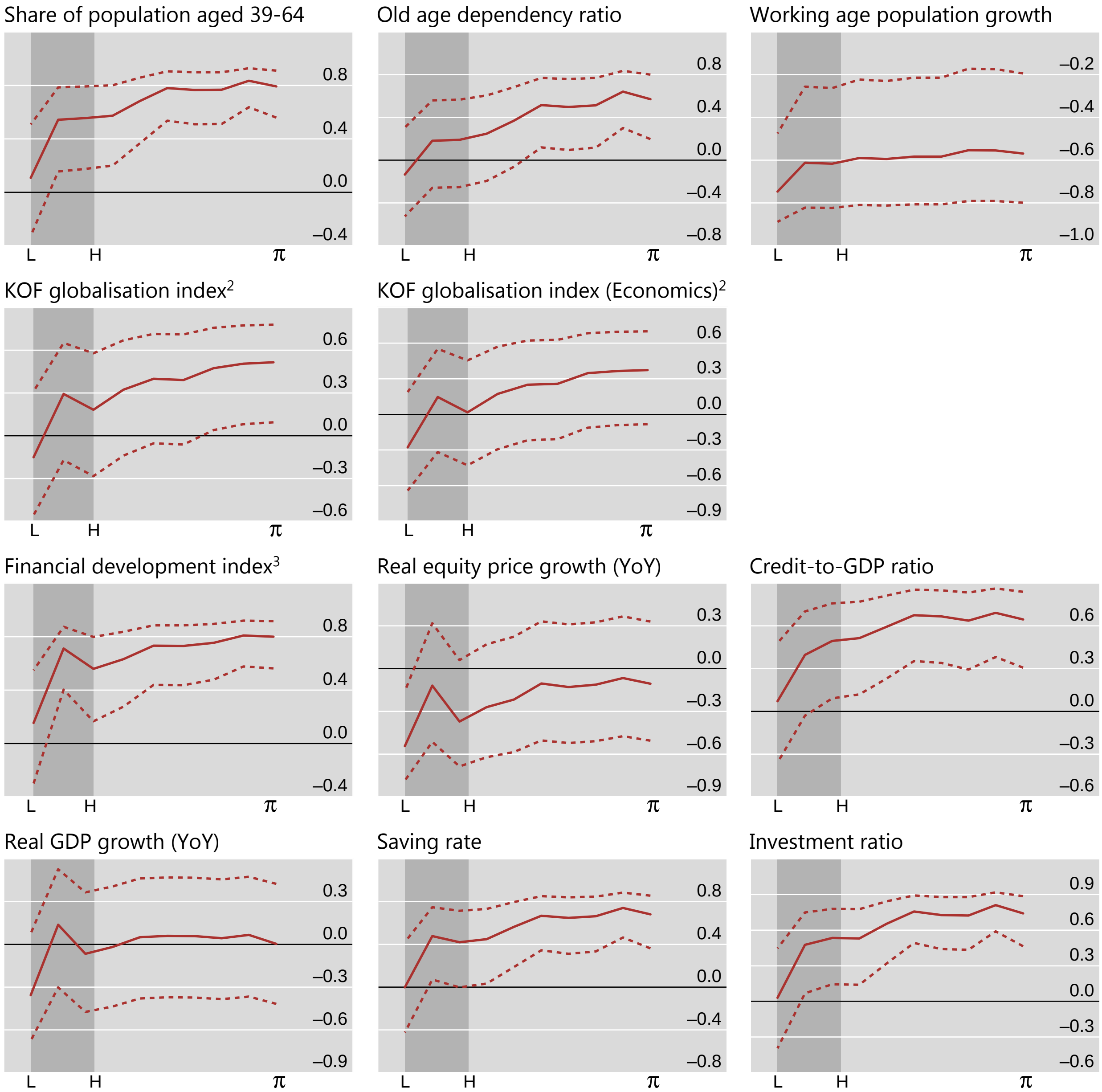
[1] Squared coherence, known as coherency, is estimated using Welch's averaged periodogram method. It is similar to the coefficient of determination R^2, and measures the strength of linear association between two stochastic processes at a specific frequency or frequency band. [2] The overall KOF Index of Globalisation covers the economic, social and political dimensions of globalisation. For details on the Index and the Economics sub-index, see Dreher (2006) and Dreher, Gaston and Martens (2008). [3] For details on the financial development index, see Sahay et al (2015).

Source: author's calculations.

Frequency-specific correlation coefficient estimates: China[1]

With real interest rate

Graph B.2.2.4



Horizontal axis indicates frequency ranging from 0 to π; vertical axis indicates spectral density. The dashed lines indicate 95% confidence intervals. The shaded area indicates the business-cycle frequency, ranging from six quarters (marked by "H") to 32 quarters (marked by "L"). The area between 0 and L corresponds to the low frequency range which contains the trend component.

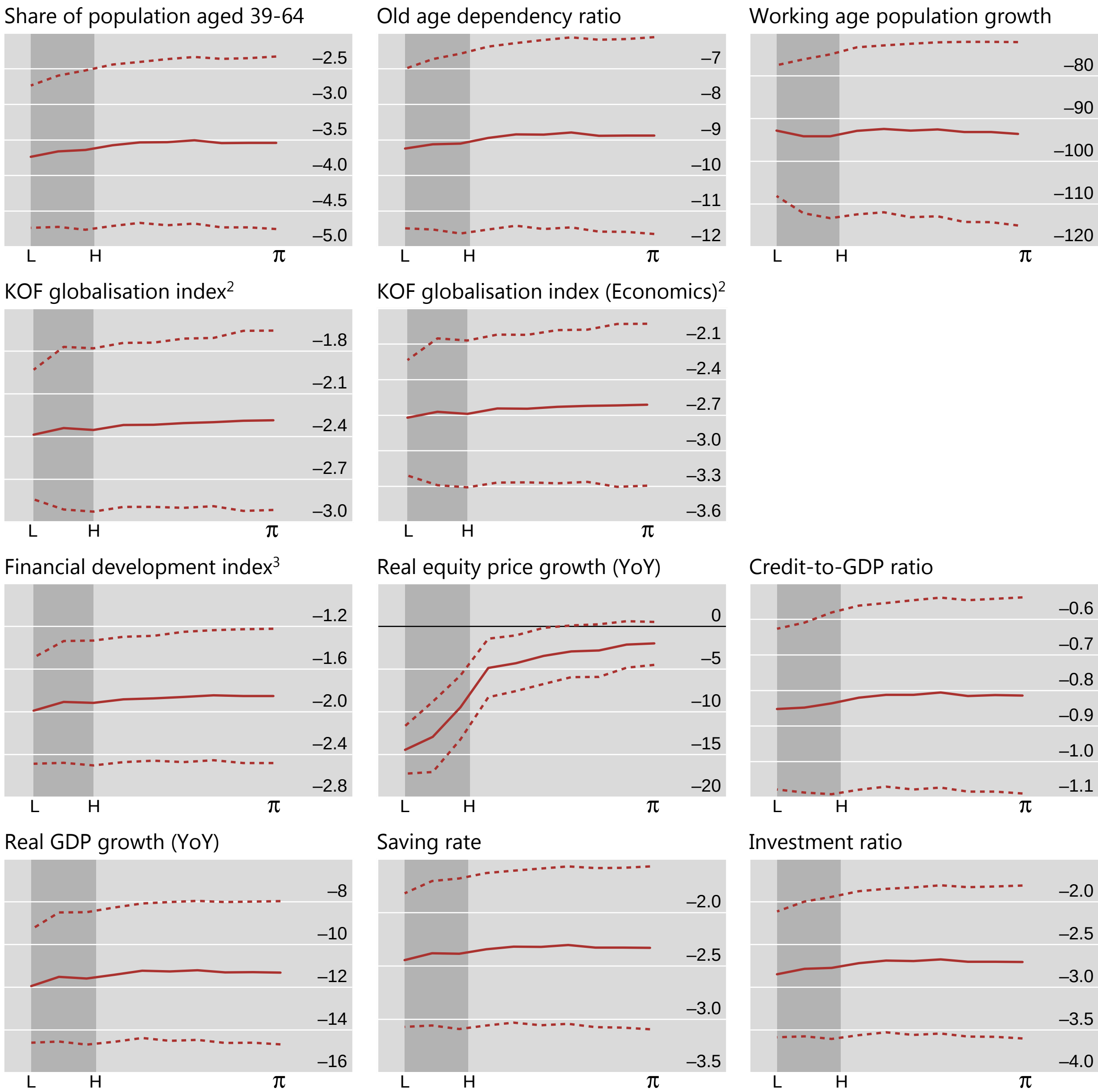
[1] The frequency-specific coefficient of correlation measures the strength of correlation between two stochastic processes at a specific frequency or frequency band. See Zhu (2005). [2] The overall KOF Index of Globalisation covers the economic, social and political dimensions of globalisation. For details on the Index and the Economics sub-index, see Dreher (2006) and Dreher, Gaston and Martens (2008). [3] For details on the financial development index, see Sahay et al (2015).

Source: author's calculations.

Frequency-specific regression coefficient estimates: China[1]

Real interest rate as regressand

Graph B.2.2.5



Horizontal axis indicates frequency ranging from 0 to π; vertical axis indicates spectral density. The dashed lines indicate 95% confidence intervals. The shaded area indicates the business-cycle frequency, ranging from six quarters (marked by "H") to 32 quarters (marked by "L"). The area between 0 and L corresponds to the low frequency range which contains the trend component.

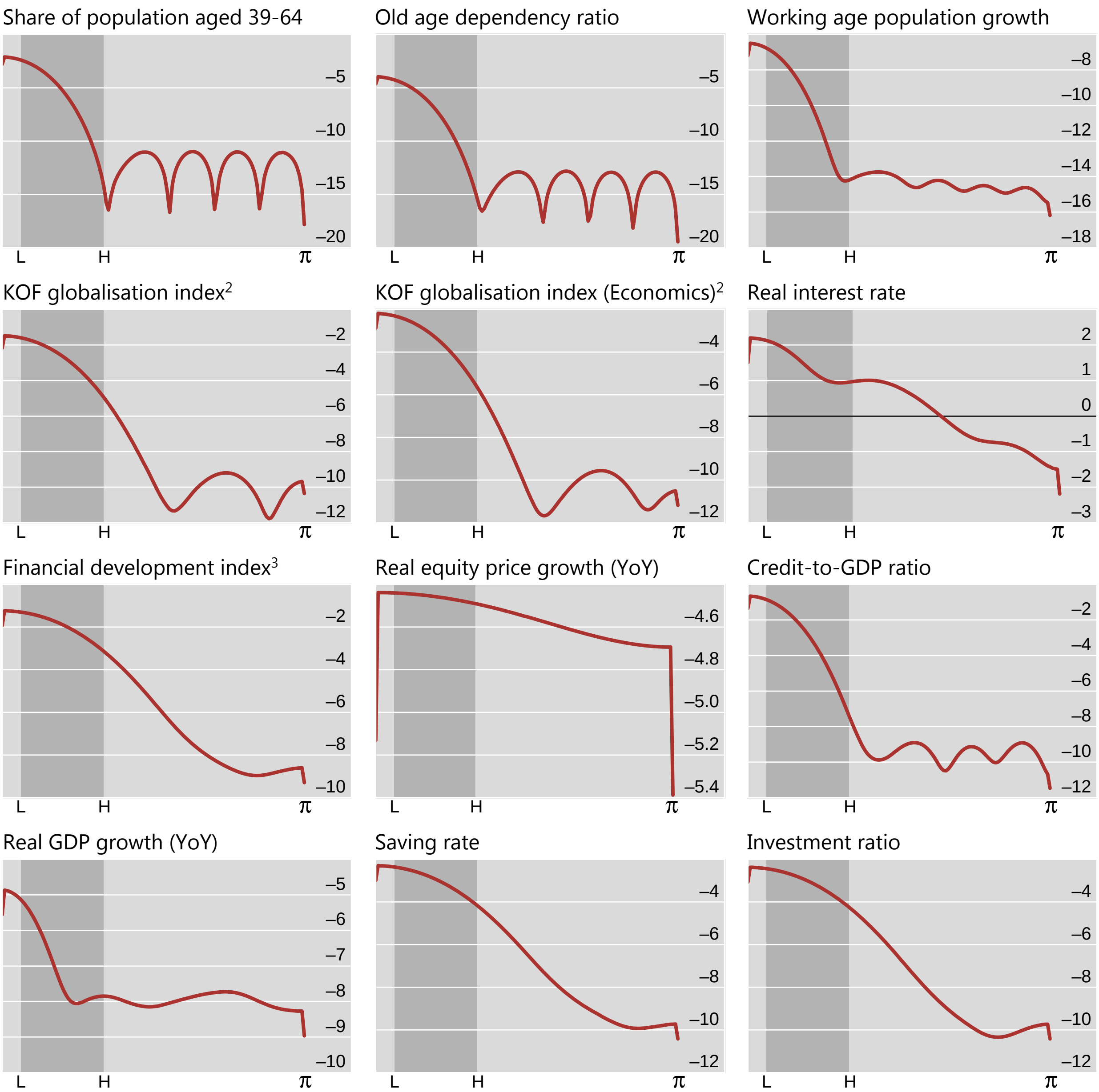
[1] The frequency-specific coefficient of regression indicates the degree of linear association between two stochastic processes at a specific frequency or frequency band. See Zhu (2005). [2] The overall KOF Index of Globalisation covers the economic, social and political dimensions of globalisation. For details on the Index and the Economics sub-index, see Dreher (2006) and Dreher, Gaston and Martens (2008). [3] For details on the financial development index, see Sahay et al (2015).

Source: author's calculations.

B.2.3. India

Spectral density estimates: India[1]

In logarithm — Graph B.2.3.1



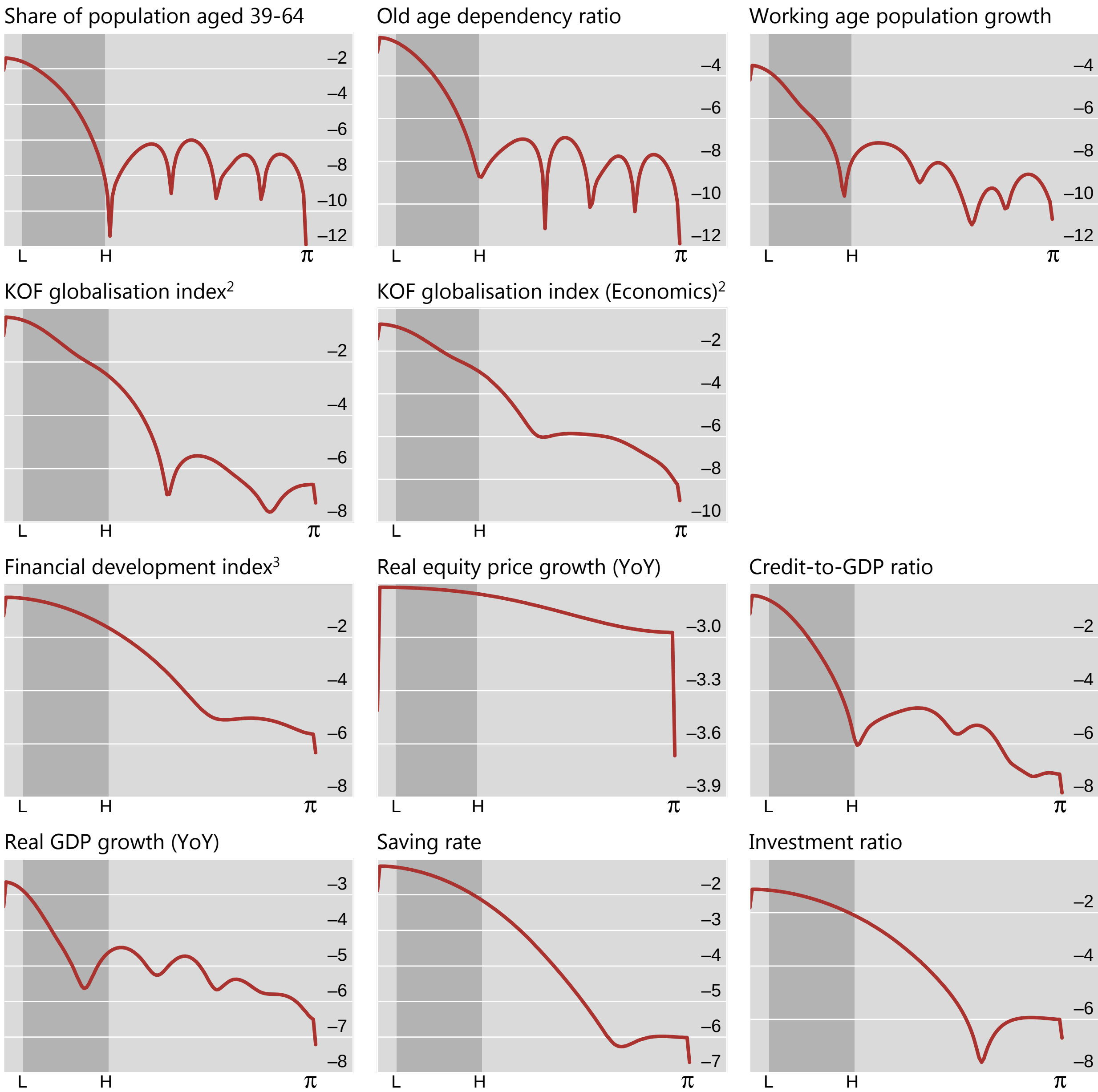
Horizontal axis indicates frequency ranging from 0 to π; vertical axis indicates spectral density. The shaded area indicates the business-cycle frequency, ranging from six quarters (marked by "H") to 32 quarters (marked by "L"). The area between 0 and L corresponds to the low frequency range which contains the trend component.

[1] Spectral density, or power spectrum, is estimated using Welch's method. It records the contribution of the component(s) belonging to a specific frequency or frequency band to the total variance of a stochastic process. [2] The overall KOF Index of Globalisation covers the economic, social and political dimensions of globalisation. For details on the Index and the Economics sub-index, see Dreher (2006) and Dreher, Gaston and Martens (2008). [3] For details on the financial development index, see Sahay et al (2015).

Source: author's calculations.

Cospectral density estimates: India[1]

In logarithm, with real interest rate Graph B.2.3.2



Horizontal axis indicates frequency ranging from 0 to π; vertical axis indicates spectral density. The shaded area indicates the business-cycle frequency, ranging from six quarters (marked by "H") to 32 quarters (marked by "L"). The area between 0 and L corresponds to the low frequency range which contains the trend component.

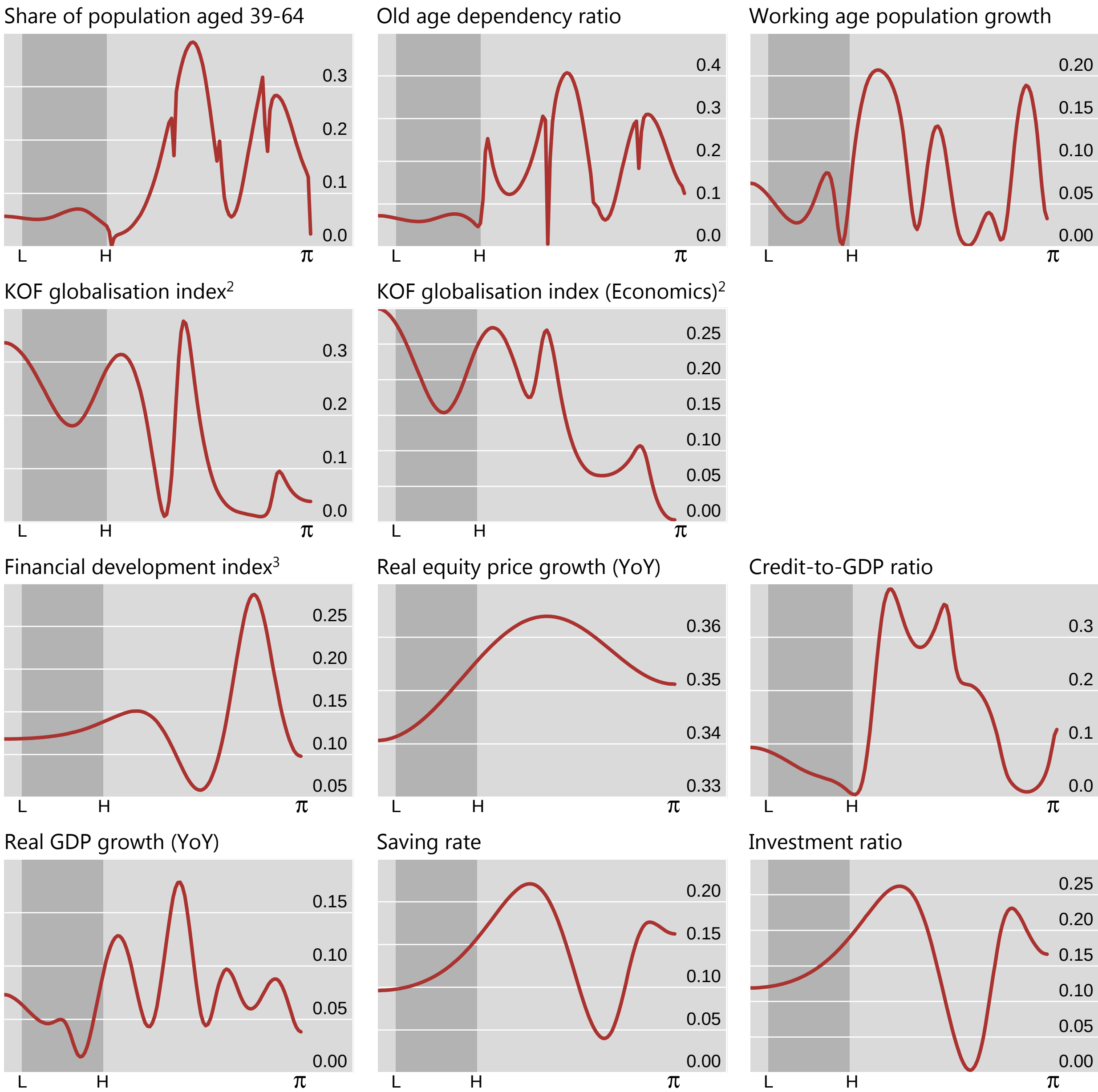
[1] Cospectral density, also known as cross power spectral density or cospectrum, is estimated using Welch's averaged, modified periodogram method. It represents the covariance between the in-phase components of two stochastic processes at a specific frequency or frequency band. [2] The overall KOF Index of Globalisation covers the economic, social and political dimensions of globalisation. For details on the Index and the Economics sub-index, see Dreher (2006) and Dreher, Gaston and Martens (2008). [3] For details on the financial development index, see Sahay et al (2015).

Source: author's calculations.

Squared coherence estimates: India[1]

With real interest rate

Graph B.2.3.3



Horizontal axis indicates frequency ranging from 0 to π; vertical axis indicates spectral density. The shaded area indicates the business-cycle frequency, ranging from six quarters (marked by "H") to 32 quarters (marked by "L"). The area between 0 and L corresponds to the low frequency range which contains the trend component.

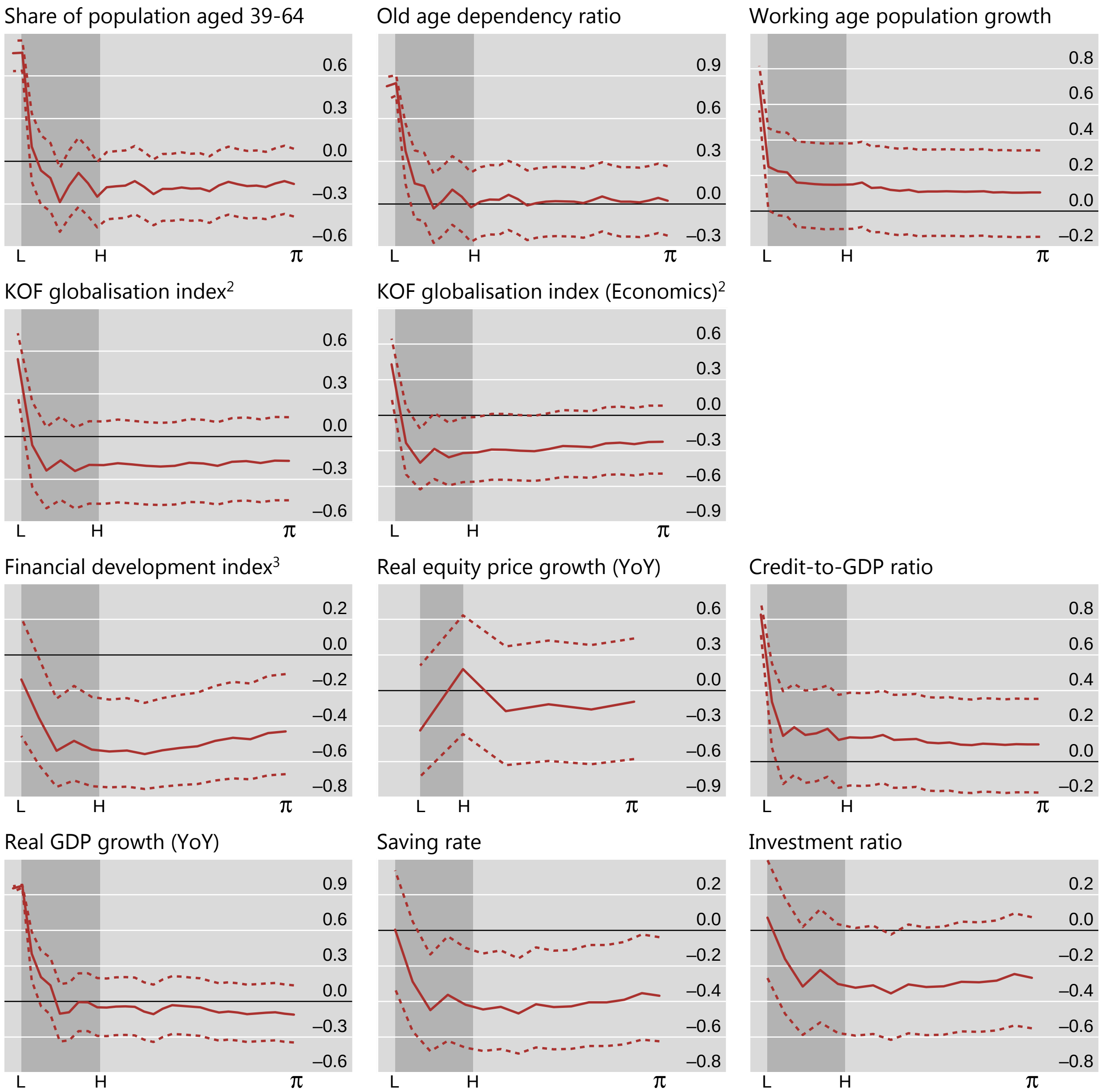
[1] Squared coherence, known as coherency, is estimated using Welch's averaged periodogram method. It is similar to the coefficient of determination R^2, and measures the strength of linear association between two stochastic processes at a specific frequency or frequency band. [2] The overall KOF Index of Globalisation covers the economic, social and political dimensions of globalisation. For details on the Index and the Economics sub-index, see Dreher (2006) and Dreher, Gaston and Martens (2008). [3] For details on the financial development index, see Sahay et al (2015).

Source: author's calculations.

Frequency-specific correlation coefficient estimates: India[1]

With real interest rate

Graph B.2.3.4



Horizontal axis indicates frequency ranging from 0 to π; vertical axis indicates spectral density. The dashed lines indicate 95% confidence intervals. The shaded area indicates the business-cycle frequency, ranging from six quarters (marked by "H") to 32 quarters (marked by "L"). The area between 0 and L corresponds to the low frequency range which contains the trend component.

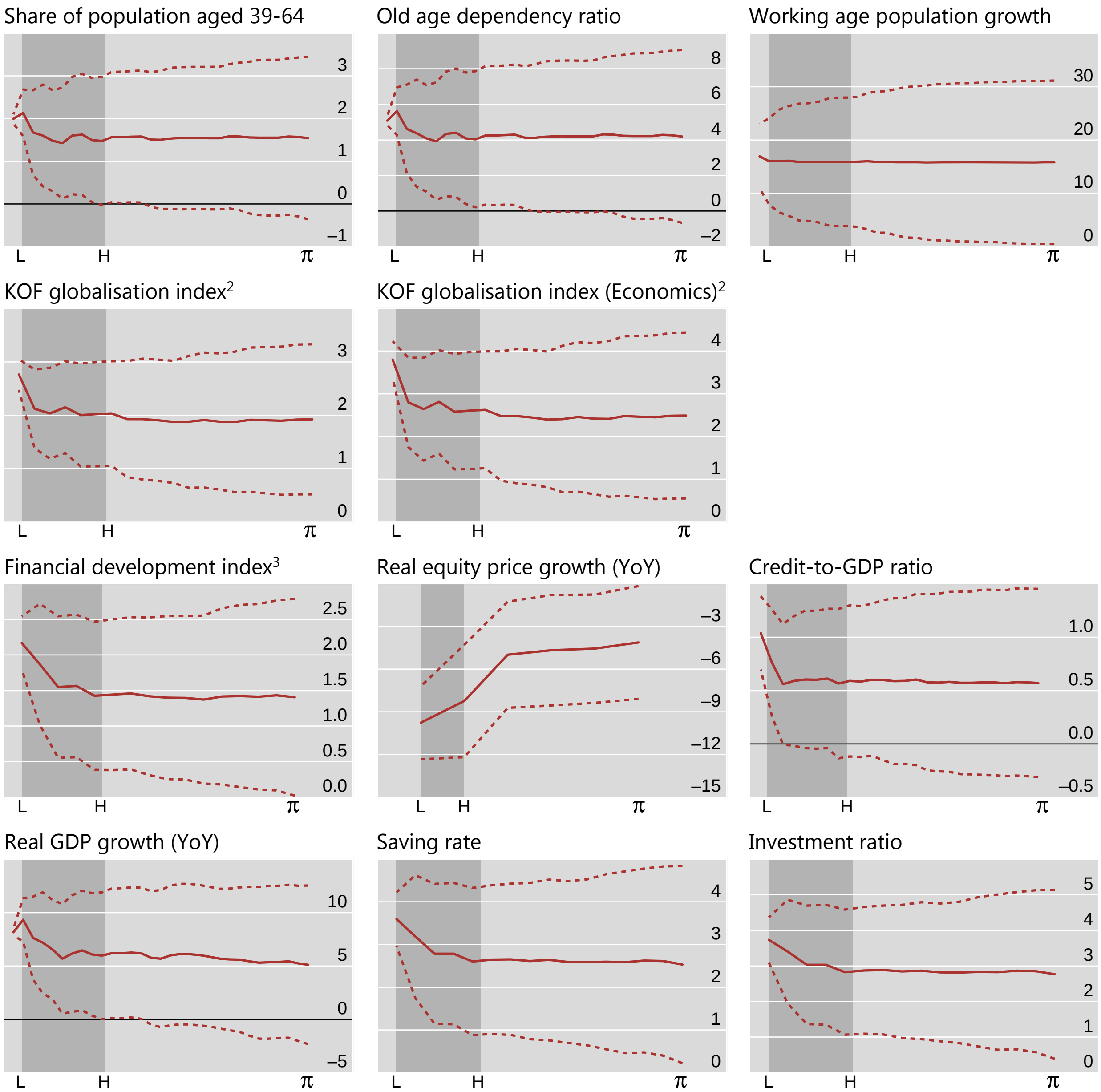
[1] The frequency-specific coefficient of correlation measures the strength of correlation between two stochastic processes at a specific frequency or frequency band. See Zhu (2005). [2] The overall KOF Index of Globalisation covers the economic, social and political dimensions of globalisation. For details on the Index and the Economics sub-index, see Dreher (2006) and Dreher, Gaston and Martens (2008). [3] For details on the financial development index, see Sahay et al (2015).

Source: author's calculations.

Frequency-specific regression coefficient estimates: India[1]

Real interest rate as regressand

Graph B.2.3.5



Horizontal axis indicates frequency ranging from 0 to π; vertical axis indicates spectral density. The dashed lines indicate 95% confidence intervals. The shaded area indicates the business-cycle frequency, ranging from six quarters (marked by "H") to 32 quarters (marked by "L"). The area between 0 and L corresponds to the low frequency range which contains the trend component.

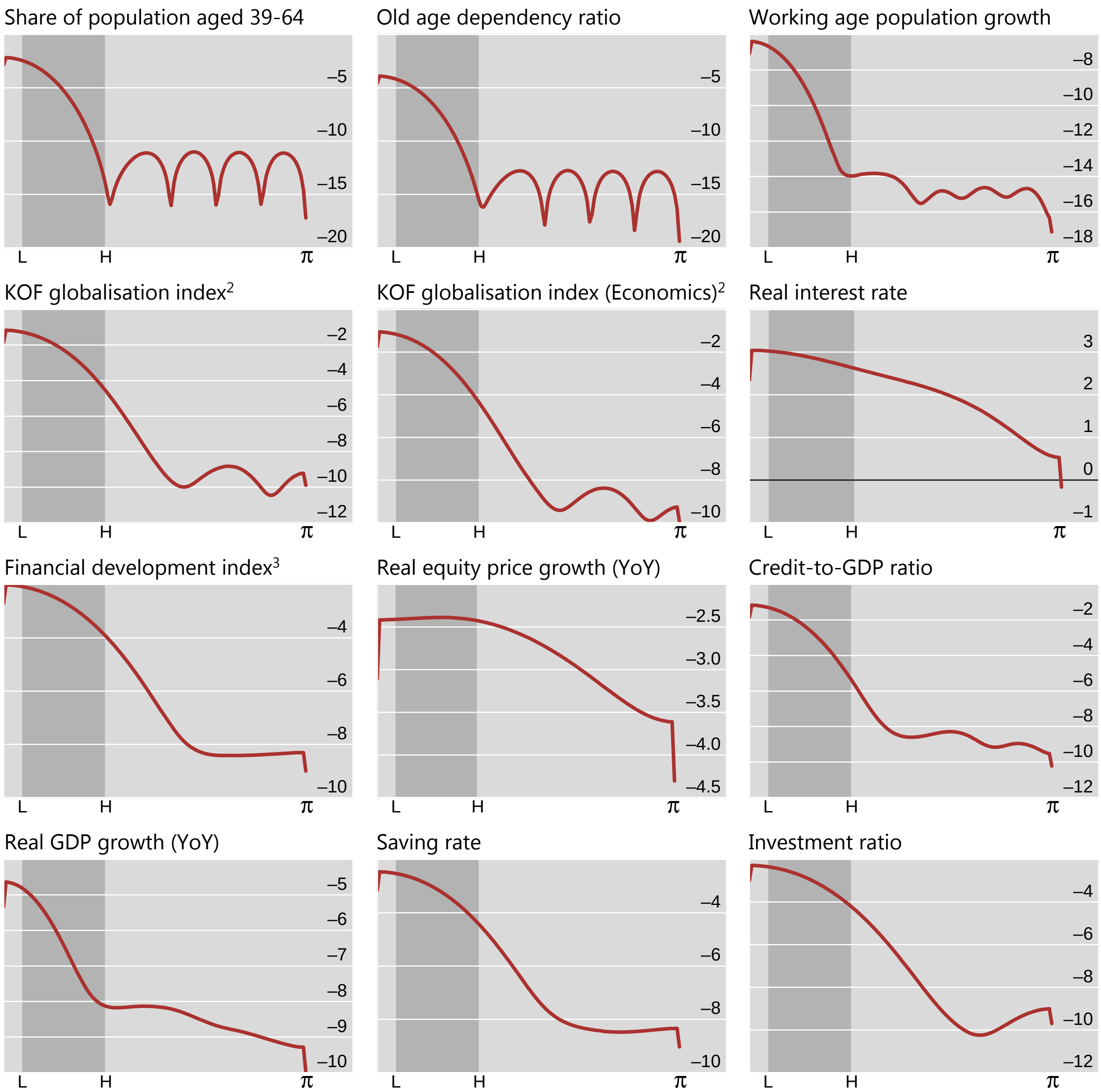
[1] The frequency-specific coefficient of regression indicates the degree of linear association between two stochastic processes at a specific frequency or frequency band. See Zhu (2005). [2] The overall KOF Index of Globalisation covers the economic, social and political dimensions of globalisation. For details on the Index and the Economics sub-index, see Dreher (2006) and Dreher, Gaston and Martens (2008). [3] For details on the financial development index, see Sahay et al (2015).

Source: author's calculations.

B.2.4. Indonesia

Spectral density estimates: Indonesia[1]

In logarithm Graph B.2.4.1



Horizontal axis indicates frequency ranging from 0 to π; vertical axis indicates spectral density. The shaded area indicates the business-cycle frequency, ranging from six quarters (marked by "H") to 32 quarters (marked by "L"). The area between 0 and L corresponds to the low frequency range which contains the trend component.

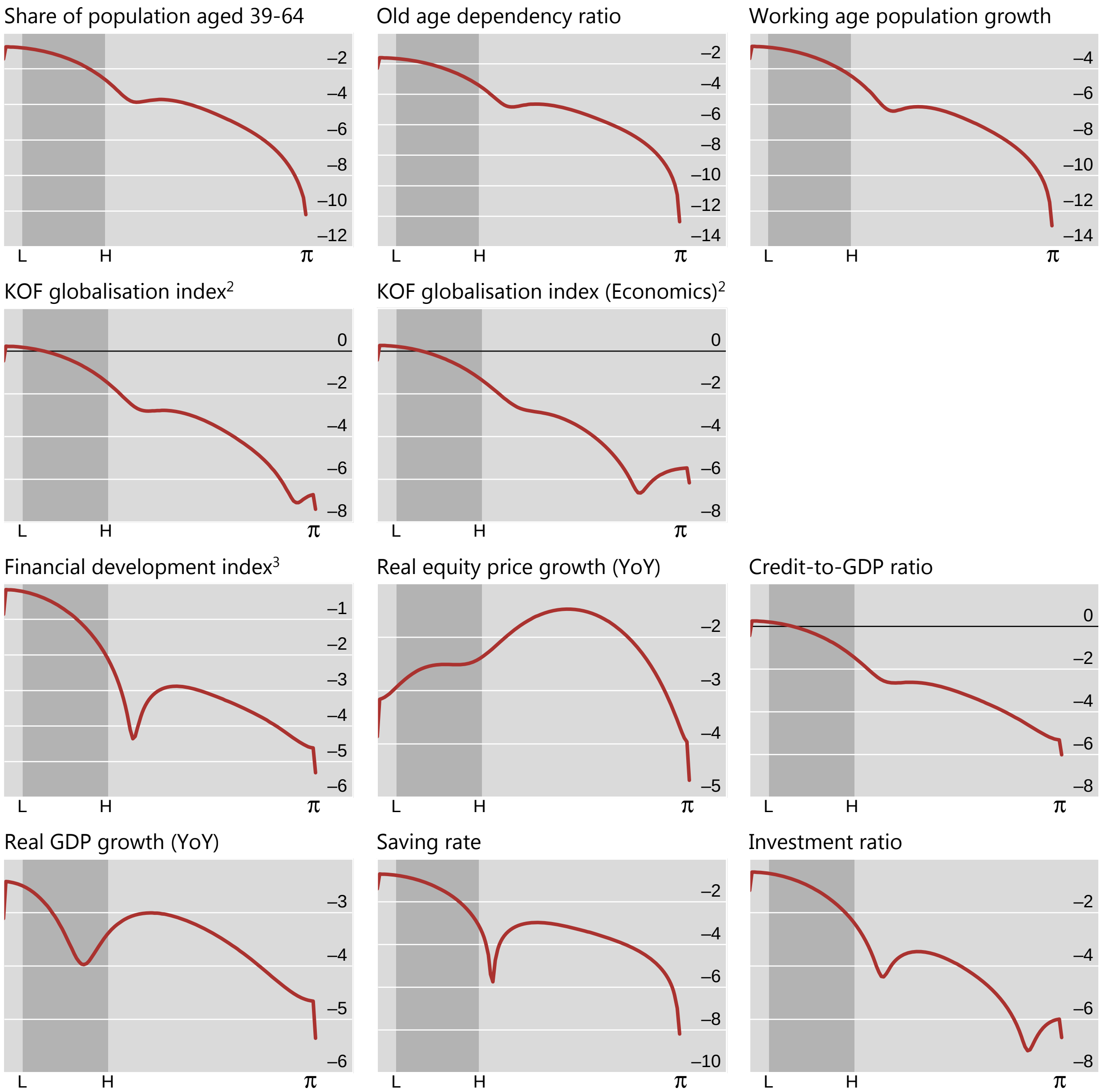
[1] Spectral density, or power spectrum, is estimated using Welch's method. It records the contribution of the component(s) belonging to a specific frequency or frequency band to the total variance of a stochastic process. [2] The overall KOF Index of Globalisation covers the economic, social and political dimensions of globalisation. For details on the Index and the Economics sub-index, see Dreher (2006) and Dreher, Gaston and Martens (2008). [3] For details on the financial development index, see Sahay et al (2015).

Source: author's calculations.

Cospectral density estimates: Indonesia[1]

In logarithm, with real interest rate

Graph B.2.4.2



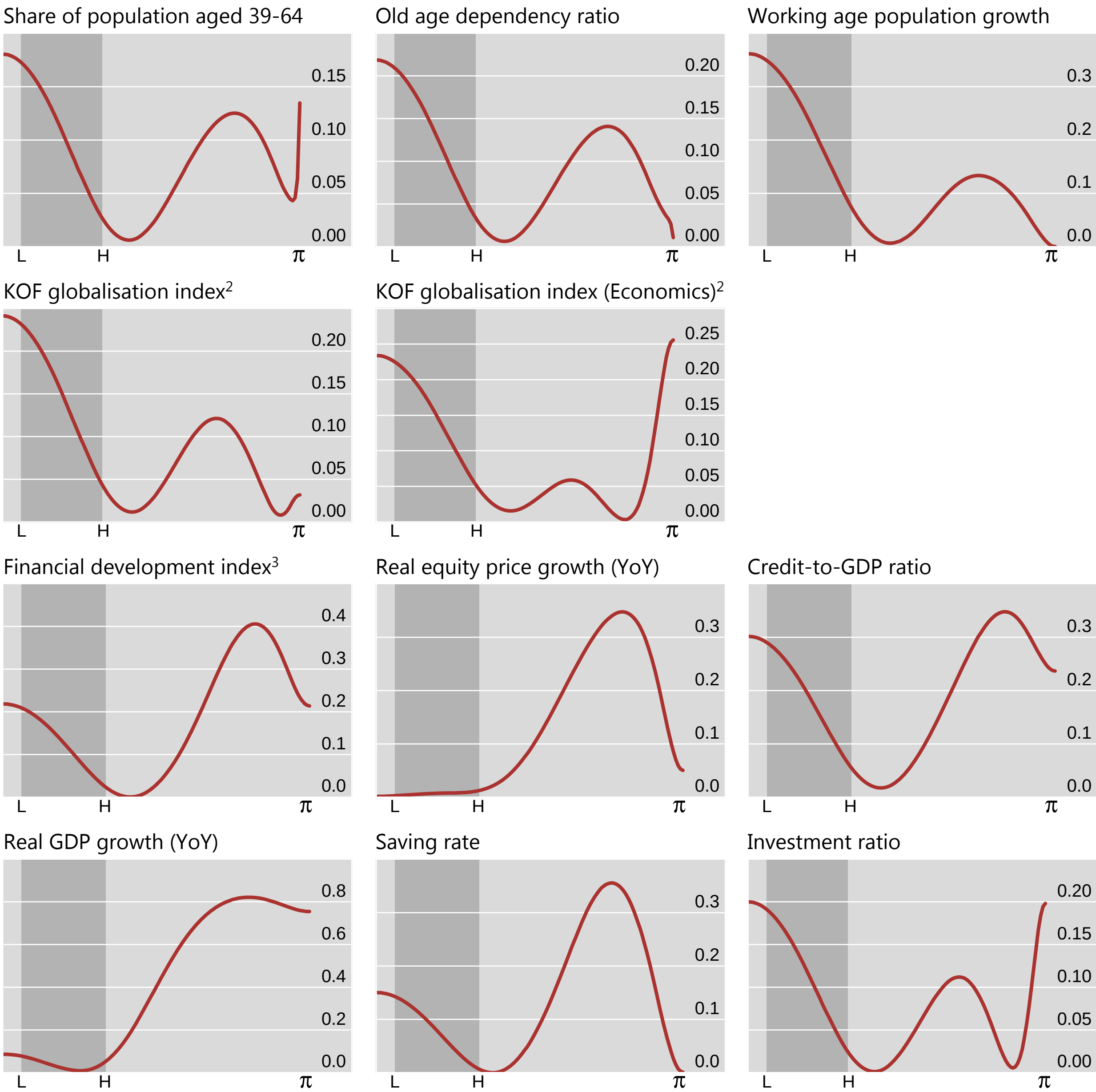
Horizontal axis indicates frequency ranging from 0 to π; vertical axis indicates spectral density. The shaded area indicates the business-cycle frequency, ranging from six quarters (marked by "H") to 32 quarters (marked by "L"). The area between 0 and L corresponds to the low frequency range which contains the trend component.

[1] Cospectral density, also known as cross power spectral density or cospectrum, is estimated using Welch's averaged, modified periodogram method. It represents the covariance between the in-phase components of two stochastic processes at a specific frequency or frequency band. [2] The overall KOF Index of Globalisation covers the economic, social and political dimensions of globalisation. For details on the Index and the Economics sub-index, see Dreher (2006) and Dreher, Gaston and Martens (2008). [3] For details on the financial development index, see Sahay et al (2015).

Source: author's calculations.

Squared coherence estimates: Indonesia[1]

With real interest rate — Graph B.2.4.3



Horizontal axis indicates frequency ranging from 0 to π; vertical axis indicates spectral density. The shaded area indicates the business-cycle frequency, ranging from six quarters (marked by "H") to 32 quarters (marked by "L"). The area between 0 and L corresponds to the low frequency range which contains the trend component.

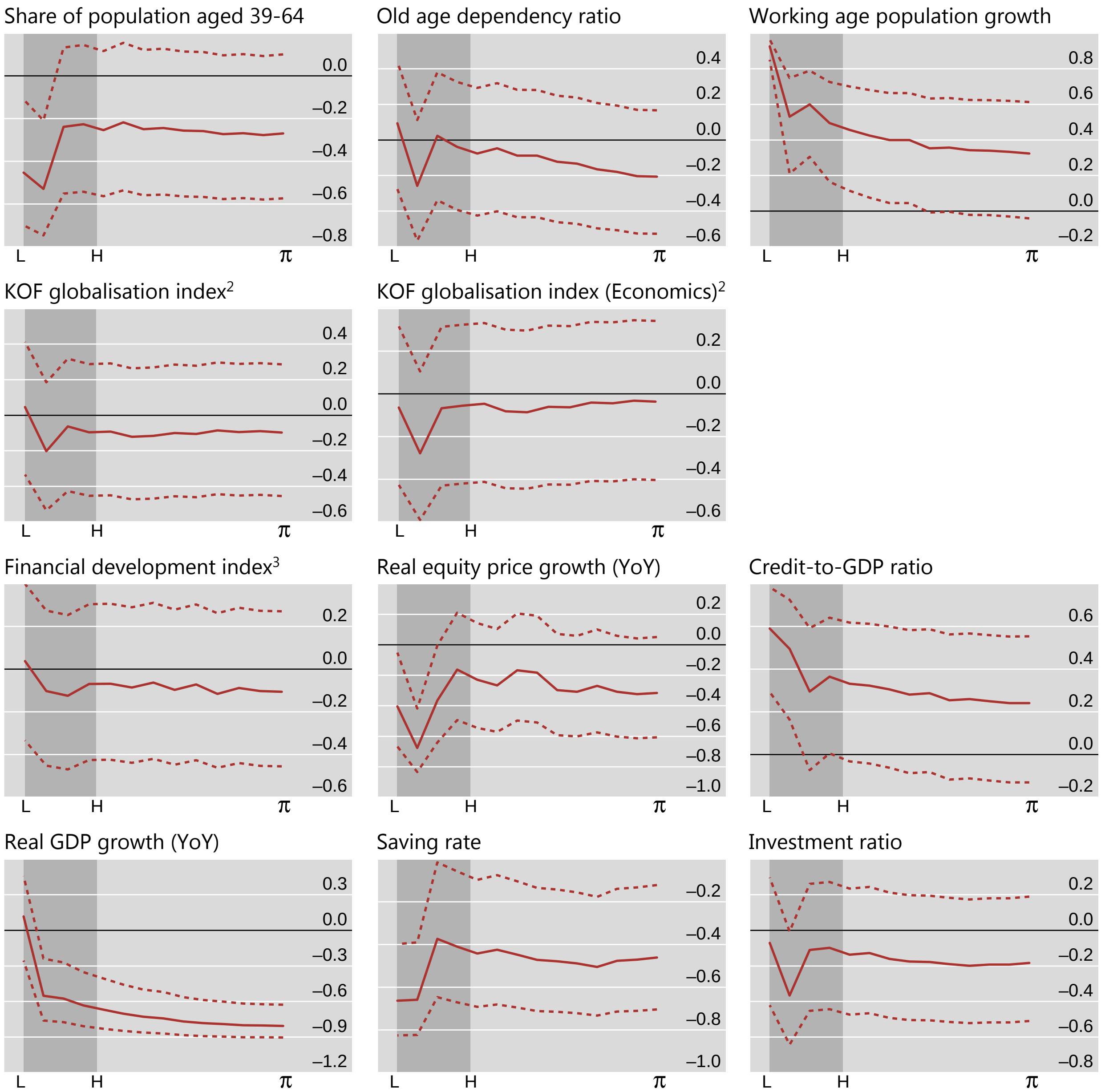
[1] Squared coherence, known as coherency, is estimated using Welch's averaged periodogram method. It is similar to the coefficient of determination R^2, and measures the strength of linear association between two stochastic processes at a specific frequency or frequency band. [2] The overall KOF Index of Globalisation covers the economic, social and political dimensions of globalisation. For details on the Index and the Economics sub-index, see Dreher (2006) and Dreher, Gaston and Martens (2008). [3] For details on the financial development index, see Sahay et al (2015).

Source: author's calculations.

Frequency-specific correlation coefficient estimates: Indonesia[1]

With real interest rate

Graph B.2.4.4



Horizontal axis indicates frequency ranging from 0 to π; vertical axis indicates spectral density. The dashed lines indicate 95% confidence intervals. The shaded area indicates the business-cycle frequency, ranging from six quarters (marked by "H") to 32 quarters (marked by "L"). The area between 0 and L corresponds to the low frequency range which contains the trend component.

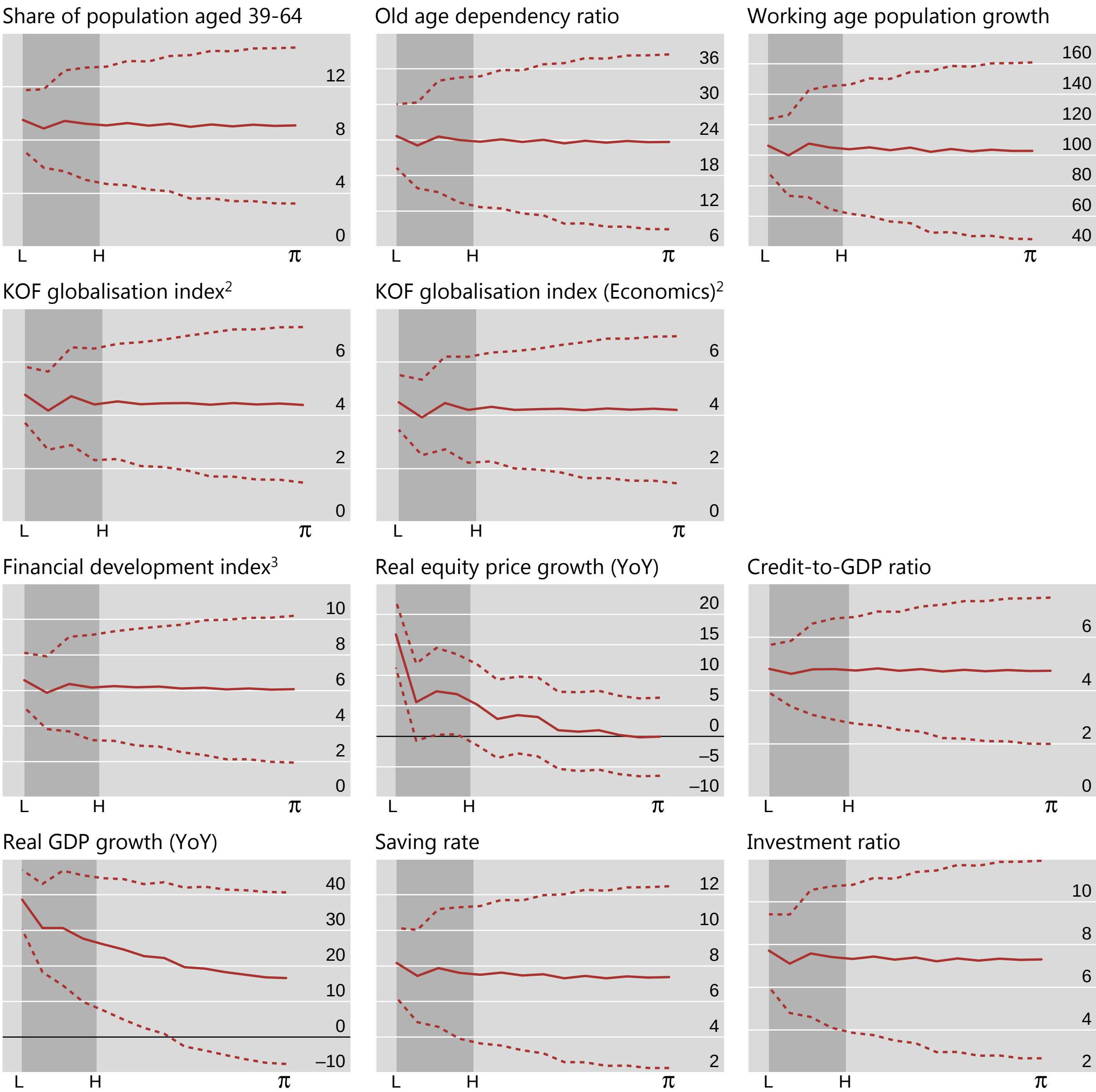
[1] The frequency-specific coefficient of correlation measures the strength of correlation between two stochastic processes at a specific frequency or frequency band. See Zhu (2005). [2] The overall KOF Index of Globalisation covers the economic, social and political dimensions of globalisation. For details on the Index and the Economics sub-index, see Dreher (2006) and Dreher, Gaston and Martens (2008). [3] For details on the financial development index, see Sahay et al (2015).

Source: author's calculations.

Frequency-specific regression coefficient estimates: Indonesia[1]

Real interest rate as regressand

Graph B.2.4.5



Horizontal axis indicates frequency ranging from 0 to π; vertical axis indicates spectral density. The dashed lines indicate 95% confidence intervals. The shaded area indicates the business-cycle frequency, ranging from six quarters (marked by "H") to 32 quarters (marked by "L"). The area between 0 and L corresponds to the low frequency range which contains the trend component.

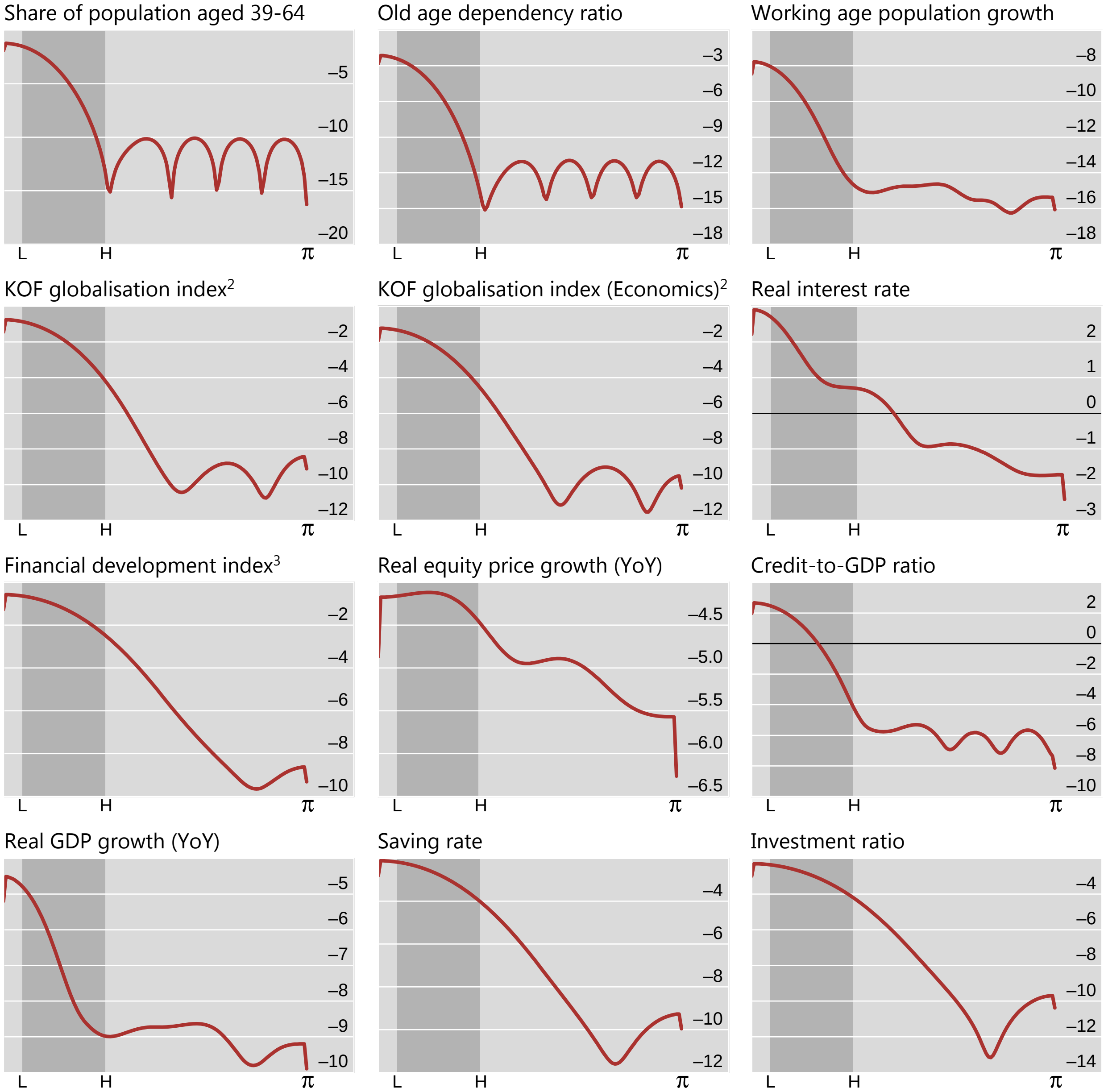
[1] The frequency-specific coefficient of regression indicates the degree of linear association between two stochastic processes at a specific frequency or frequency band. See Zhu (2005). [2] The overall KOF Index of Globalisation covers the economic, social and political dimensions of globalisation. For details on the Index and the Economics sub-index, see Dreher (2006) and Dreher, Gaston and Martens (2008). [3] For details on the financial development index, see Sahay et al (2015).

Source: author's calculations.

B.2.5. Japan

Spectral density estimates: Japan[1]

In logarithm Graph B.2.5.1



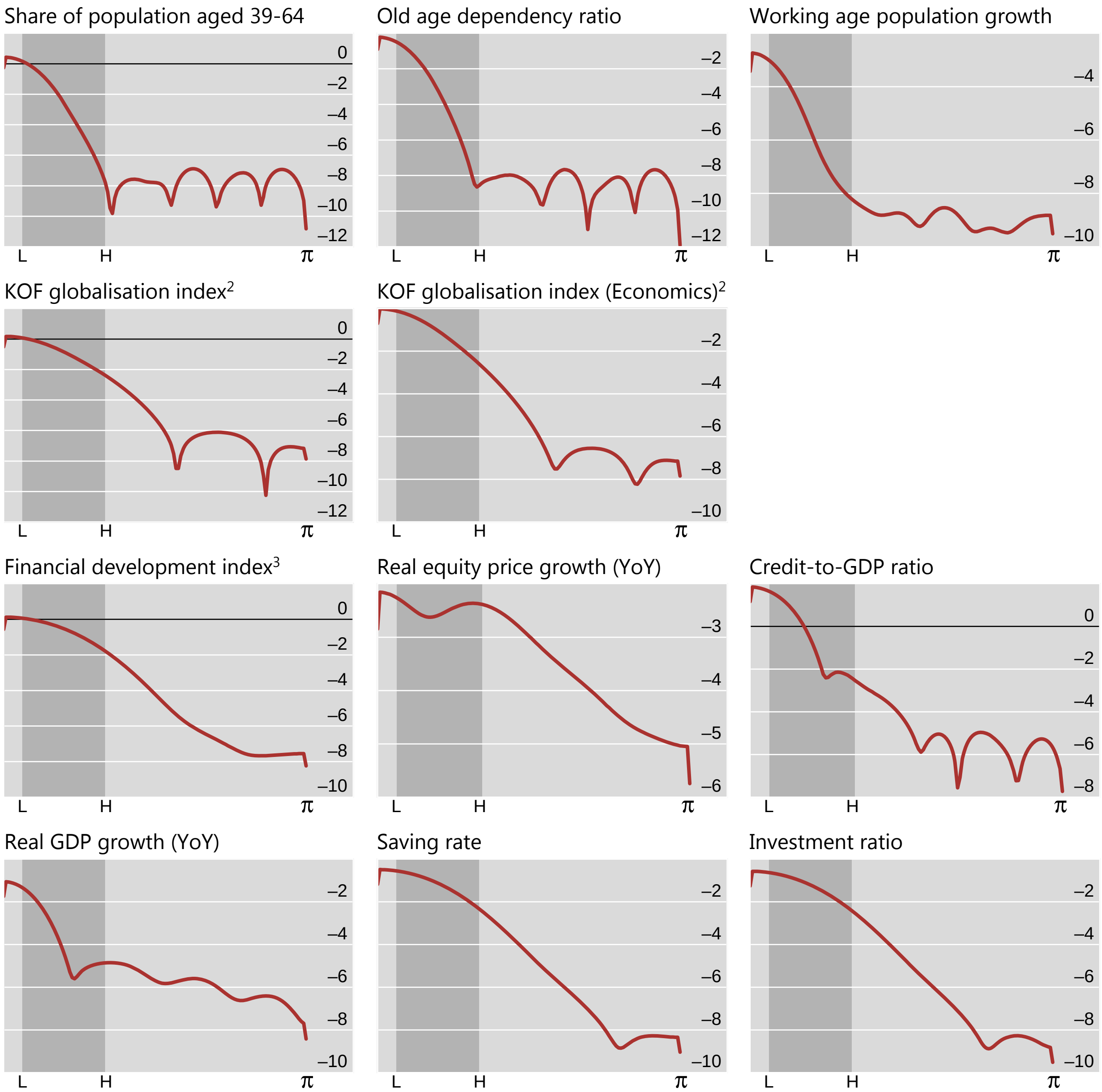
Horizontal axis indicates frequency ranging from 0 to π; vertical axis indicates spectral density. The shaded area indicates the business-cycle frequency, ranging from six quarters (marked by "H") to 32 quarters (marked by "L"). The area between 0 and L corresponds to the low frequency range which contains the trend component.

[1] Spectral density, or power spectrum, is estimated using Welch's method. It records the contribution of the component(s) belonging to a specific frequency or frequency band to the total variance of a stochastic process. [2] The overall KOF Index of Globalisation covers the economic, social and political dimensions of globalisation. For details on the Index and the Economics sub-index, see Dreher (2006) and Dreher, Gaston and Martens (2008). [3] For details on the financial development index, see Sahay et al (2015).

Source: author's calculations.

Cospectral density estimates: Japan[1]

In logarithm, with real interest rate — Graph B.2.5.2



Horizontal axis indicates frequency ranging from 0 to π; vertical axis indicates spectral density. The shaded area indicates the business-cycle frequency, ranging from six quarters (marked by "H") to 32 quarters (marked by "L"). The area between 0 and L corresponds to the low frequency range which contains the trend component.

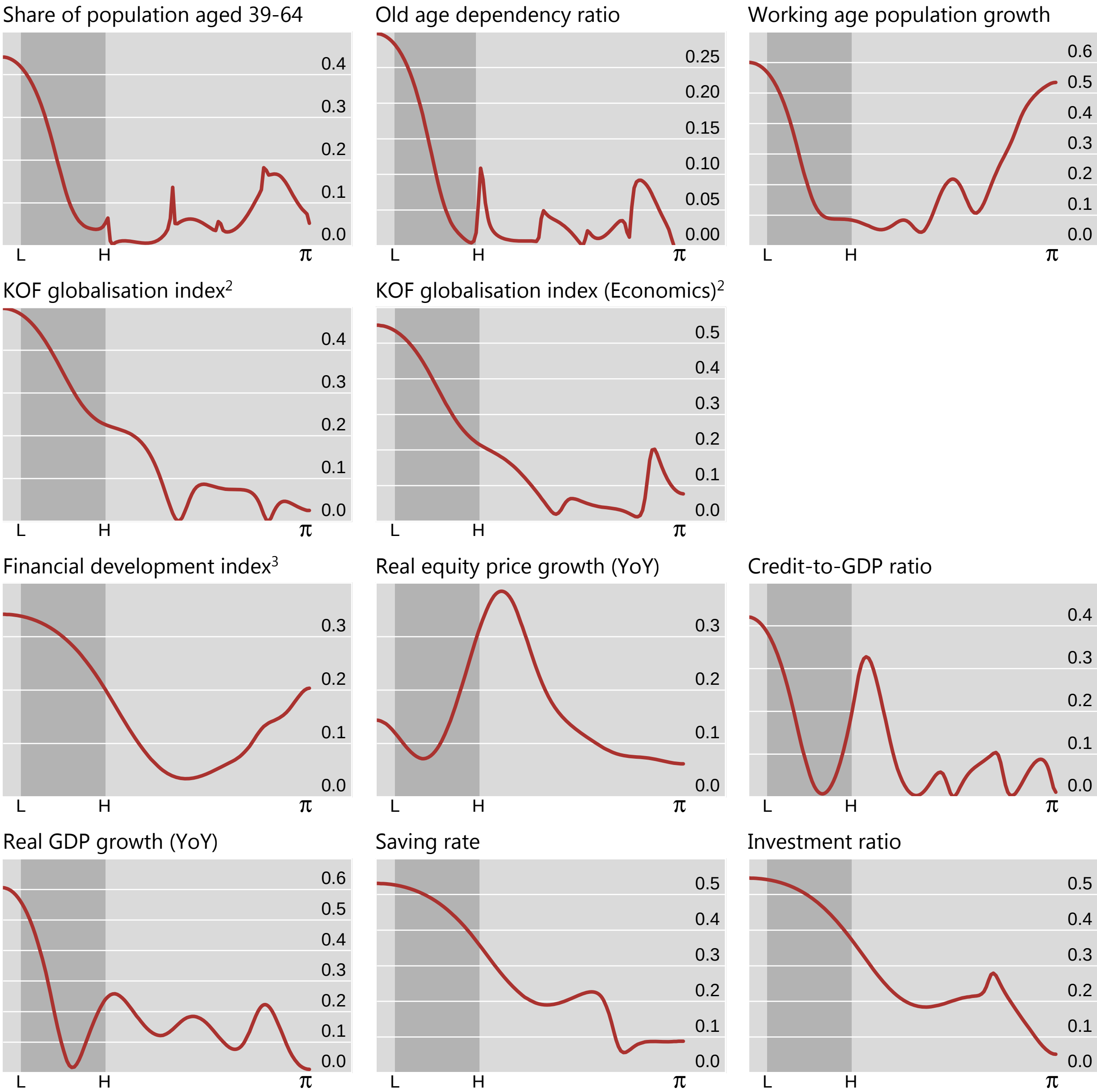
[1] Cospectral density, also known as cross power spectral density or cospectrum, is estimated using Welch's averaged, modified periodogram method. It represents the covariance between the in-phase components of two stochastic processes at a specific frequency or frequency band. [2] The overall KOF Index of Globalisation covers the economic, social and political dimensions of globalisation. For details on the Index and the Economics sub-index, see Dreher (2006) and Dreher, Gaston and Martens (2008). [3] For details on the financial development index, see Sahay et al (2015).

Source: author's calculations.

Squared coherence estimates: Japan[1]

With real interest rate

Graph B.2.5.3



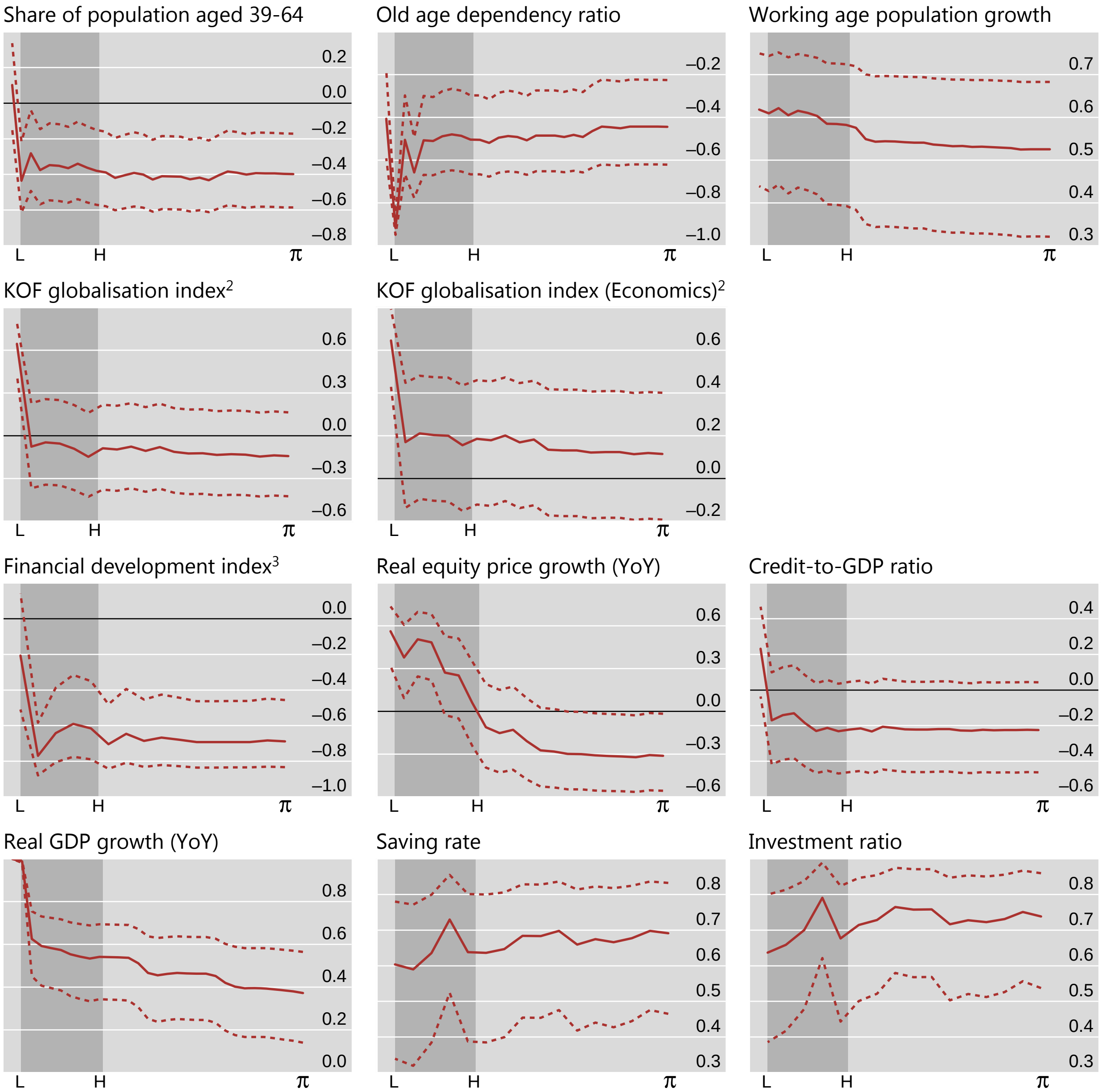
Horizontal axis indicates frequency ranging from 0 to π; vertical axis indicates spectral density. The shaded area indicates the business-cycle frequency, ranging from six quarters (marked by "H") to 32 quarters (marked by "L"). The area between 0 and L corresponds to the low frequency range which contains the trend component.

[1] Squared coherence, known as coherency, is estimated using Welch's averaged periodogram method. It is similar to the coefficient of determination R^2, and measures the strength of linear association between two stochastic processes at a specific frequency or frequency band. [2] The overall KOF Index of Globalisation covers the economic, social and political dimensions of globalisation. For details on the Index and the Economics sub-index, see Dreher (2006) and Dreher, Gaston and Martens (2008). [3] For details on the financial development index, see Sahay et al (2015).

Source: author's calculations.

Frequency-specific correlation coefficient estimates: Japan[1]

With real interest rate Graph B.2.5.4



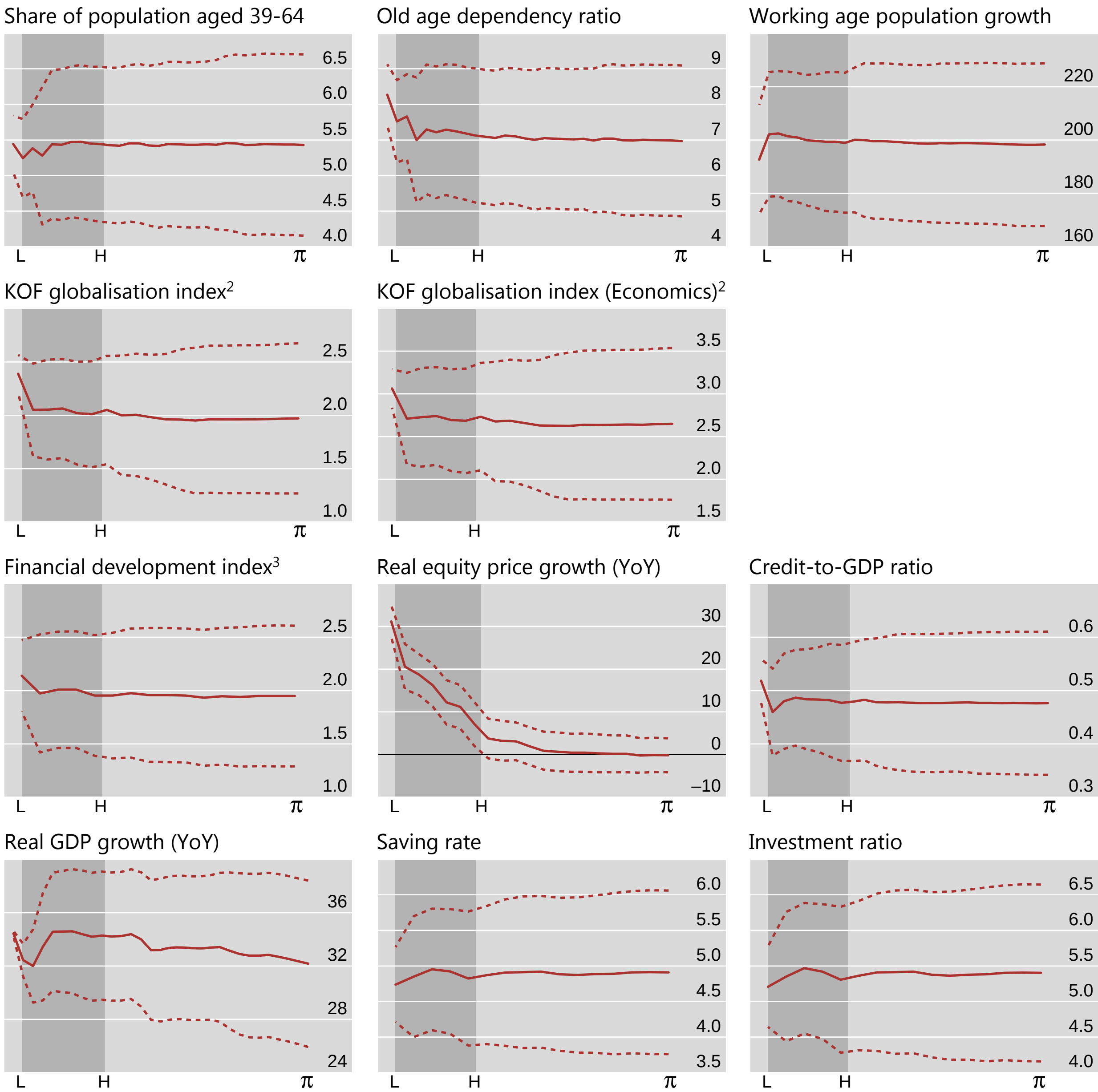
Horizontal axis indicates frequency ranging from 0 to π; vertical axis indicates spectral density. The dashed lines indicate 95% confidence intervals. The shaded area indicates the business-cycle frequency, ranging from six quarters (marked by "H") to 32 quarters (marked by "L"). The area between 0 and L corresponds to the low frequency range which contains the trend component.

[1] The frequency-specific coefficient of correlation measures the strength of correlation between two stochastic processes at a specific frequency or frequency band. See Zhu (2005). [2] The overall KOF Index of Globalisation covers the economic, social and political dimensions of globalisation. For details on the Index and the Economics sub-index, see Dreher (2006) and Dreher, Gaston and Martens (2008). [3] For details on the financial development index, see Sahay et al (2015).

Source: author's calculations.

Frequency-specific regression coefficient estimates: Japan[1]

Real interest rate as regressand | Graph B.2.5.5



Horizontal axis indicates frequency ranging from 0 to π; vertical axis indicates spectral density. The dashed lines indicate 95% confidence intervals. The shaded area indicates the business-cycle frequency, ranging from six quarters (marked by "H") to 32 quarters (marked by "L"). The area between 0 and L corresponds to the low frequency range which contains the trend component.

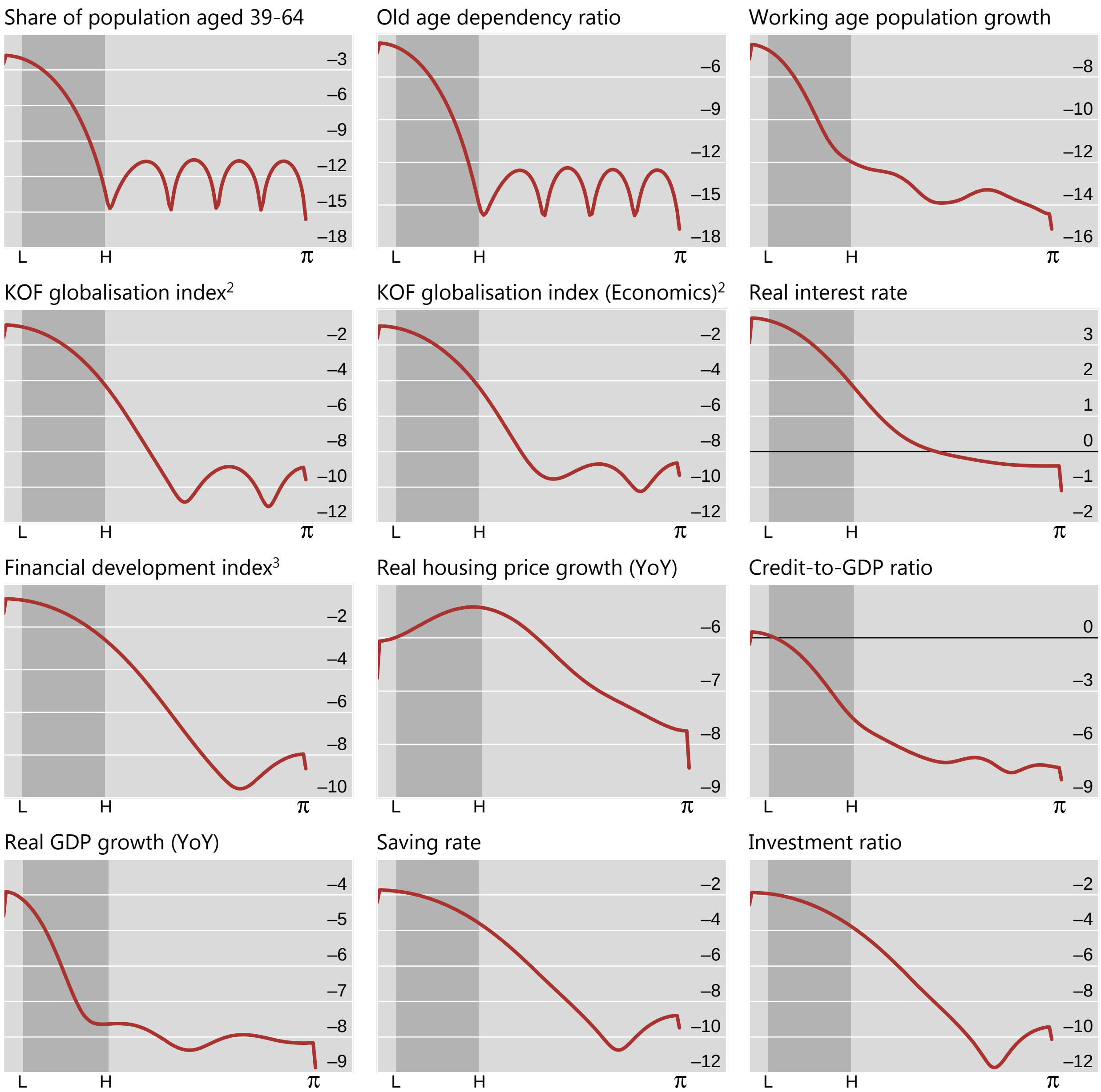
[1] The frequency-specific coefficient of regression indicates the degree of linear association between two stochastic processes at a specific frequency or frequency band. See Zhu (2005). [2] The overall KOF Index of Globalisation covers the economic, social and political dimensions of globalisation. For details on the Index and the Economics sub-index, see Dreher (2006) and Dreher, Gaston and Martens (2008). [3] For details on the financial development index, see Sahay et al (2015).

Source: author's calculations.

B.2.6. Korea

Spectral density estimates: Korea[1]

In logarithm Graph B.2.6.1



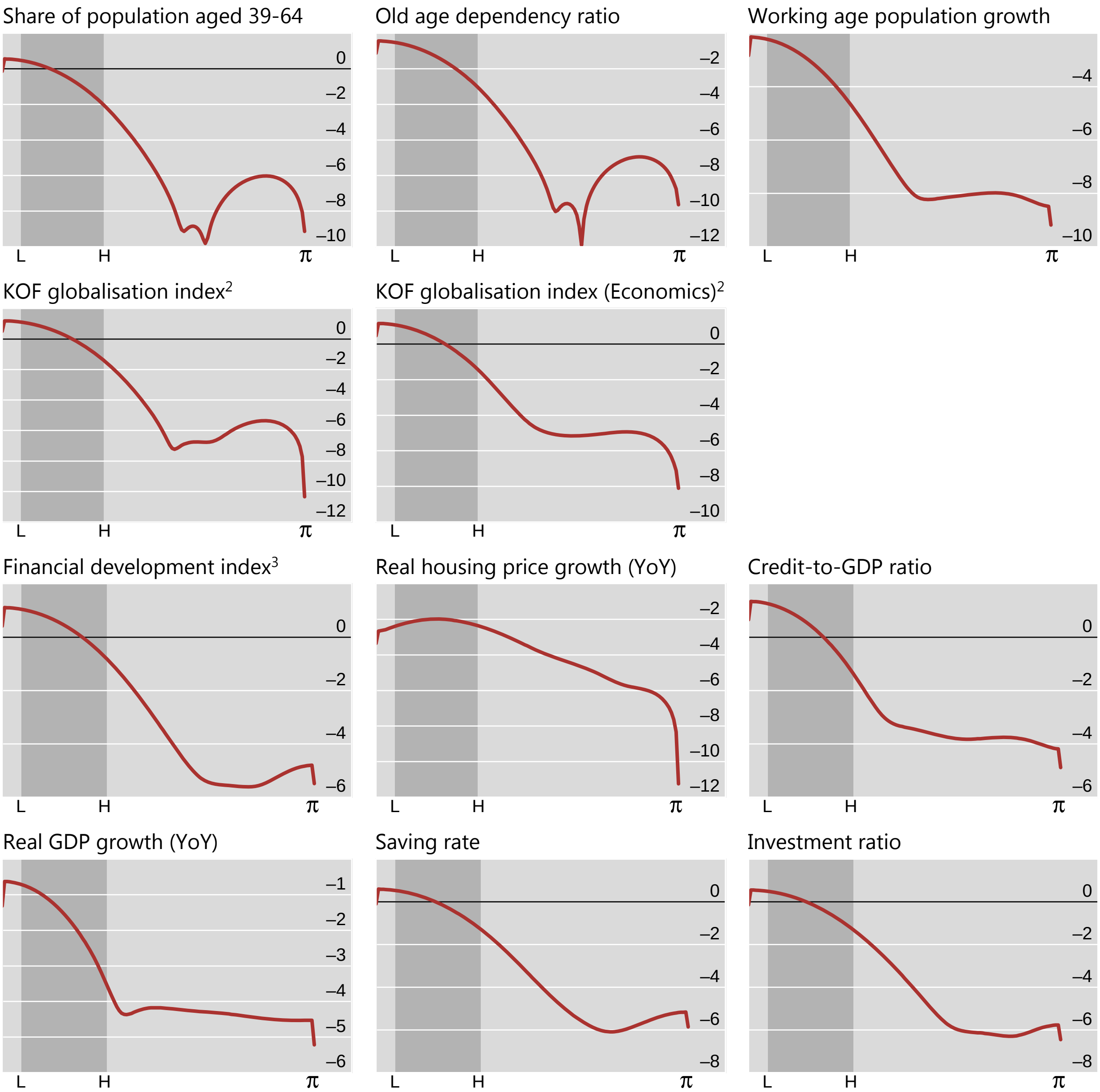
Horizontal axis indicates frequency ranging from 0 to π; vertical axis indicates spectral density. The shaded area indicates the business-cycle frequency, ranging from six quarters (marked by "H") to 32 quarters (marked by "L"). The area between 0 and L corresponds to the low frequency range which contains the trend component.

[1] Spectral density, or power spectrum, is estimated using Welch's method. It records the contribution of the component(s) belonging to a specific frequency or frequency band to the total variance of a stochastic process. [2] The overall KOF Index of Globalisation covers the economic, social and political dimensions of globalisation. For details on the Index and the Economics sub-index, see Dreher (2006) and Dreher, Gaston and Martens (2008). [3] For details on the financial development index, see Sahay et al (2015).

Source: author's calculations.

Cospectral density estimates: Korea[1]

In logarithm, with real interest rate — Graph B.2.6.2



Horizontal axis indicates frequency ranging from 0 to π; vertical axis indicates spectral density. The shaded area indicates the business-cycle frequency, ranging from six quarters (marked by "H") to 32 quarters (marked by "L"). The area between 0 and L corresponds to the low frequency range which contains the trend component.

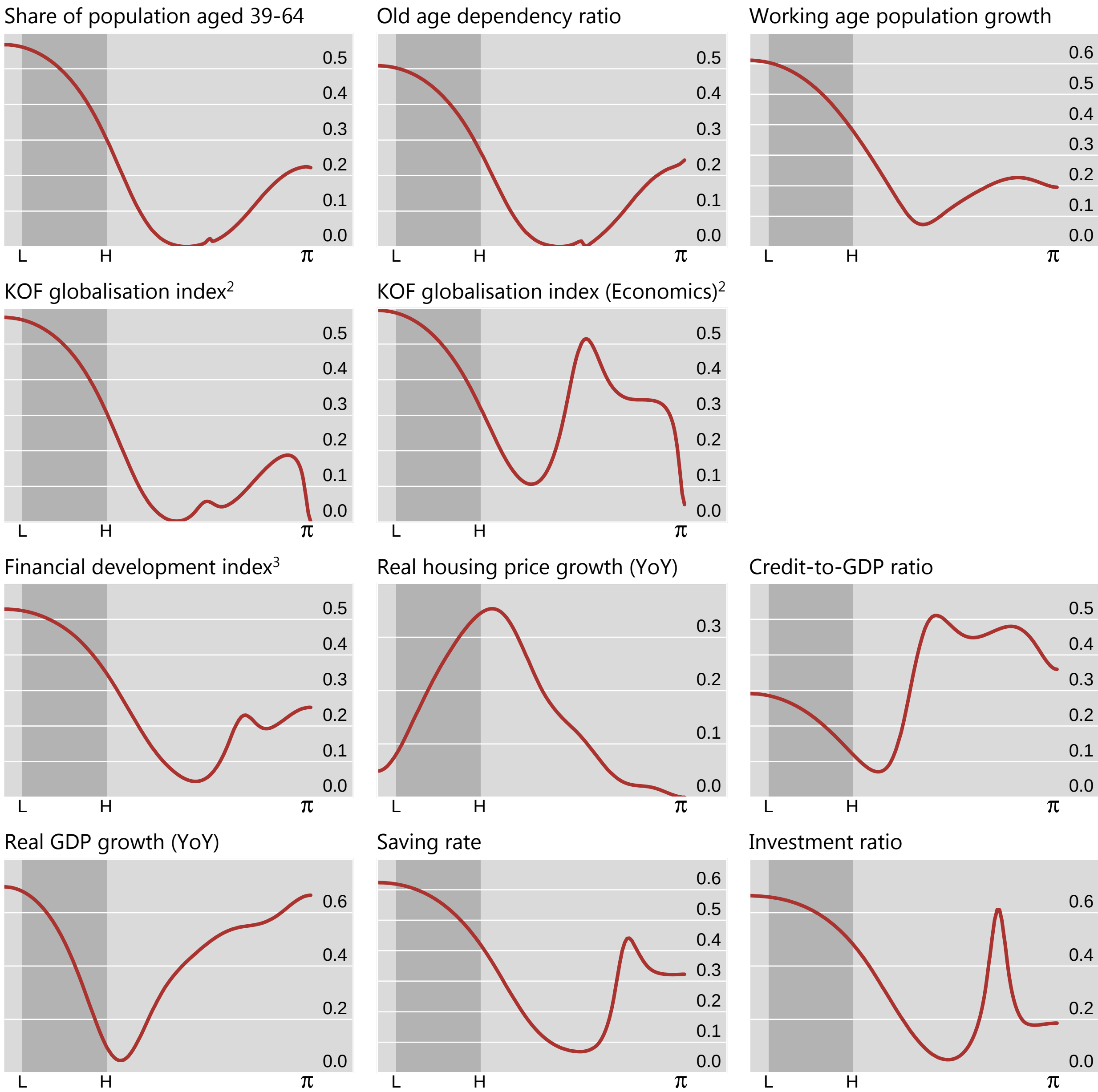
[1] Cospectral density, also known as cross power spectral density or cospectrum, is estimated using Welch's averaged, modified periodogram method. It represents the covariance between the in-phase components of two stochastic processes at a specific frequency or frequency band. [2] The overall KOF Index of Globalisation covers the economic, social and political dimensions of globalisation. For details on the Index and the Economics sub-index, see Dreher (2006) and Dreher, Gaston and Martens (2008). [3] For details on the financial development index, see Sahay et al (2015).

Source: author's calculations.

Squared coherence estimates: Korea[1]

With real interest rate

Graph B.2.6.3



Horizontal axis indicates frequency ranging from 0 to π; vertical axis indicates spectral density. The shaded area indicates the business-cycle frequency, ranging from six quarters (marked by "H") to 32 quarters (marked by "L"). The area between 0 and L corresponds to the low frequency range which contains the trend component.

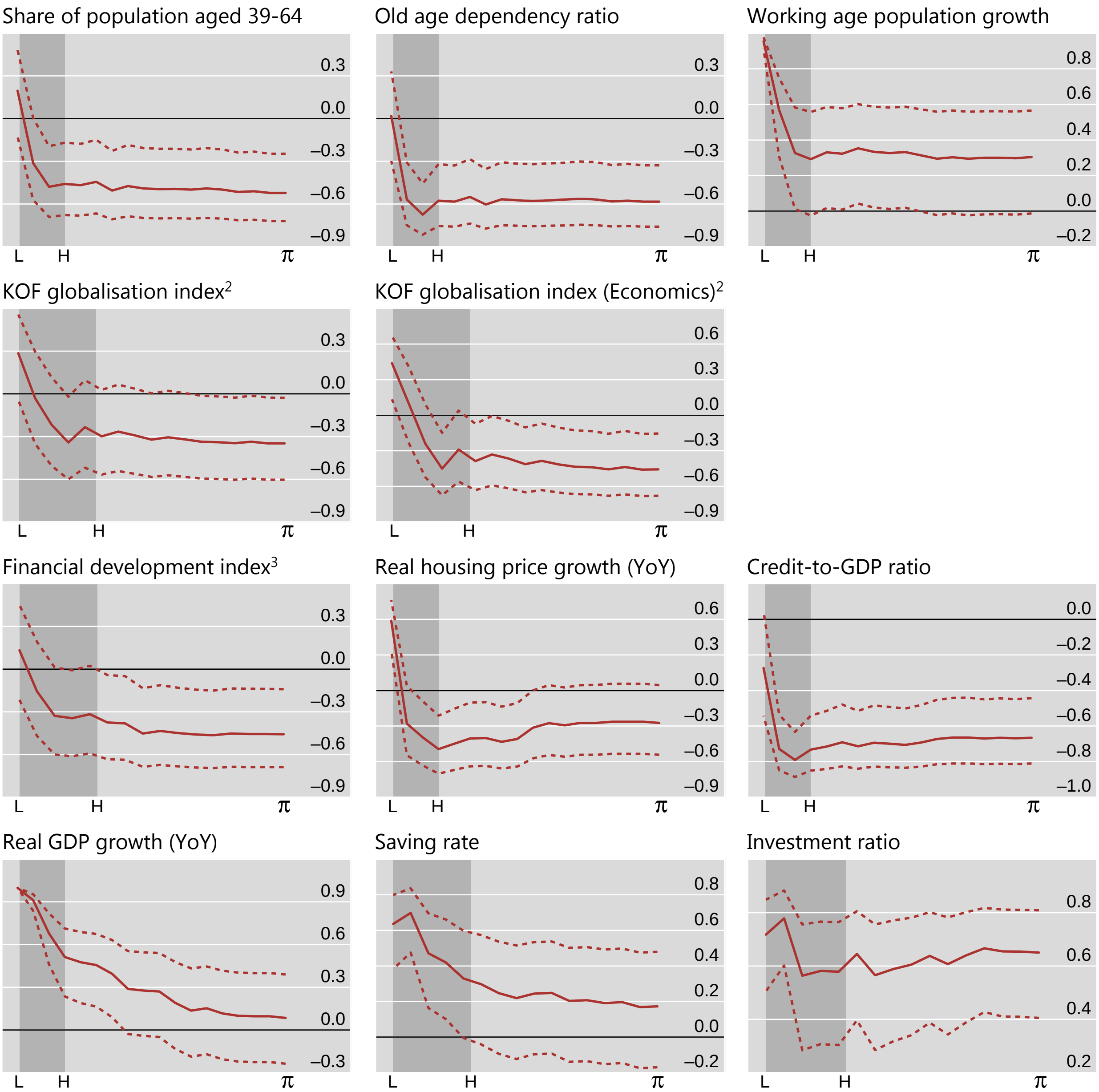
[1] Squared coherence, known as coherency, is estimated using Welch's averaged periodogram method. It is similar to the coefficient of determination R^2, and measures the strength of linear association between two stochastic processes at a specific frequency or frequency band. [2] The overall KOF Index of Globalisation covers the economic, social and political dimensions of globalisation. For details on the Index and the Economics sub-index, see Dreher (2006) and Dreher, Gaston and Martens (2008). [3] For details on the financial development index, see Sahay et al (2015).

Source: author's calculations.

Frequency-specific correlation coefficient estimates: Korea[1]

With real interest rate

Graph B.2.6.4



Horizontal axis indicates frequency ranging from 0 to π; vertical axis indicates spectral density. The dashed lines indicate 95% confidence intervals. The shaded area indicates the business-cycle frequency, ranging from six quarters (marked by "H") to 32 quarters (marked by "L"). The area between 0 and L corresponds to the low frequency range which contains the trend component.

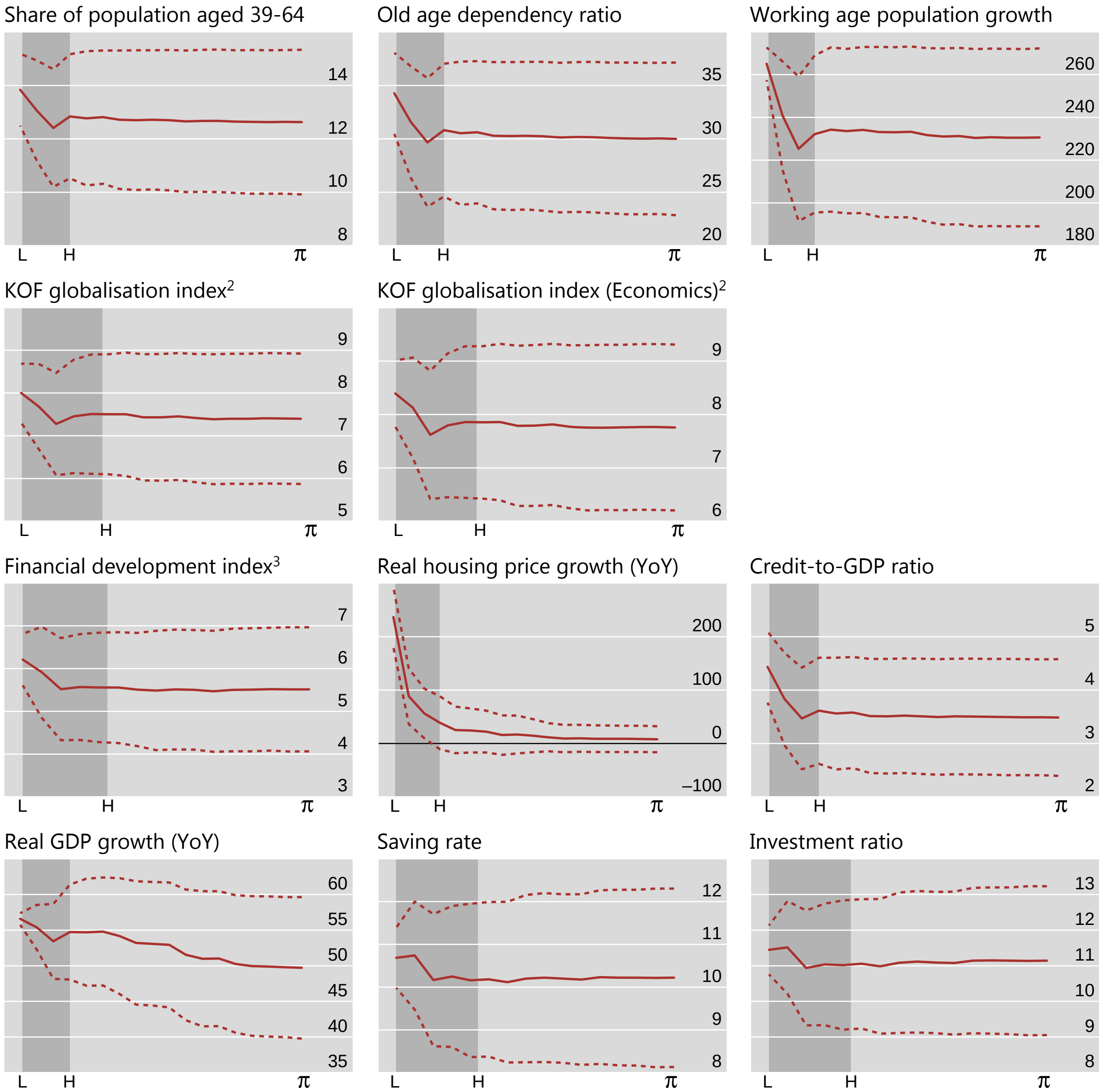
[1] The frequency-specific coefficient of correlation measures the strength of correlation between two stochastic processes at a specific frequency or frequency band. See Zhu (2005). [2] The overall KOF Index of Globalisation covers the economic, social and political dimensions of globalisation. For details on the Index and the Economics sub-index, see Dreher (2006) and Dreher, Gaston and Martens (2008). [3] For details on the financial development index, see Sahay et al (2015).

Source: author's calculations.

Frequency-specific regression coefficient estimates: Korea[1]

Real interest rate as regressand

Graph B.2.6.5



Horizontal axis indicates frequency ranging from 0 to π; vertical axis indicates spectral density. The dashed lines indicate 95% confidence intervals. The shaded area indicates the business-cycle frequency, ranging from six quarters (marked by "H") to 32 quarters (marked by "L"). The area between 0 and L corresponds to the low frequency range which contains the trend component.

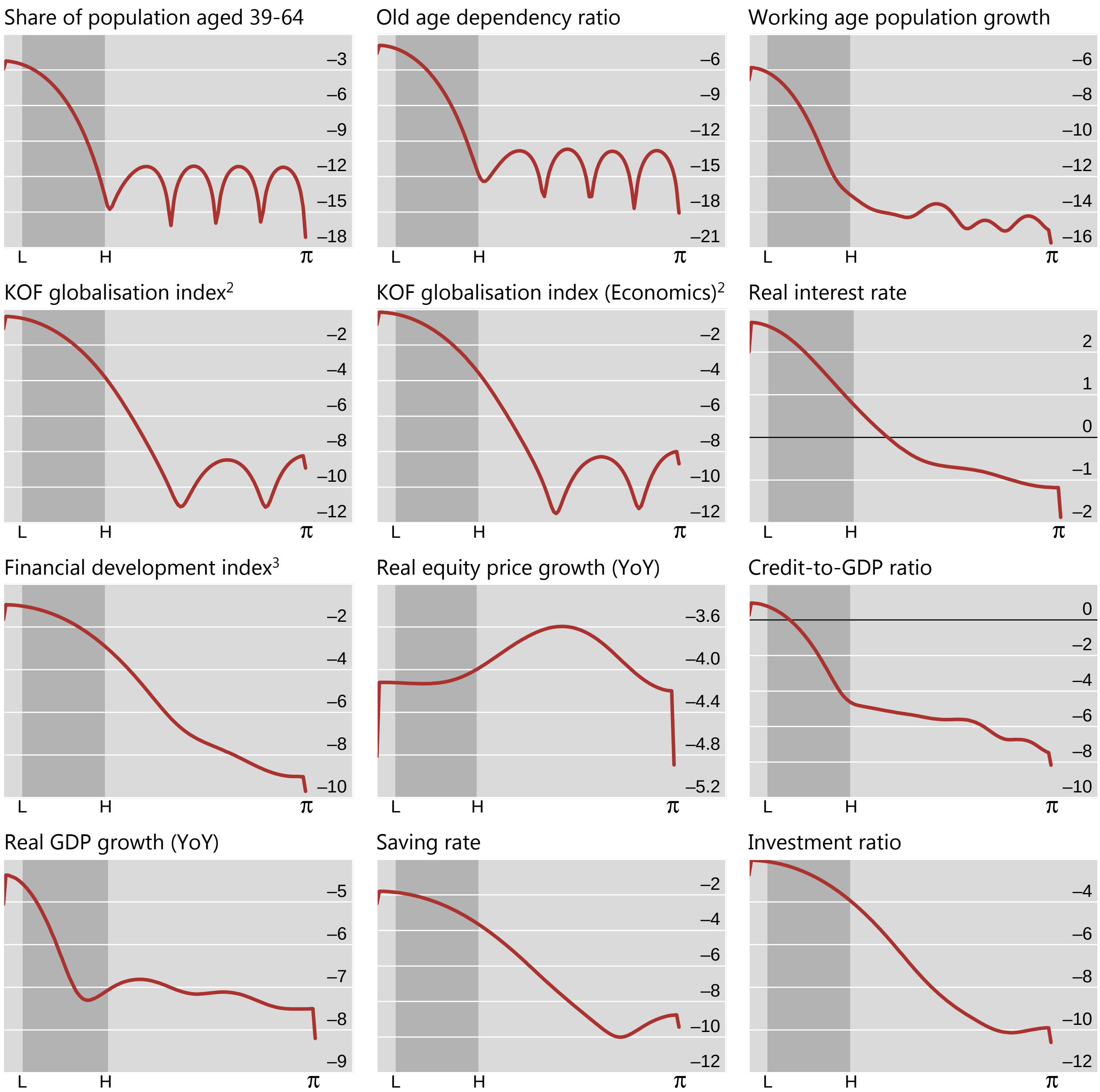
[1] The frequency-specific coefficient of regression indicates the degree of linear association between two stochastic processes at a specific frequency or frequency band. See Zhu (2005). [2] The overall KOF Index of Globalisation covers the economic, social and political dimensions of globalisation. For details on the Index and the Economics sub-index, see Dreher (2006) and Dreher, Gaston and Martens (2008). [3] For details on the financial development index, see Sahay et al (2015).

Source: author's calculations.

B.2.7. Malaysia

Spectral density estimates: Malaysia[1]

In logarithm — Graph B.2.7.1



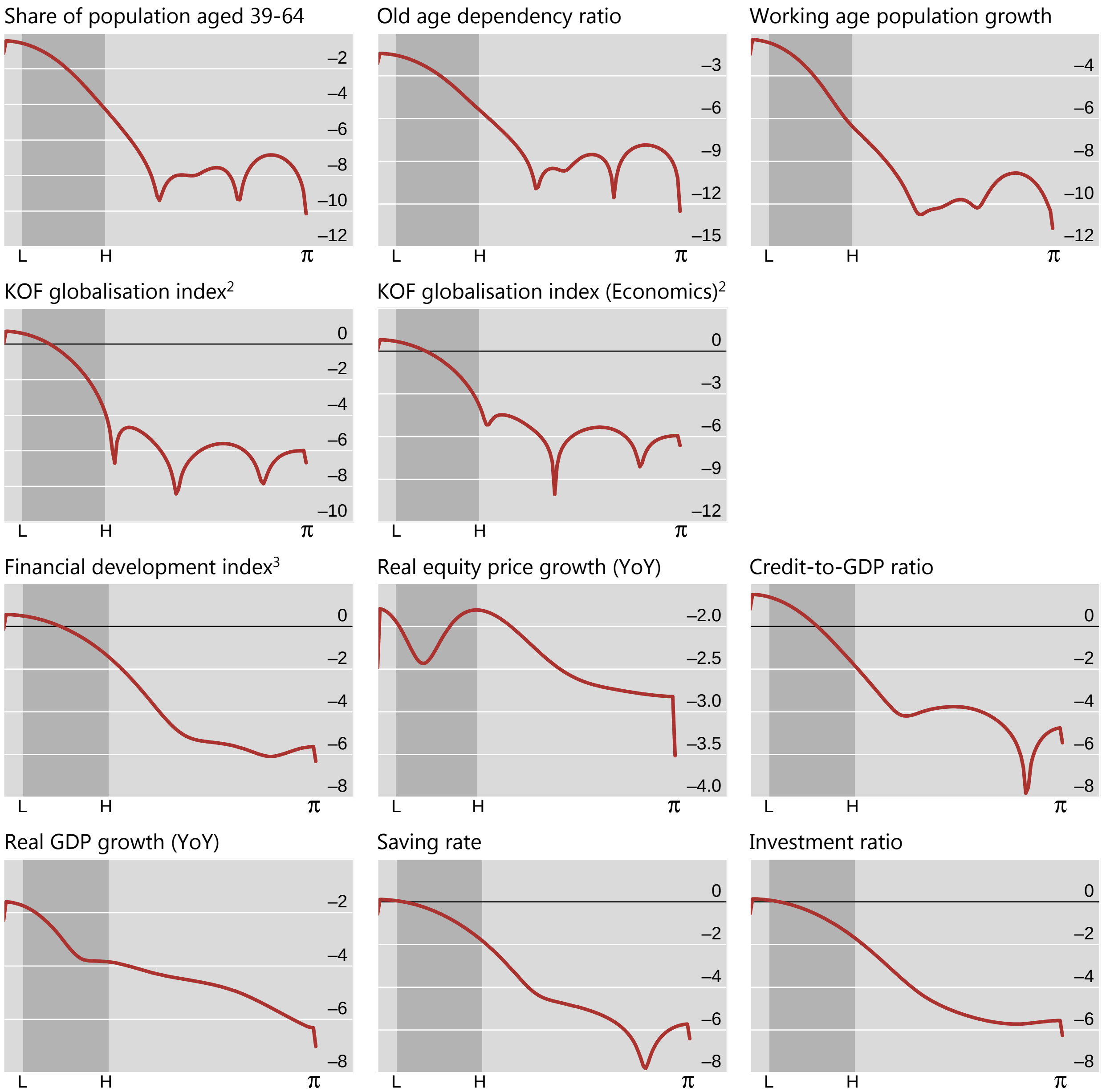
Horizontal axis indicates frequency ranging from 0 to π; vertical axis indicates spectral density. The shaded area indicates the business-cycle frequency, ranging from six quarters (marked by "H") to 32 quarters (marked by "L"). The area between 0 and L corresponds to the low frequency range which contains the trend component.

[1] Spectral density, or power spectrum, is estimated using Welch's method. It records the contribution of the component(s) belonging to a specific frequency or frequency band to the total variance of a stochastic process. [2] The overall KOF Index of Globalisation covers the economic, social and political dimensions of globalisation. For details on the Index and the Economics sub-index, see Dreher (2006) and Dreher, Gaston and Martens (2008). [3] For details on the financial development index, see Sahay et al (2015).

Source: author's calculations.

Cospectral density estimates: Malaysia[1]

In logarithm, with real interest rate Graph B.2.7.2



Horizontal axis indicates frequency ranging from 0 to π; vertical axis indicates spectral density. The shaded area indicates the business-cycle frequency, ranging from six quarters (marked by "H") to 32 quarters (marked by "L"). The area between 0 and L corresponds to the low frequency range which contains the trend component.

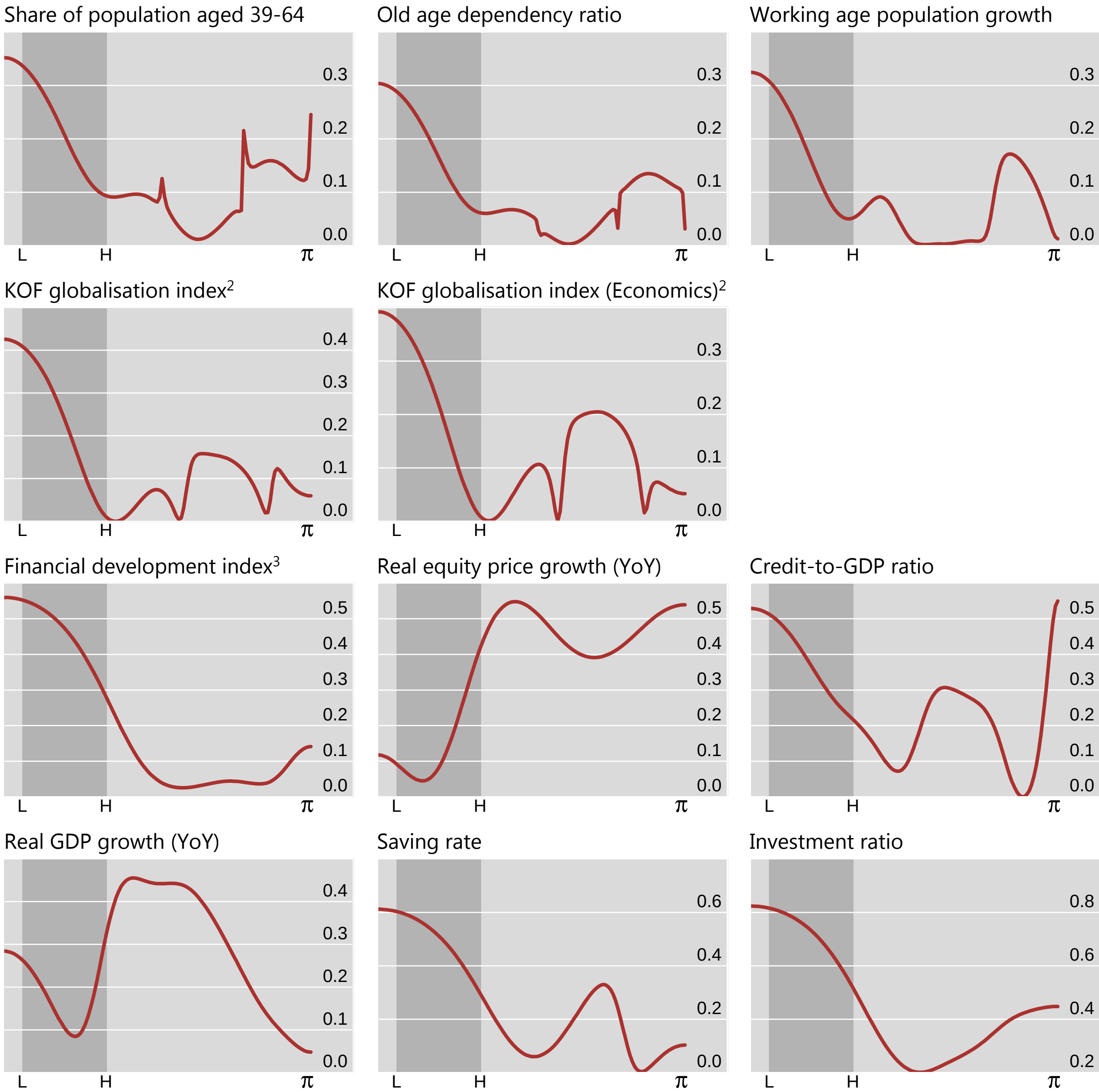
[1] Cospectral density, also known as cross power spectral density or cospectrum, is estimated using Welch's averaged, modified periodogram method. It represents the covariance between the in-phase components of two stochastic processes at a specific frequency or frequency band. [2] The overall KOF Index of Globalisation covers the economic, social and political dimensions of globalisation. For details on the Index and the Economics sub-index, see Dreher (2006) and Dreher, Gaston and Martens (2008). [3] For details on the financial development index, see Sahay et al (2015).

Source: author's calculations.

Squared coherence estimates: Malaysia[1]

With real interest rate

Graph B.2.7.3



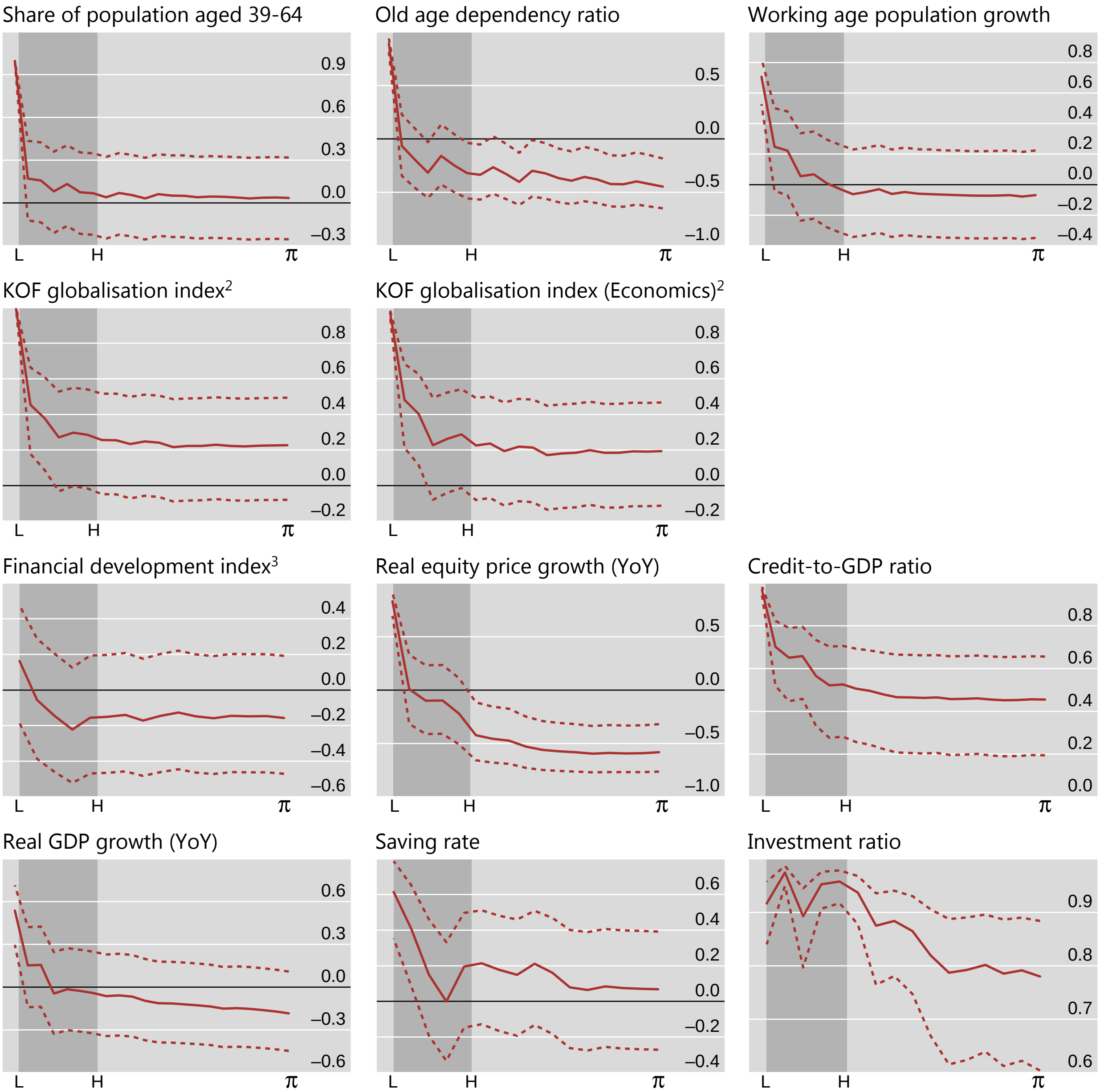
Horizontal axis indicates frequency ranging from 0 to π; vertical axis indicates spectral density. The shaded area indicates the business-cycle frequency, ranging from six quarters (marked by "H") to 32 quarters (marked by "L"). The area between 0 and L corresponds to the low frequency range which contains the trend component.

[1] Squared coherence, known as coherency, is estimated using Welch's averaged periodogram method. It is similar to the coefficient of determination R^2, and measures the strength of linear association between two stochastic processes at a specific frequency or frequency band. [2] The overall KOF Index of Globalisation covers the economic, social and political dimensions of globalisation. For details on the Index and the Economics sub-index, see Dreher (2006) and Dreher, Gaston and Martens (2008). [3] For details on the financial development index, see Sahay et al (2015).

Source: author's calculations.

Frequency-specific correlation coefficient estimates: Malaysia[1]

With real interest rate | Graph B.2.7.4



Horizontal axis indicates frequency ranging from 0 to π; vertical axis indicates spectral density. The dashed lines indicate 95% confidence intervals. The shaded area indicates the business-cycle frequency, ranging from six quarters (marked by "H") to 32 quarters (marked by "L"). The area between 0 and L corresponds to the low frequency range which contains the trend component.

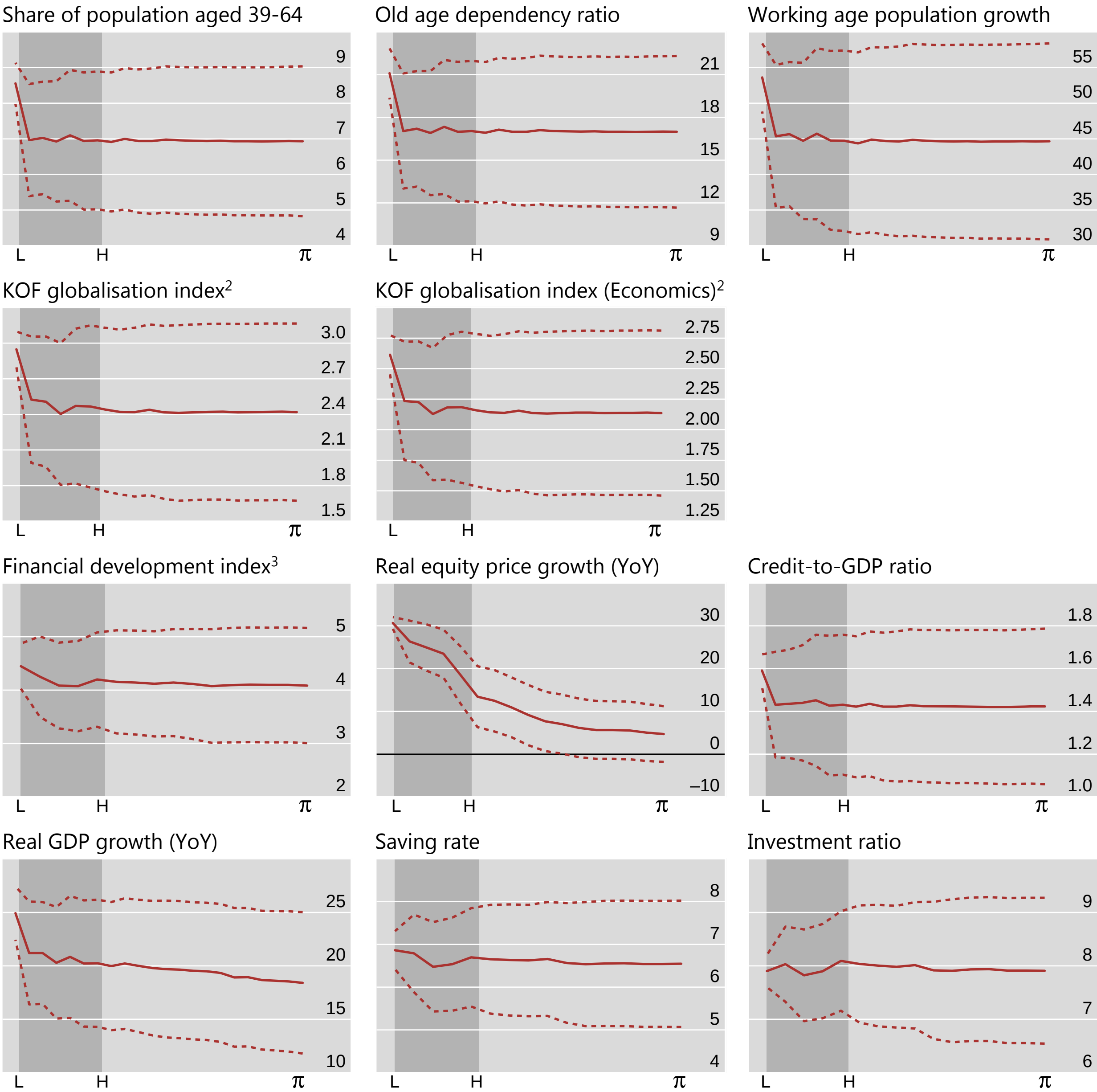
[1] The frequency-specific coefficient of correlation measures the strength of correlation between two stochastic processes at a specific frequency or frequency band. See Zhu (2005). [2] The overall KOF Index of Globalisation covers the economic, social and political dimensions of globalisation. For details on the Index and the Economics sub-index, see Dreher (2006) and Dreher, Gaston and Martens (2008). [3] For details on the financial development index, see Sahay et al (2015).

Source: author's calculations.

Frequency-specific regression coefficient estimates: Malaysia[1]

Real interest rate as regressand

Graph B.2.7.5



Horizontal axis indicates frequency ranging from 0 to π; vertical axis indicates spectral density. The dashed lines indicate 95% confidence intervals. The shaded area indicates the business-cycle frequency, ranging from six quarters (marked by "H") to 32 quarters (marked by "L"). The area between 0 and L corresponds to the low frequency range which contains the trend component.

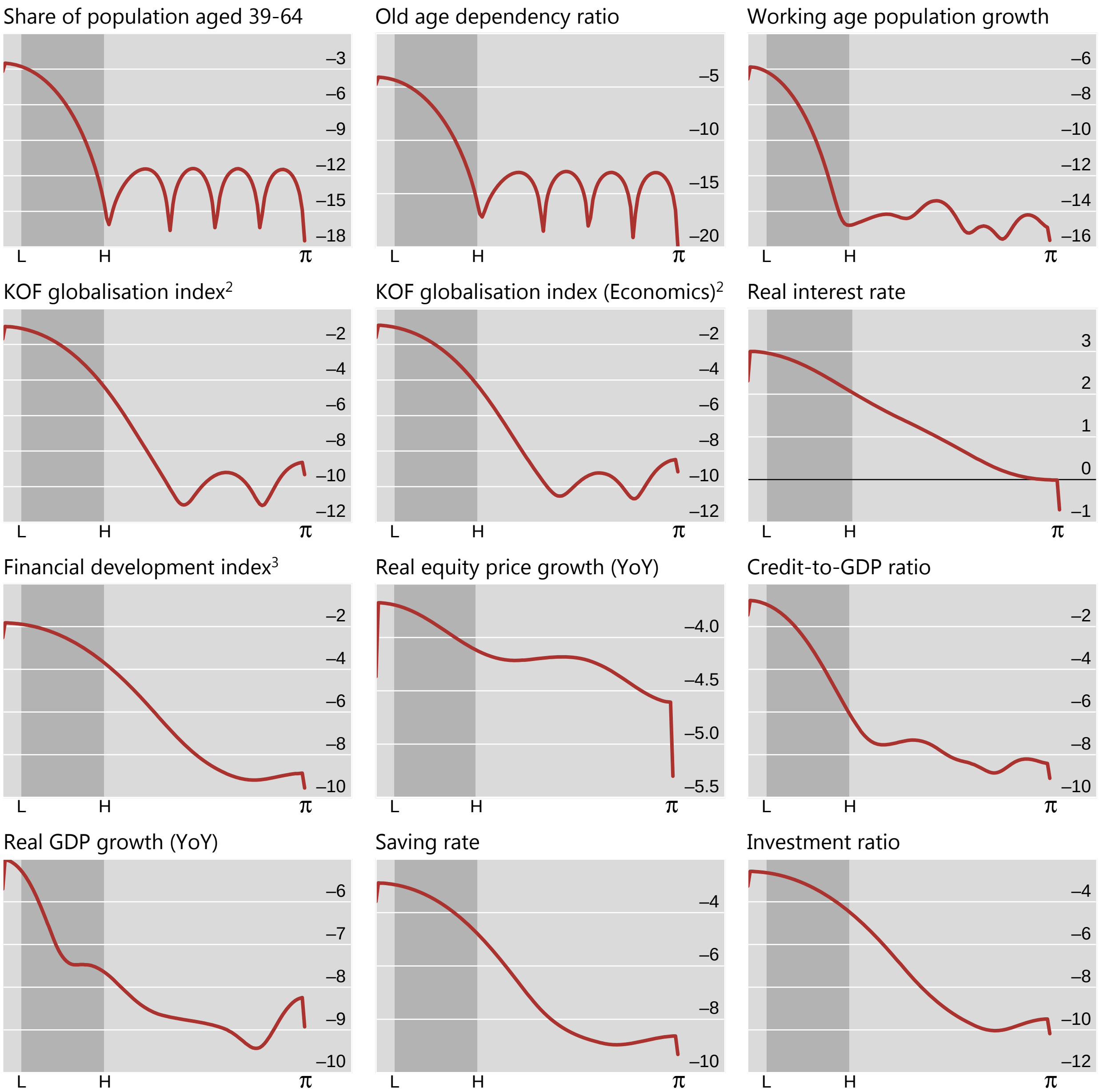
[1] The frequency-specific coefficient of regression indicates the degree of linear association between two stochastic processes at a specific frequency or frequency band. See Zhu (2005). [2] The overall KOF Index of Globalisation covers the economic, social and political dimensions of globalisation. For details on the Index and the Economics sub-index, see Dreher (2006) and Dreher, Gaston and Martens (2008). [3] For details on the financial development index, see Sahay et al (2015).

Source: author's calculations.

B.2.8. The Philippines

Spectral density estimates: Philippines[1]

In logarithm | Graph B.2.8.1



Horizontal axis indicates frequency ranging from 0 to π; vertical axis indicates spectral density. The shaded area indicates the business-cycle frequency, ranging from six quarters (marked by "H") to 32 quarters (marked by "L"). The area between 0 and L corresponds to the low frequency range which contains the trend component.

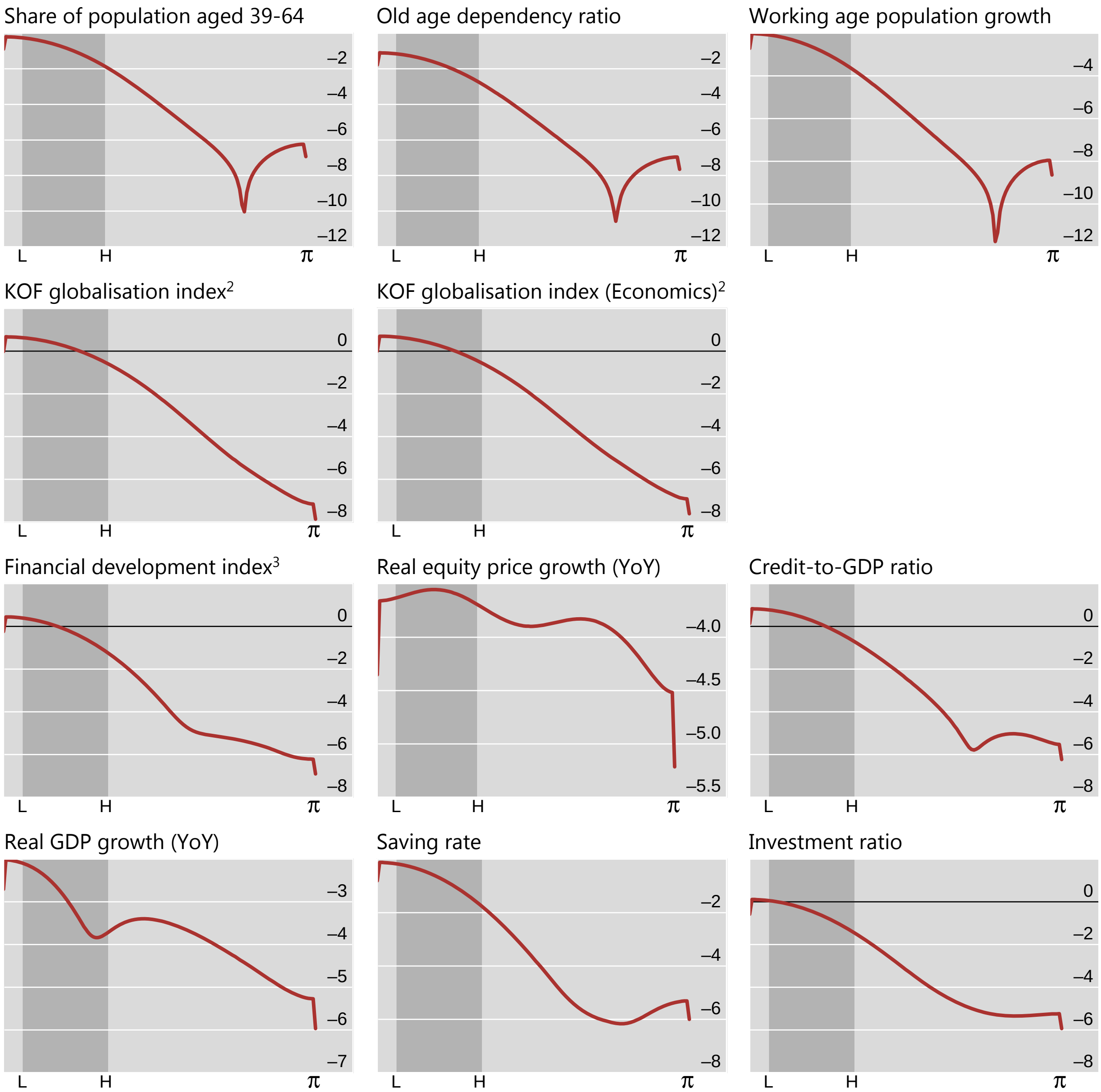
[1] Spectral density, or power spectrum, is estimated using Welch's method. It records the contribution of the component(s) belonging to a specific frequency or frequency band to the total variance of a stochastic process. [2] The overall KOF Index of Globalisation covers the economic, social and political dimensions of globalisation. For details on the Index and the Economics sub-index, see Dreher (2006) and Dreher, Gaston and Martens (2008). [3] For details on the financial development index, see Sahay et al (2015).

Source: author's calculations.

Cospectral density estimates: Philippines[1]

In logarithm, with real interest rate

Graph B.2.8.2



Horizontal axis indicates frequency ranging from 0 to π; vertical axis indicates spectral density. The shaded area indicates the business-cycle frequency, ranging from six quarters (marked by "H") to 32 quarters (marked by "L"). The area between 0 and L corresponds to the low frequency range which contains the trend component.

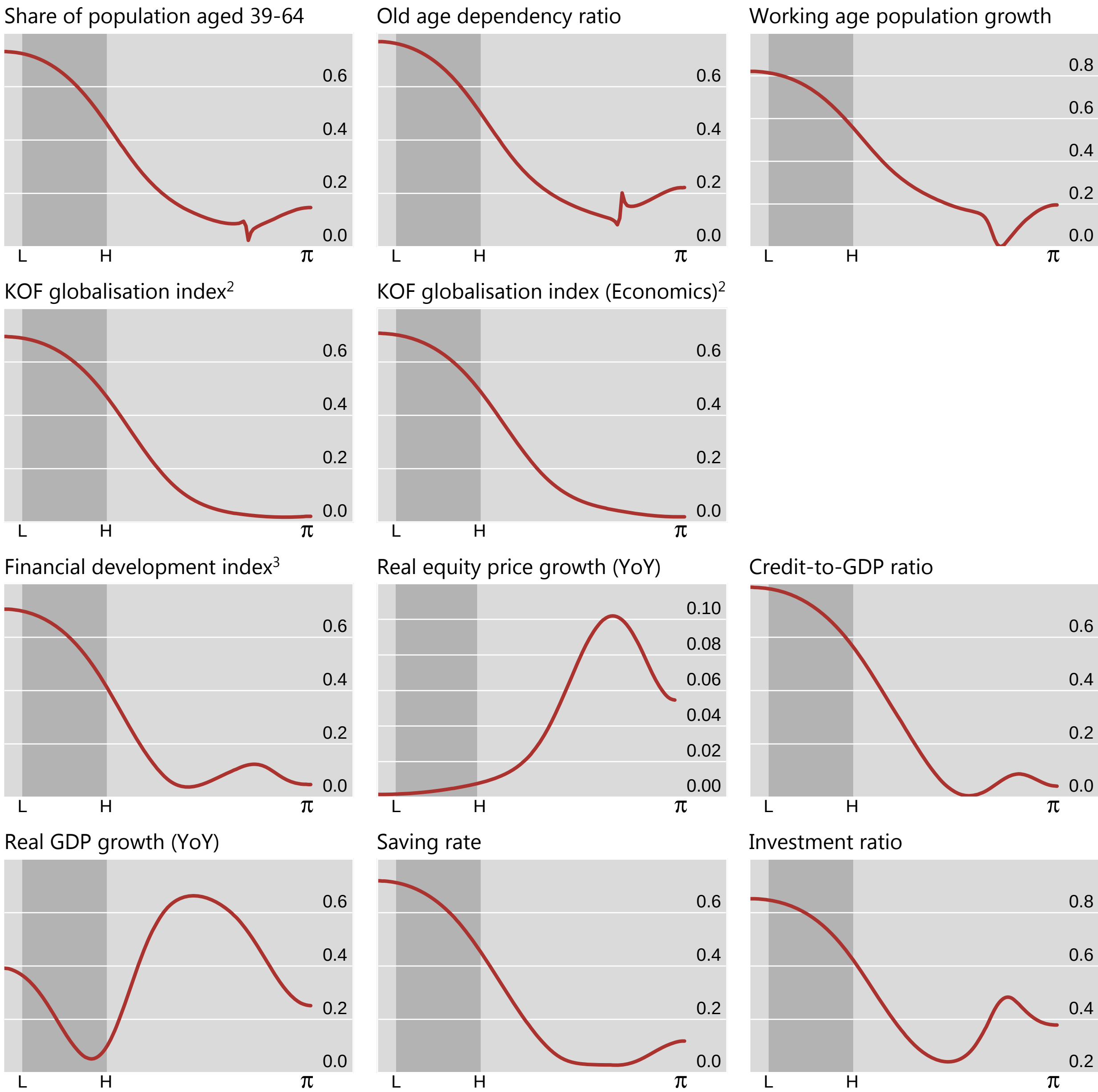
[1] Cospectral density, also known as cross power spectral density or cospectrum, is estimated using Welch's averaged, modified periodogram method. It represents the covariance between the in-phase components of two stochastic processes at a specific frequency or frequency band. [2] The overall KOF Index of Globalisation covers the economic, social and political dimensions of globalisation. For details on the Index and the Economics sub-index, see Dreher (2006) and Dreher, Gaston and Martens (2008). [3] For details on the financial development index, see Sahay et al (2015).

Source: author's calculations.

Squared coherence estimates: Philippines[1]

With real interest rate

Graph B.2.8.3



Horizontal axis indicates frequency ranging from 0 to π; vertical axis indicates spectral density. The shaded area indicates the business-cycle frequency, ranging from six quarters (marked by "H") to 32 quarters (marked by "L"). The area between 0 and L corresponds to the low frequency range which contains the trend component.

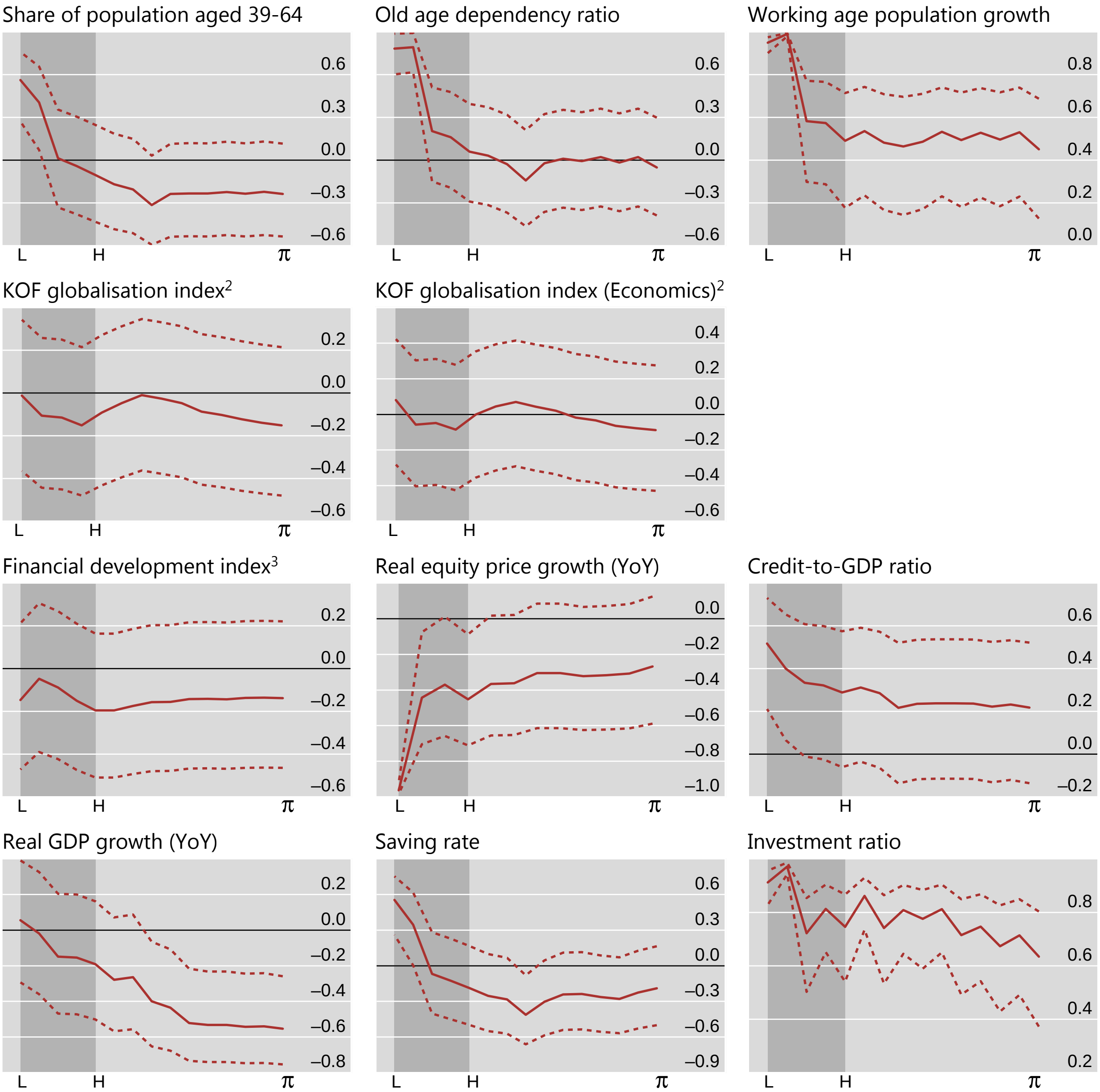
[1] Squared coherence, known as coherency, is estimated using Welch's averaged periodogram method. It is similar to the coefficient of determination R^2, and measures the strength of linear association between two stochastic processes at a specific frequency or frequency band. [2] The overall KOF Index of Globalisation covers the economic, social and political dimensions of globalisation. For details on the Index and the Economics sub-index, see Dreher (2006) and Dreher, Gaston and Martens (2008). [3] For details on the financial development index, see Sahay et al (2015).

Source: author's calculations.

Frequency-specific correlation coefficient estimates: Philippines[1]

With real interest rate

Graph B.2.8.4



Horizontal axis indicates frequency ranging from 0 to π; vertical axis indicates spectral density. The dashed lines indicate 95% confidence intervals. The shaded area indicates the business-cycle frequency, ranging from six quarters (marked by "H") to 32 quarters (marked by "L"). The area between 0 and L corresponds to the low frequency range which contains the trend component.

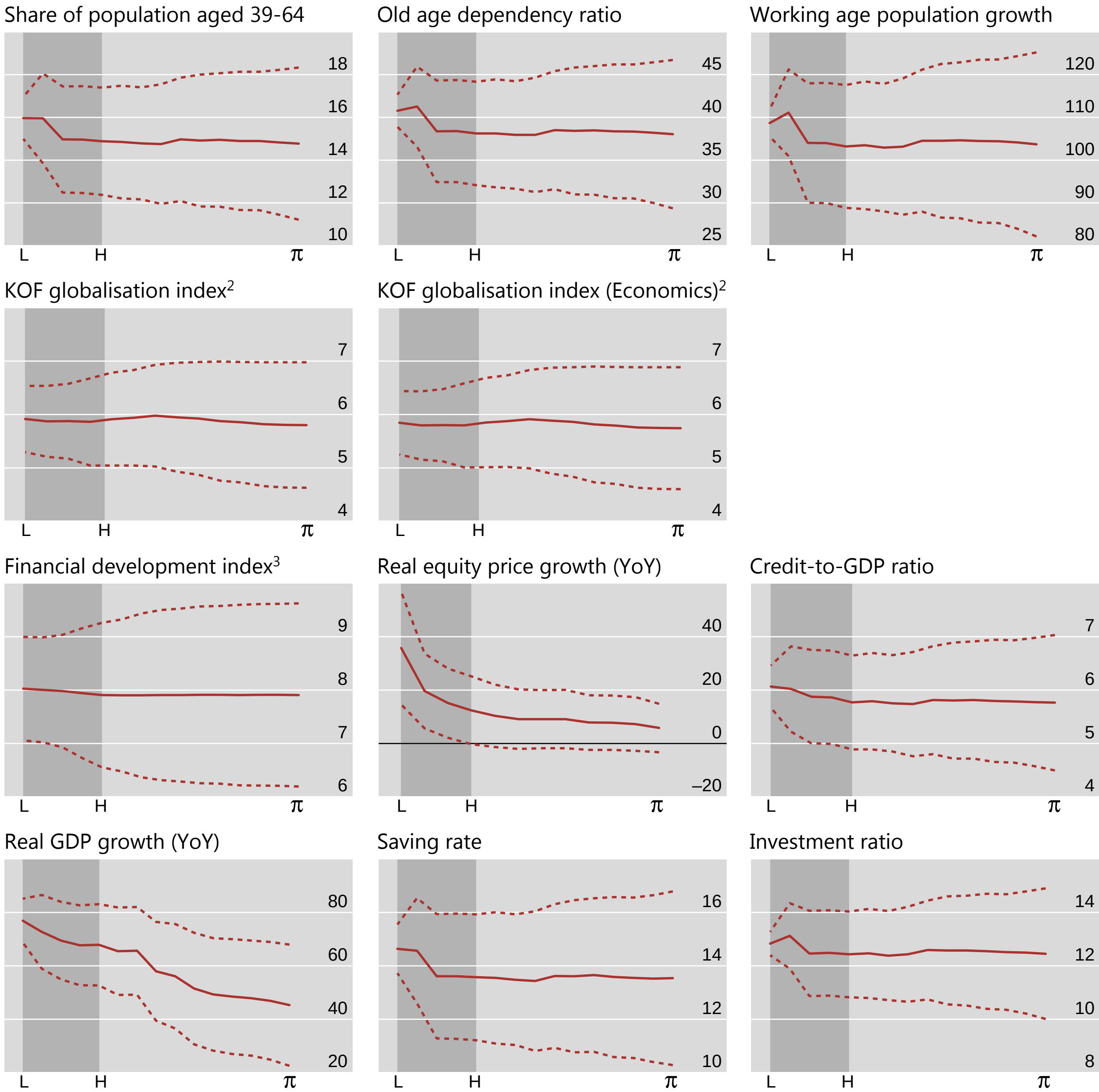
[1] The frequency-specific coefficient of correlation measures the strength of correlation between two stochastic processes at a specific frequency or frequency band. See Zhu (2005). [2] The overall KOF Index of Globalisation covers the economic, social and political dimensions of globalisation. For details on the Index and the Economics sub-index, see Dreher (2006) and Dreher, Gaston and Martens (2008). [3] For details on the financial development index, see Sahay et al (2015).

Source: author's calculations.

Frequency-specific regression coefficient estimates: Philippines[1]

Real interest rate as regressand

Graph B.2.8.5



Horizontal axis indicates frequency ranging from 0 to π; vertical axis indicates spectral density. The dashed lines indicate 95% confidence intervals. The shaded area indicates the business-cycle frequency, ranging from six quarters (marked by "H") to 32 quarters (marked by "L"). The area between 0 and L corresponds to the low frequency range which contains the trend component.

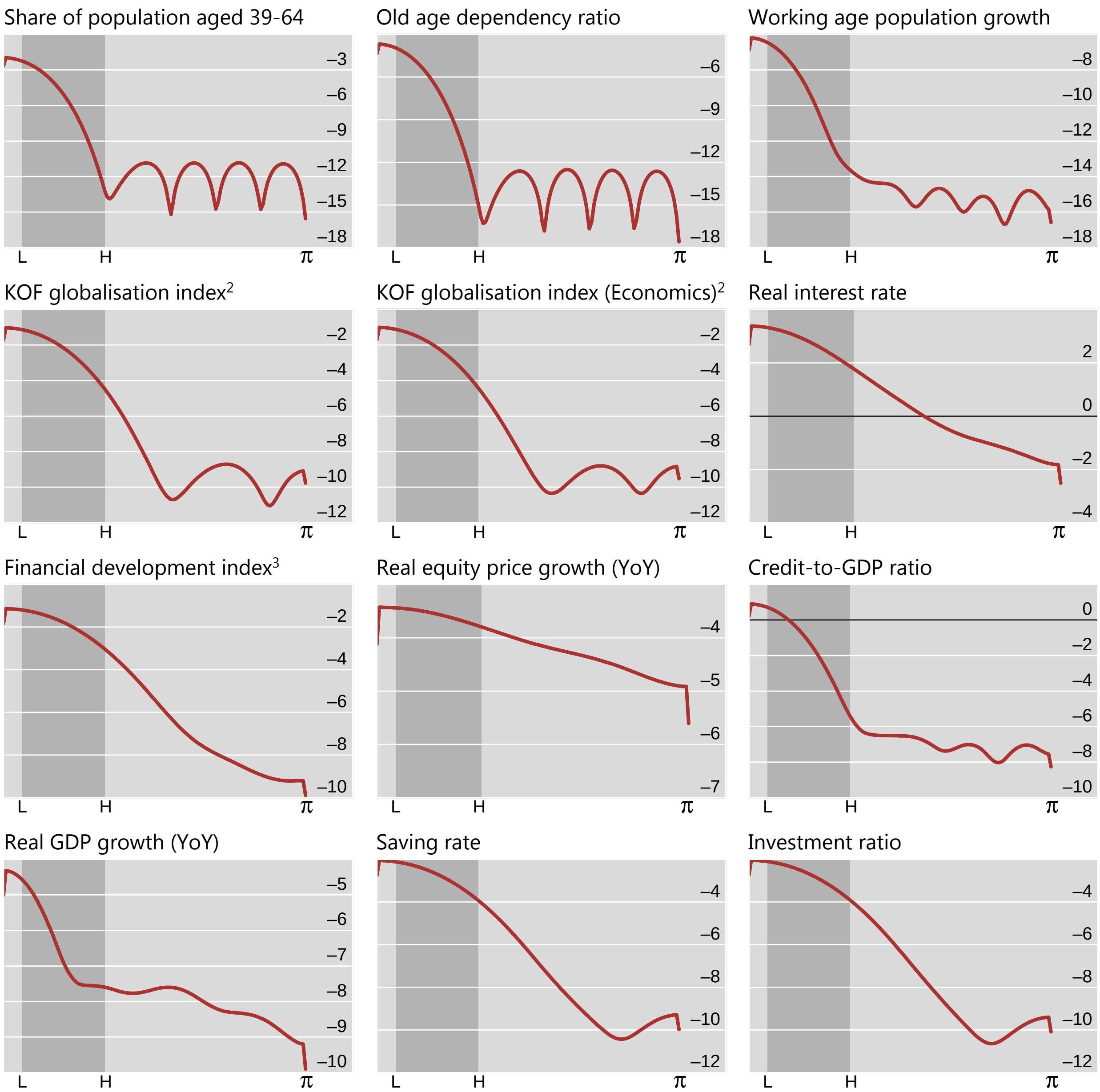
[1] The frequency-specific coefficient of regression indicates the degree of linear association between two stochastic processes at a specific frequency or frequency band. See Zhu (2005). [2] The overall KOF Index of Globalisation covers the economic, social and political dimensions of globalisation. For details on the Index and the Economics sub-index, see Dreher (2006) and Dreher, Gaston and Martens (2008). [3] For details on the financial development index, see Sahay et al (2015).

Source: author's calculations.

B.2.9. Thailand

Spectral density estimates: Thailand[1]

In logarithm | Graph B.2.9.1



Horizontal axis indicates frequency ranging from 0 to π; vertical axis indicates spectral density. The shaded area indicates the business-cycle frequency, ranging from six quarters (marked by "H") to 32 quarters (marked by "L"). The area between 0 and L corresponds to the low frequency range which contains the trend component.

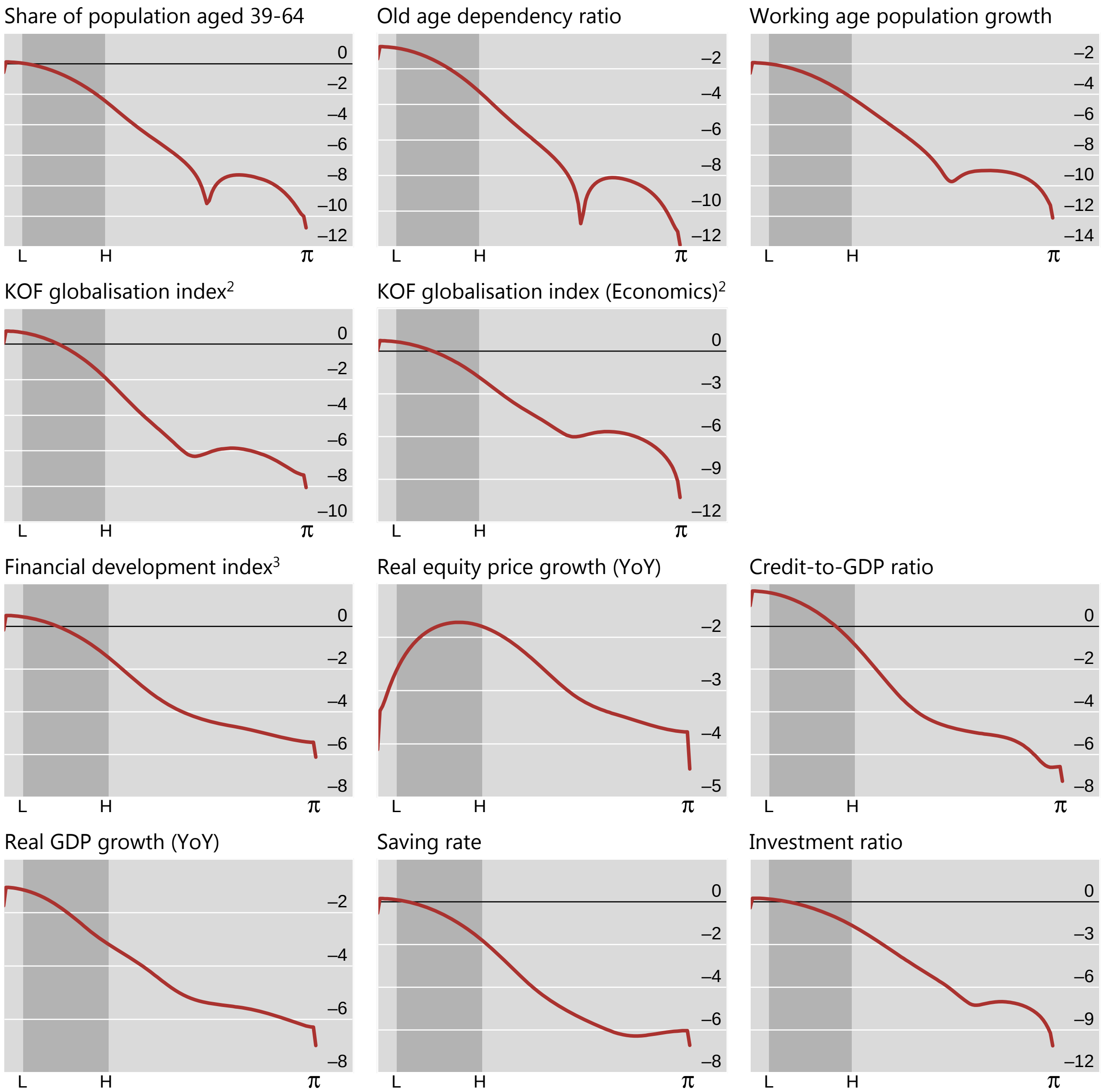
[1] Spectral density, or power spectrum, is estimated using Welch's method. It records the contribution of the component(s) belonging to a specific frequency or frequency band to the total variance of a stochastic process. [2] The overall KOF Index of Globalisation covers the economic, social and political dimensions of globalisation. For details on the Index and the Economics sub-index, see Dreher (2006) and Dreher, Gaston and Martens (2008). [3] For details on the financial development index, see Sahay et al (2015).

Source: author's calculations.

Cospectral density estimates: Thailand[1]

In logarithm, with real interest rate

Graph B.2.9.2



Horizontal axis indicates frequency ranging from 0 to π; vertical axis indicates spectral density. The shaded area indicates the business-cycle frequency, ranging from six quarters (marked by "H") to 32 quarters (marked by "L"). The area between 0 and L corresponds to the low frequency range which contains the trend component.

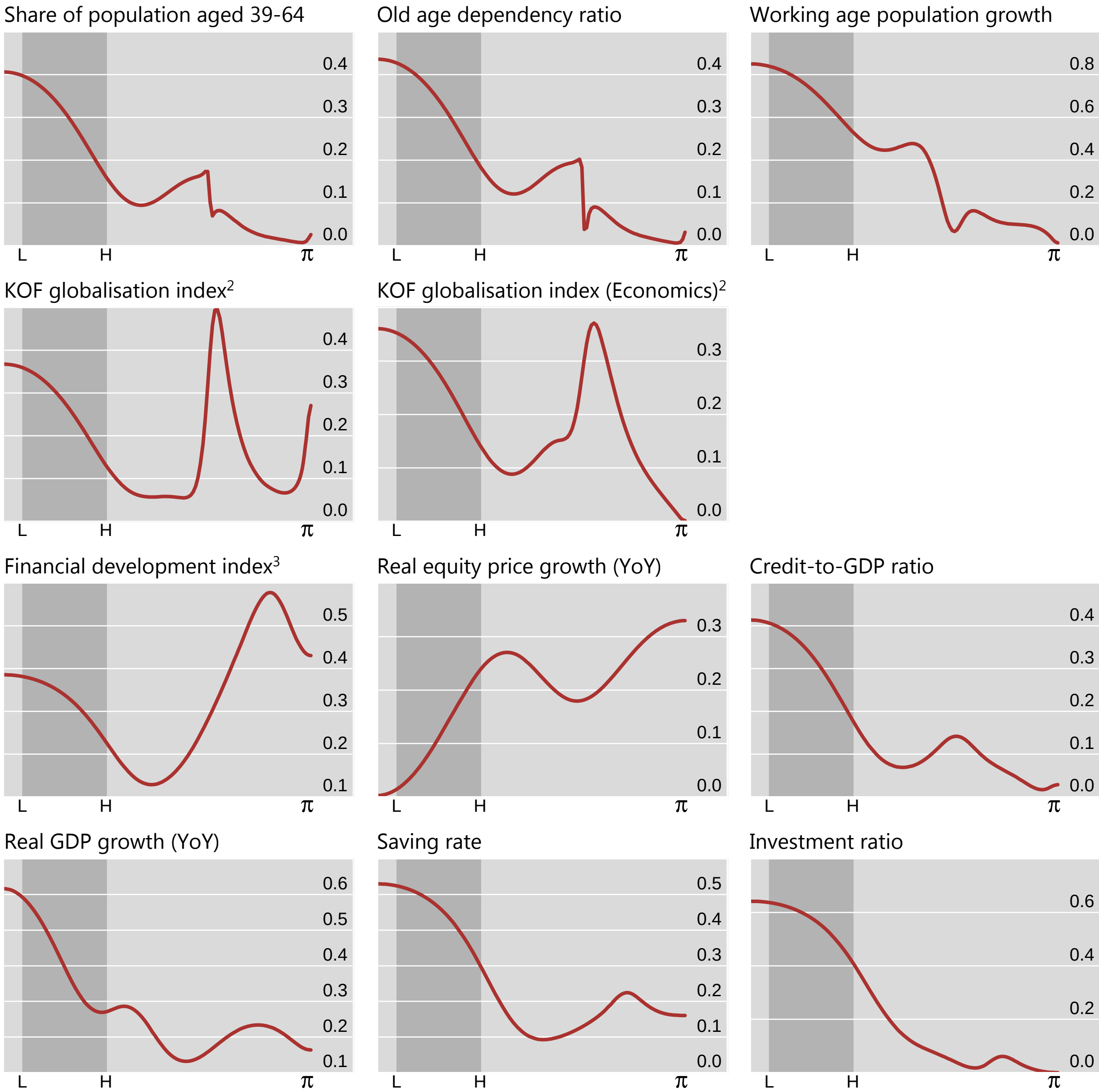
[1] Cospectral density, also known as cross power spectral density or cospectrum, is estimated using Welch's averaged, modified periodogram method. It represents the covariance between the in-phase components of two stochastic processes at a specific frequency or frequency band. [2] The overall KOF Index of Globalisation covers the economic, social and political dimensions of globalisation. For details on the Index and the Economics sub-index, see Dreher (2006) and Dreher, Gaston and Martens (2008). [3] For details on the financial development index, see Sahay et al (2015).

Source: author's calculations.

Squared coherence estimates: Thailand[1]

With real interest rate

Graph B.2.9.3



Horizontal axis indicates frequency ranging from 0 to π; vertical axis indicates spectral density. The shaded area indicates the business-cycle frequency, ranging from six quarters (marked by "H") to 32 quarters (marked by "L"). The area between 0 and L corresponds to the low frequency range which contains the trend component.

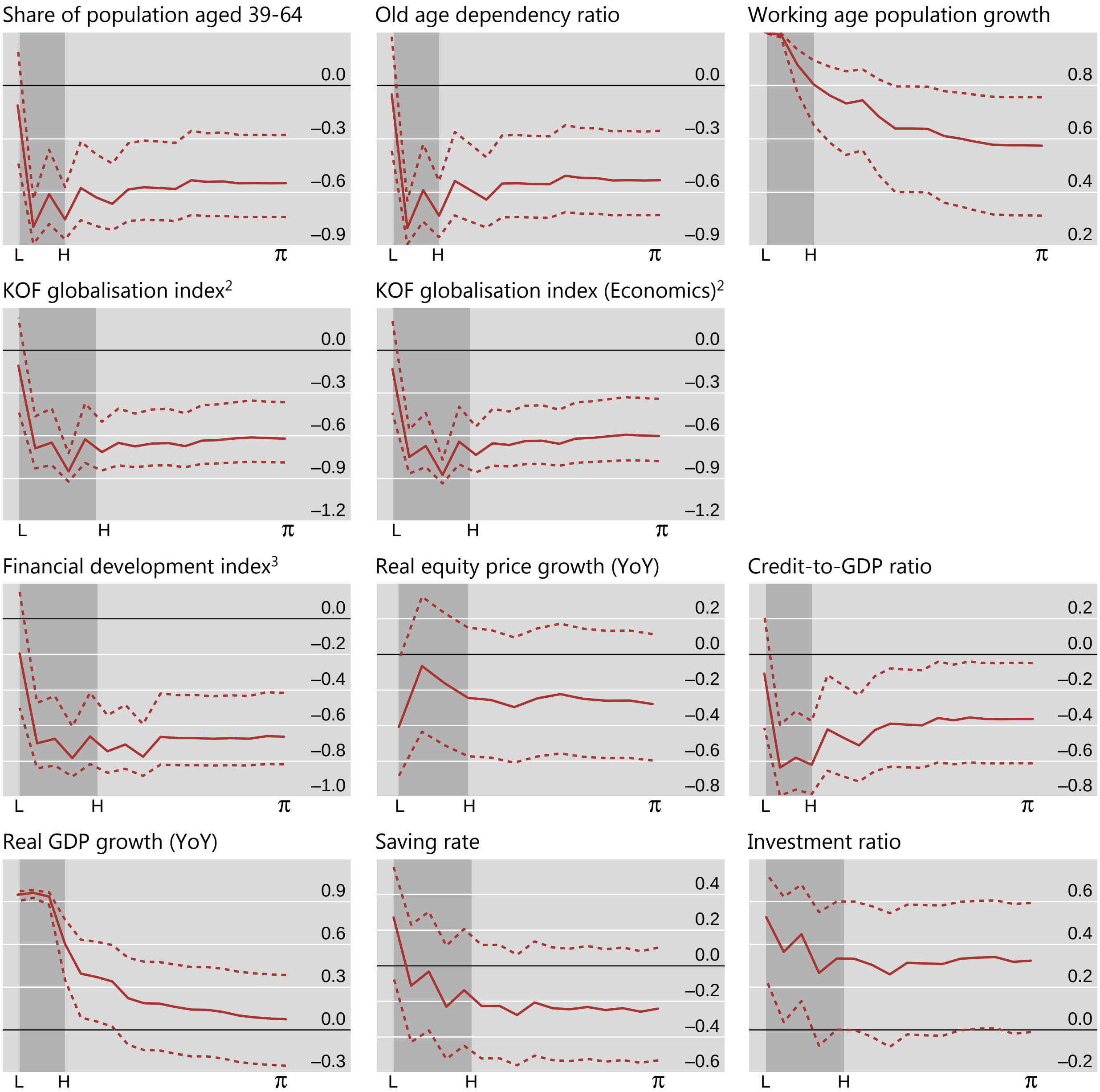
[1] Squared coherence, known as coherency, is estimated using Welch's averaged periodogram method. It is similar to the coefficient of determination R^2, and measures the strength of linear association between two stochastic processes at a specific frequency or frequency band. [2] The overall KOF Index of Globalisation covers the economic, social and political dimensions of globalisation. For details on the Index and the Economics sub-index, see Dreher (2006) and Dreher, Gaston and Martens (2008). [3] For details on the financial development index, see Sahay et al (2015).

Source: author's calculations.

Frequency-specific correlation coefficient estimates: Thailand[1]

With real interest rate

Graph B.2.9.4



Horizontal axis indicates frequency ranging from 0 to π; vertical axis indicates spectral density. The dashed lines indicate 95% confidence intervals. The shaded area indicates the business-cycle frequency, ranging from six quarters (marked by "H") to 32 quarters (marked by "L"). The area between 0 and L corresponds to the low frequency range which contains the trend component.

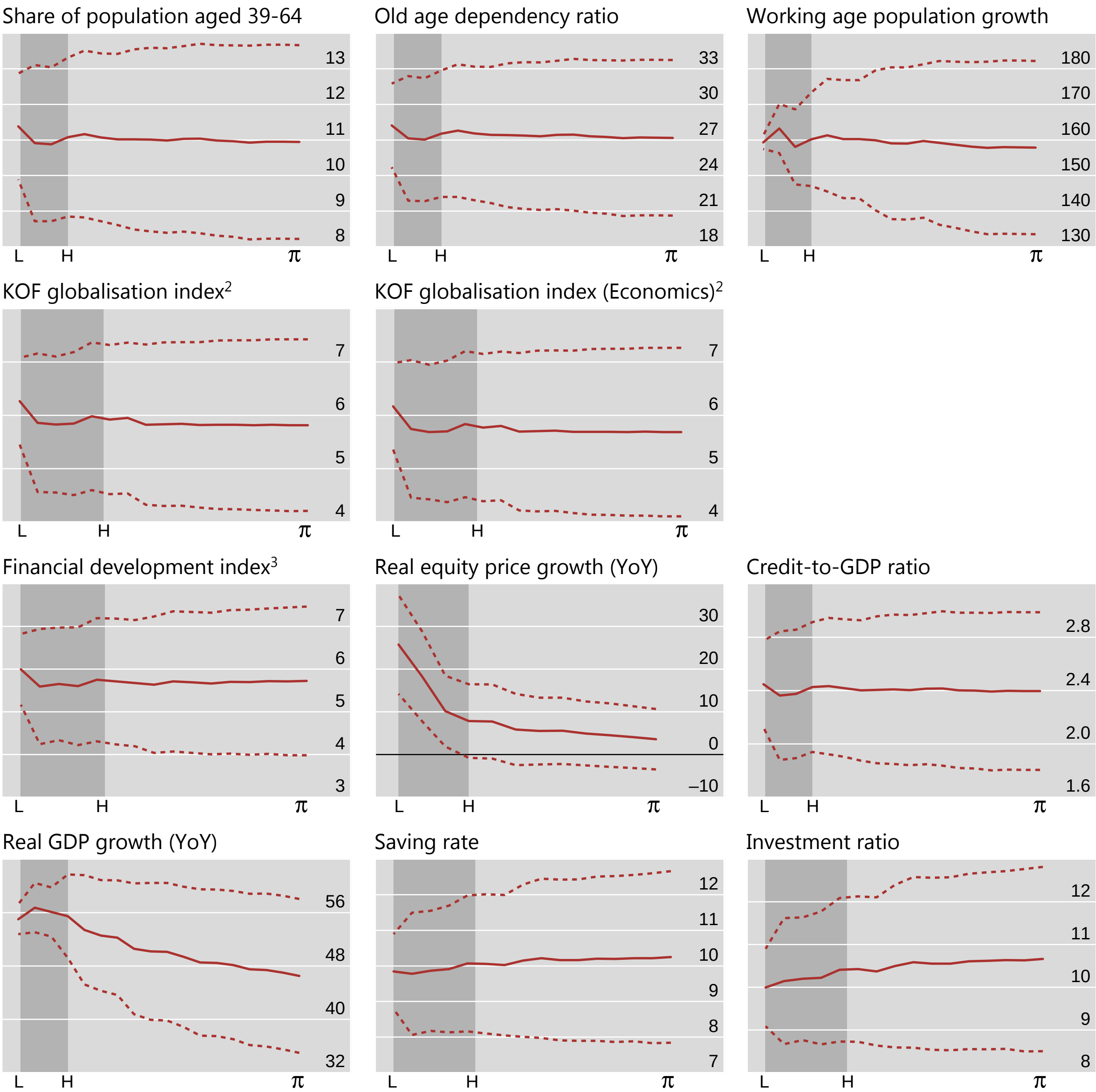
[1] The frequency-specific coefficient of correlation measures the strength of correlation between two stochastic processes at a specific frequency or frequency band. See Zhu (2005). [2] The overall KOF Index of Globalisation covers the economic, social and political dimensions of globalisation. For details on the Index and the Economics sub-index, see Dreher (2006) and Dreher, Gaston and Martens (2008). [3] For details on the financial development index, see Sahay et al (2015).

Source: author's calculations.

Frequency-specific regression coefficient estimates: Thailand[1]

Real interest rate as regressand

Graph B.2.9.5



Horizontal axis indicates frequency ranging from 0 to π; vertical axis indicates spectral density. The dashed lines indicate 95% confidence intervals. The shaded area indicates the business-cycle frequency, ranging from six quarters (marked by "H") to 32 quarters (marked by "L"). The area between 0 and L corresponds to the low frequency range which contains the trend component.

[1] The frequency-specific coefficient of regression indicates the degree of linear association between two stochastic processes at a specific frequency or frequency band. See Zhu (2005). [2] The overall KOF Index of Globalisation covers the economic, social and political dimensions of globalisation. For details on the Index and the Economics sub-index, see Dreher (2006) and Dreher, Gaston and Martens (2008). [3] For details on the financial development index, see Sahay et al (2015).

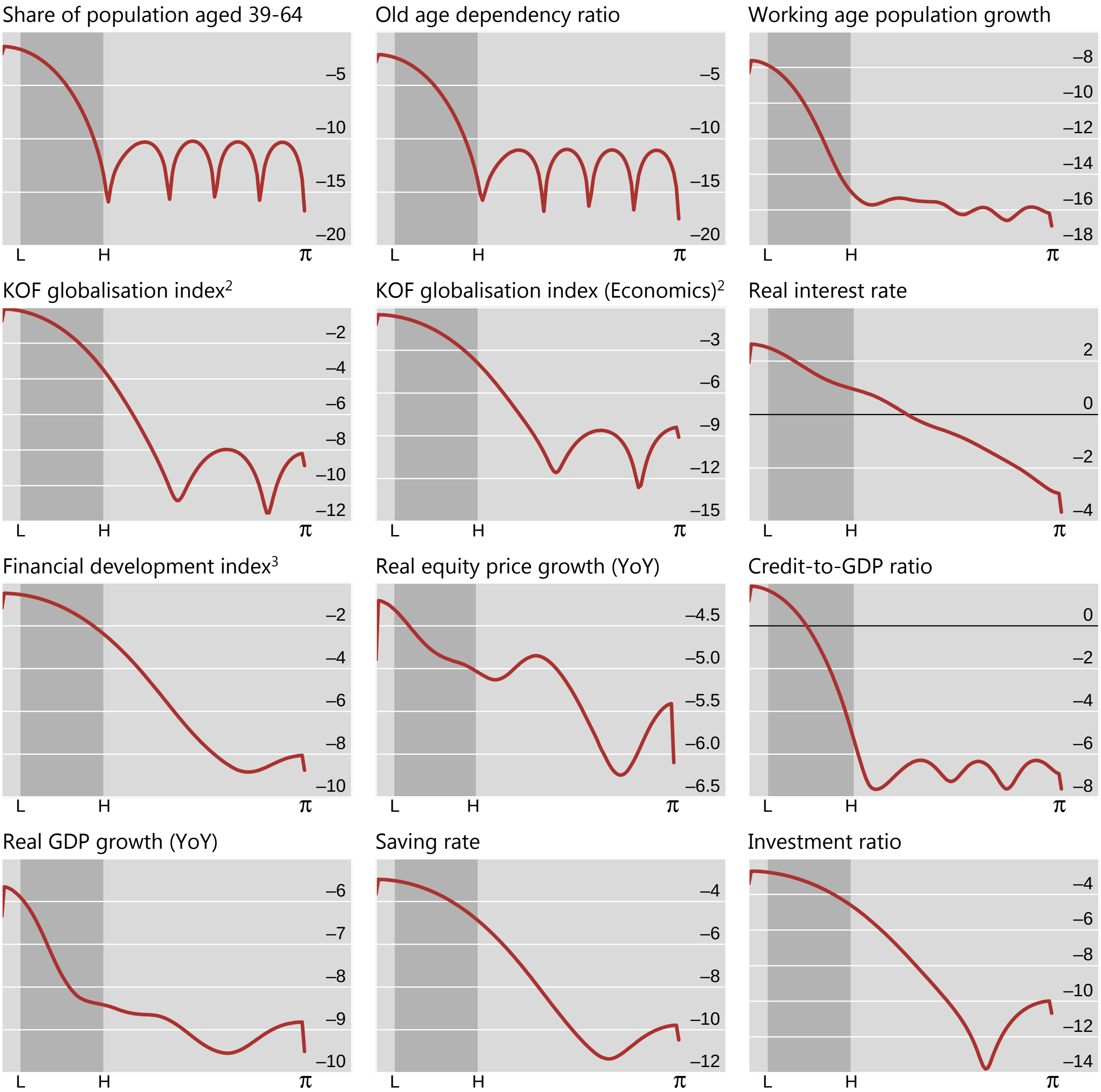
Source: author's calculations.

B.2.10. United States

Spectral density estimates: United States[1]

In logarithm

Graph B.2.10.1



Horizontal axis indicates frequency ranging from 0 to π; vertical axis indicates spectral density. The shaded area indicates the business-cycle frequency, ranging from six quarters (marked by "H") to 32 quarters (marked by "L"). The area between 0 and L corresponds to the low frequency range which contains the trend component.

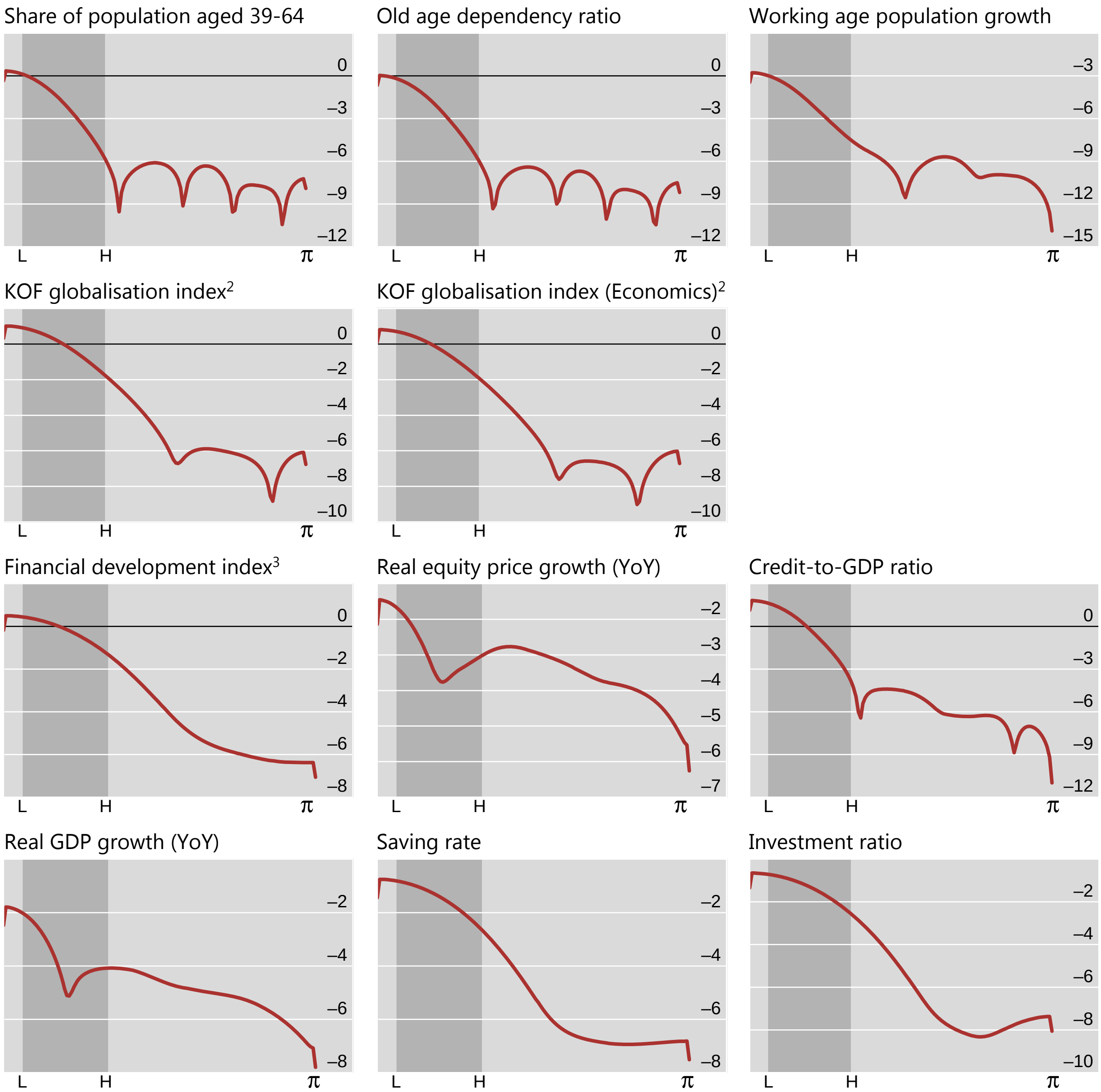
[1] Spectral density, or power spectrum, is estimated using Welch's method. It records the contribution of the component(s) belonging to a specific frequency or frequency band to the total variance of a stochastic process. [2] The overall KOF Index of Globalisation covers the economic, social and political dimensions of globalisation. For details on the Index and the Economics sub-index, see Dreher (2006) and Dreher, Gaston and Martens (2008). [3] For details on the financial development index, see Sahay et al (2015).

Source: author's calculations.

Cospectral density estimates: United States[1]

In logarithm, with real interest rate

Graph B.2.10.2



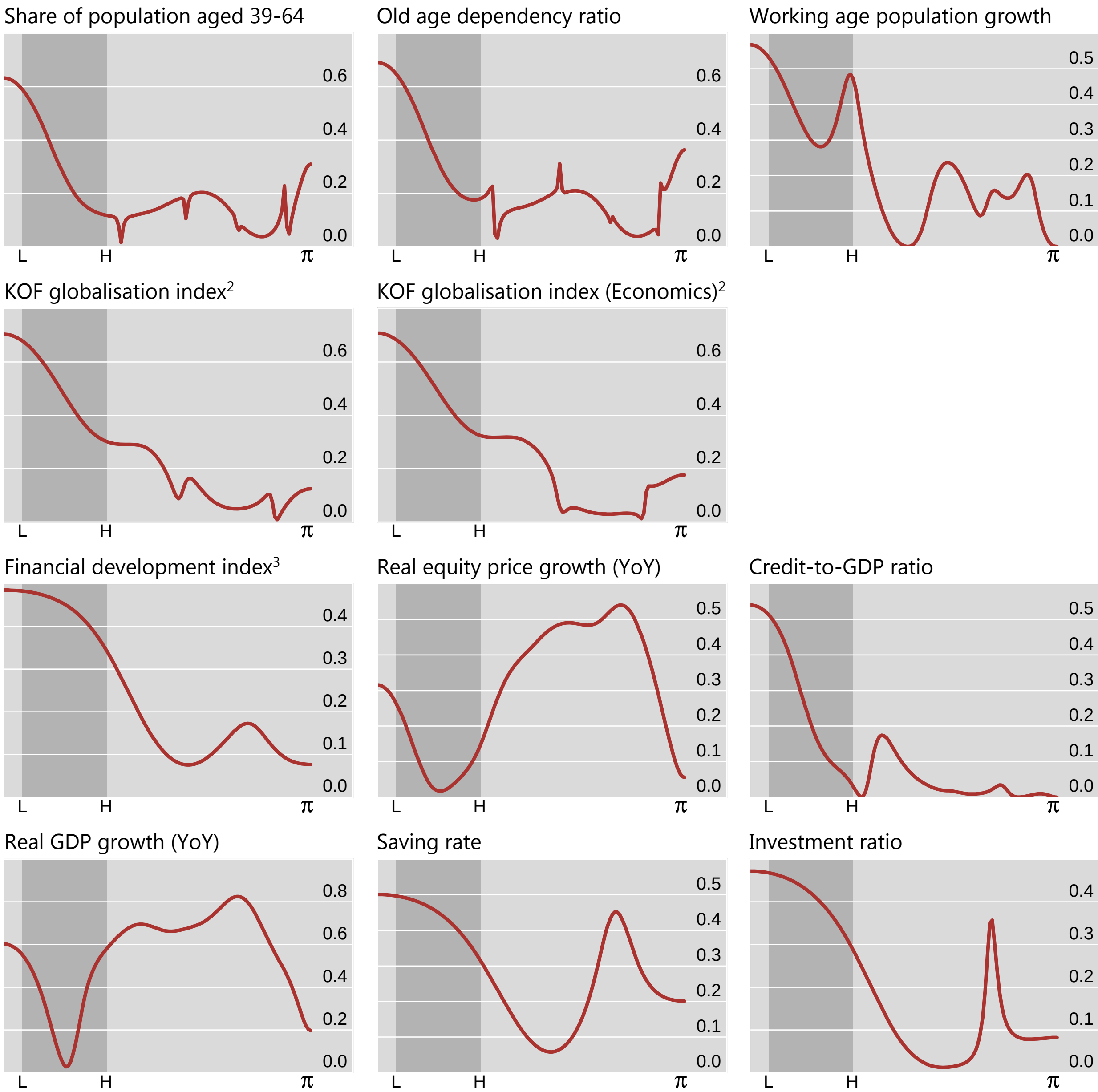
Horizontal axis indicates frequency ranging from 0 to π; vertical axis indicates spectral density. The shaded area indicates the business-cycle frequency, ranging from six quarters (marked by "H") to 32 quarters (marked by "L"). The area between 0 and L corresponds to the low frequency range which contains the trend component.

[1] Cospectral density, also known as cross power spectral density or cospectrum, is estimated using Welch's averaged, modified periodogram method. It represents the covariance between the in-phase components of two stochastic processes at a specific frequency or frequency band. [2] The overall KOF Index of Globalisation covers the economic, social and political dimensions of globalisation. For details on the Index and the Economics sub-index, see Dreher (2006) and Dreher, Gaston and Martens (2008). [3] For details on the financial development index, see Sahay et al (2015).

Source: author's calculations.

Squared coherence estimates: United States[1]

With real interest rate — Graph B.2.10.3



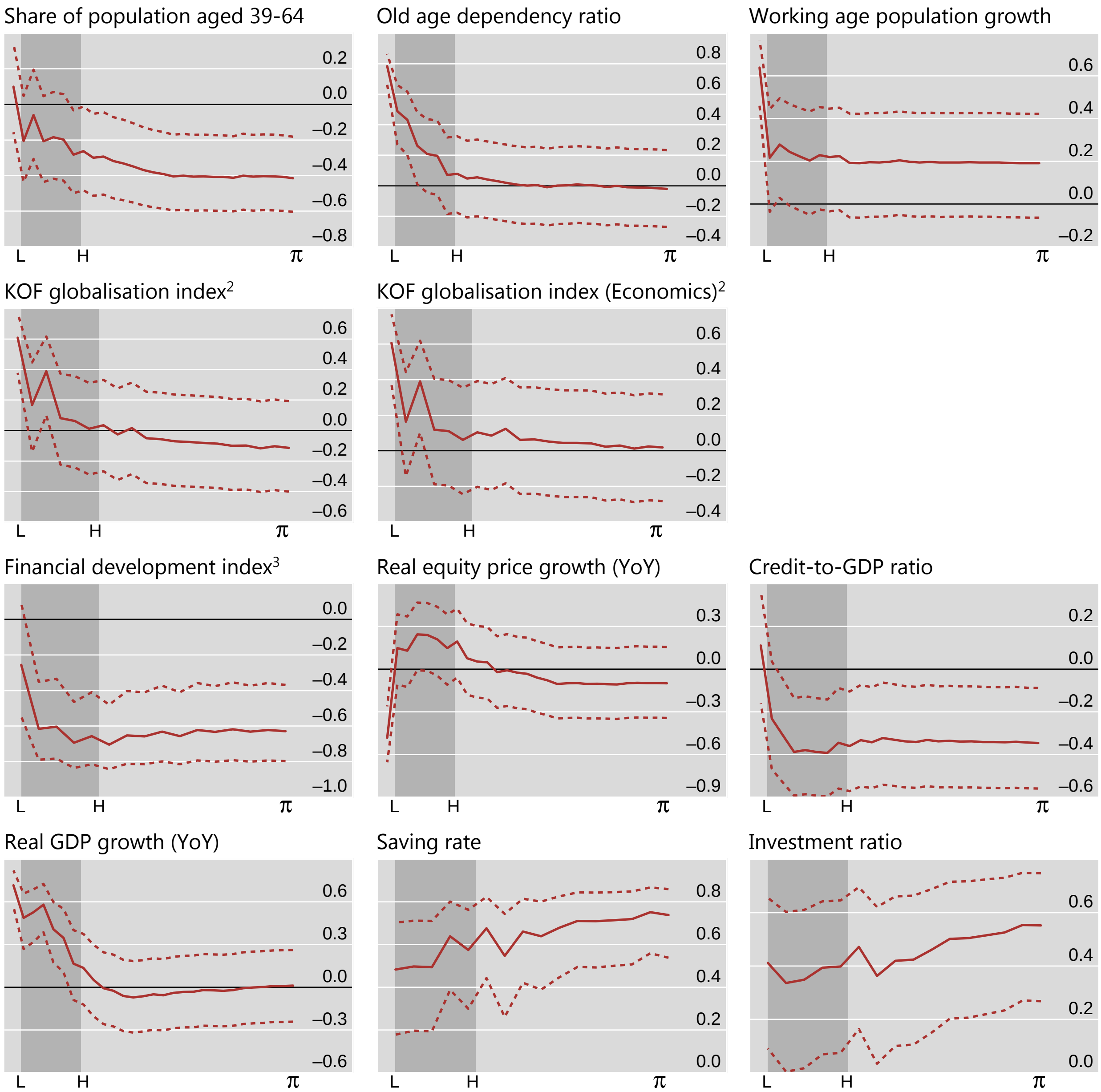
Horizontal axis indicates frequency ranging from 0 to π; vertical axis indicates spectral density. The shaded area indicates the business-cycle frequency, ranging from six quarters (marked by "H") to 32 quarters (marked by "L"). The area between 0 and L corresponds to the low frequency range which contains the trend component.

[1] Squared coherence, known as coherency, is estimated using Welch's averaged periodogram method. It is similar to the coefficient of determination R^2, and measures the strength of linear association between two stochastic processes at a specific frequency or frequency band. [2] The overall KOF Index of Globalisation covers the economic, social and political dimensions of globalisation. For details on the Index and the Economics sub-index, see Dreher (2006) and Dreher, Gaston and Martens (2008). [3] For details on the financial development index, see Sahay et al (2015).

Source: author's calculations.

Frequency-specific correlation coefficient estimates: United States[1]

With real interest rate | Graph B.2.10.4



Horizontal axis indicates frequency ranging from 0 to π; vertical axis indicates spectral density. The dashed lines indicate 95% confidence intervals. The shaded area indicates the business-cycle frequency, ranging from six quarters (marked by "H") to 32 quarters (marked by "L"). The area between 0 and L corresponds to the low frequency range which contains the trend component.

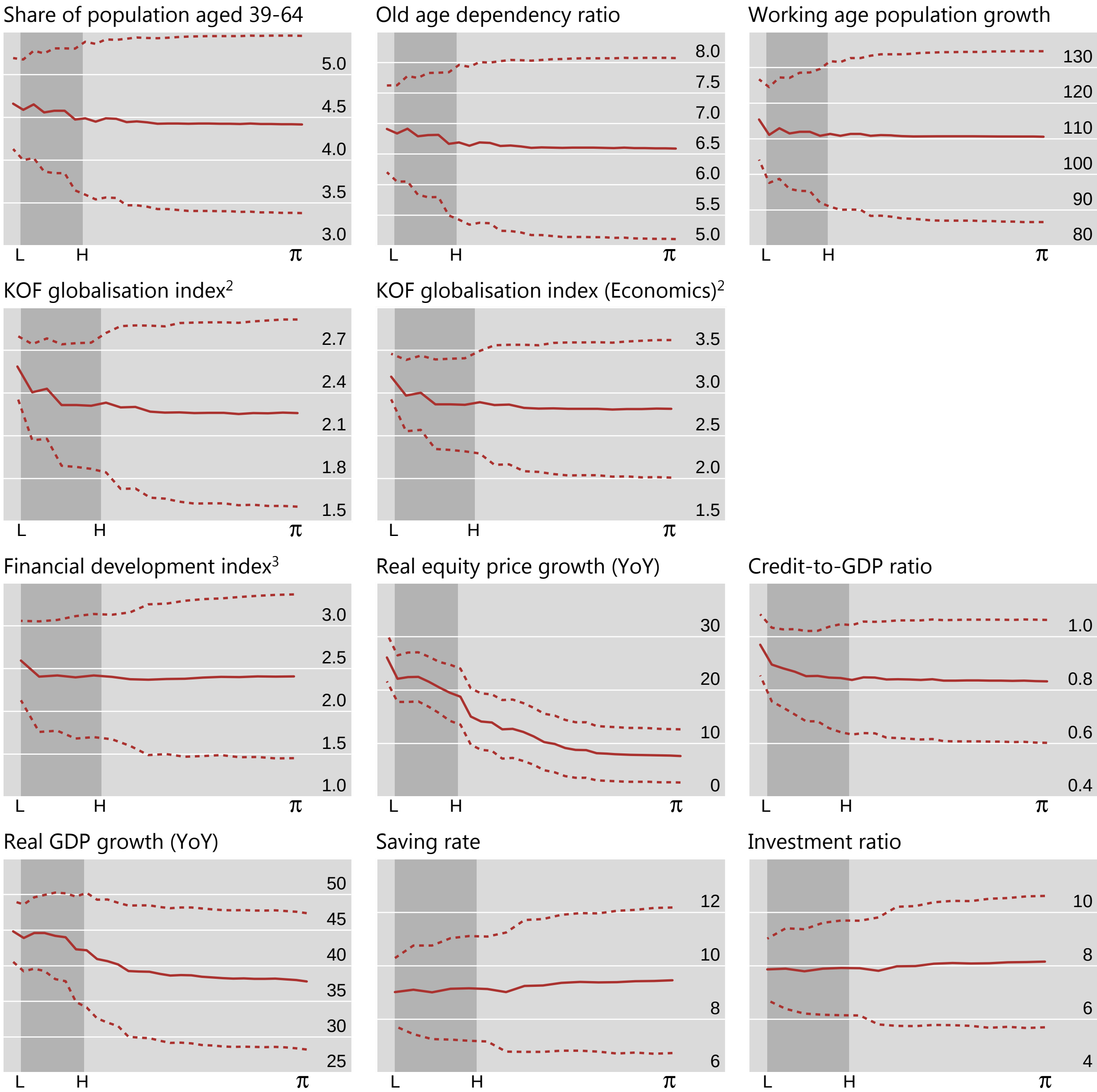
[1] The frequency-specific coefficient of correlation measures the strength of correlation between two stochastic processes at a specific frequency or frequency band. See Zhu (2005). [2] The overall KOF Index of Globalisation covers the economic, social and political dimensions of globalisation. For details on the Index and the Economics sub-index, see Dreher (2006) and Dreher, Gaston and Martens (2008). [3] For details on the financial development index, see Sahay et al (2015).

Source: author's calculations.

Frequency-specific regression coefficient estimates: United States[1]

Real interest rate as regressand

Graph B.2.10.5



Horizontal axis indicates frequency ranging from 0 to π; vertical axis indicates spectral density. The dashed lines indicate 95% confidence intervals. The shaded area indicates the business-cycle frequency, ranging from six quarters (marked by "H") to 32 quarters (marked by "L"). The area between 0 and L corresponds to the low frequency range which contains the trend component.

[1] The frequency-specific coefficient of regression indicates the degree of linear association between two stochastic processes at a specific frequency or frequency band. See Zhu (2005). [2] The overall KOF Index of Globalisation covers the economic, social and political dimensions of globalisation. For details on the Index and the Economics sub-index, see Dreher (2006) and Dreher, Gaston and Martens (2008). [3] For details on the financial development index, see Sahay et al (2015).

Source: author's calculations.

Annex C: Data descriptions

This annex provides a detailed description of data used in this paper.

Table.C.1. Macroeconomy

Variable	Description	Source	Notes
Real GDP	Level in billions of local currencies; year-on-year growth.	IMF IFS, OECD, GFD, national data, BIS.	Different base years in different countries
GDP deflator		IMF IFS, OECD, GFD, national data, BIS.	Rebased with 2005=100.
Consumer price index (CPI)		CEIC, GFD, Datastream, national data.	
Inflation forecasts	current and next year; 6-to-10-year ahead	Consensus Economics ©; BIS calculations	
Savings	Gross national saving.	IMF WEO.	In billions of local currency.
Saving rate	Gross national savings as a percentage of GDP.	IMF WEO.	
Investment	Gross fixed capital formation.	IMF WEO.	In billions of local currency.
Investment ratio	Ratio of nominal investment to nominal GDP.	IMF WEO, BIS calculations.	
Unemployment rate		IMF WEO, OECD, CEIC, Datastream, GFD, national data.	Quarterly data not available for India and Indonesia; annual data available for India.
Employment		Eurostat, IMF IFS, IMF WEO.	in thousands; Quarterly data not available for China and India; annual data not available for India.
Oil price	Crude oil price for spot Brent.	Datastream.	In USD

Table.C.2. Financial sector

Variable	Description	Source	Notes
Nominal total credit	Total credit to private non-financial sector.	National data, BIS.	In billions of local currency. Data not available for New Zealand and the Philippines.
Nominal bank credit	Bank credit to private non-financial sector.	National data, BIS.	In billions of local currency.
Domestic credit to GDP ratio	Domestic credit as a percentage of GDP.	World Bank.	
Equity price index		Bloomberg, CEIC, BIS calculations.	
Housing price index		National data.	Rebased with 2010=100
Interest rate	Overnight interest rates.	Bloomberg, Datastream, GFD.	
China's interest rate	Average of overnight, 1-week repo, 3-month time deposit, 6-month lending and 1-year lending rates.	Datastream.	
3-month government bill rate		Bloomberg, GFD.	Data are not available for Indonesia.
10-year government bond yield		Datastream, GFD.	

Table.C.3. Demographics

Variable	Description	Source	Notes
Working age population	Population aged 15-64.	United Nations.	In thousands.
Total population		United Nations.	In thousands.
Ratio of population aged 39-64	Ratio of population aged 39-64 to total population.	United Nations, BIS calculations.	
Ratio of population aged over 64	Ratio of population aged over 64 to total population.	United Nations, BIS calculations.	
Total dependency ratio	Ratio of population aged below 20 and over 64 to population aged 20-64.	United Nations.	
Old-age dependency ratio	Ratio of population aged over 64 to population aged 20-64.	United Nations.	
Birth rate		World Bank.	Per 1000 people.
Life expectancy		World Bank.	In years.

Table.C.4. Global economy and external sector

Variable	Description	Source	Notes
Global official liquidity	Total assets of central banks in advanced economies and foreign reserves of emerging economies.[13]	IMF IFS, Datastream, national data, BIS calculations.	In trillions of USD
M3-to-GDP ratio	Weighted averages.	IMF IFS, IMF WEO, Datastream, national data.	Based on rolling GDP and PPP exchange rates.
World interest rate	Weighted (by real GDP) and unweighted world real interest rate.	King and Low (2014).	
Nominal effective exchange rate		BIS.	Index 2010=100.
Real effective exchange rate		BIS.	Index 2010=100.
Globalisation index (Overall)	KOF globalisation index (Overall).	ETH Zurich; Dreher (2006).	Data not available for Hong Kong.
Globalisation index (economics)	KOF Index of Globalisation (Sub-index of economics).	ETH Zurich; Dreher (2006).	
Financial development index		Sahay et al (2015)	

[13] Advanced economies include to Canada, Denmark, Euro Area, Japan, Sweden, Switzerland, Australia and Denmark. Emerging market economies include to Brazil, Chile, China, Czech, Hungary, India, Indonesia, Korea, Mexico, Poland, Russia, South Africa and Turkey.

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