Further Evidence on the Stationarity of China's Macroeconomic Series:

Fourier Approximated Structural Changes

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ABSTRACT

The distinction as for whether the macroeconomic variables are dominated by deterministic or stochastic trend relates to important questions of forecast precision and the understanding of the latent data generating process. The concept that many a macroeconomic variable is unit root process with an integration order of one or two has been widely acknowledged in works of empirics without due consideration of possible structural changes. This paper emphasizes that such a unit root consensus needs to be reversed when taking into account of the structural breaks' effects. Specifically, this paper focuses on breaks of smooth transition and fits the data with possible changes by Fourier approximation, which converts the estimations of locations and styles of breaks into the problem of appropriate frequency selection. An examination of China's 15 representative macroeconomic series indicates that only the financial series such as common stock prices, RMB's nominal and real effective exchange rates have good reason to be regarded as realizations of unit root process, while others, including the real GDP and foreign trades, are better regarded as trend stationary with smooth transitions. The inference based on these results affirms that China's real business cycles are indeed fluctuations around different deterministic trends when the smooth transitions' effects are excluded, it is not the noise component rather the historical events corresponding to those breaks that have persistent effects. The results also support the argument that, as for the policy implications, large government-initiated shocks aimed at improving fundamentals are indeed capable of positive effects on the balanced growth path.

Keywords: Unit Root; Trend Stationary; Structural Break; Smooth Transition; Fourier Approximation

1. Introduction

The unit root is a familiar yet appealing feature in time series; no matter how complicated the method we use to decompose series, the decomposition itself is by no means the final purpose. What we really need is to make forecast about the future based on the data we have. Whether a series contains a unit root, however, leads to different philosophies of forecast and predictive results: the optimal forecast for a trend stationary process is its deterministic trend; while the optimal forecast for a unit root process is somehow complicated, but a pretesting of the unit roots would help select a more accurate forecasting model according to Diebold and Kilian (2000). Also the two processes have distinctive differences with respect to the mean squared error of prediction, the persistency of a shock that would exert on future values, and the spurious regression pointed out by Granger and Newbold (1974). Thus it suffices an in-depth investigation for the stationarity of macroeconomic time series.

A pioneering yet influential investigation dates back to Nelson and Plosser (1982) who inspect a set of 14 commonly used macroeconomic time series of U.S. economy with ADF unit root test and conclude that 13 of those series failed to reject the null hypothesis of a unit root. Henceforth some related work (Wasserfallen, 1986) or quite a few of those who exploit other methods (Phillips and Perron, 1988; Cochrane, 1988; Kwiatkowski *et al*. 1992) generally confirm the result obtained by Nelson and Plosser. Since then, the notion that a majority of macroeconomic time series are dominated by stochastic rather than deterministic trend has been widely accepted, but the pervasive point of view ahead of Nelson and Plosser (1982) was that macro series were basically stationary processes around deterministic trends (Barro, 1976; Blanchard, 1981; Kydland and Prescott, 1982). While if the entire economic system is deemed as a stochastic process and the corresponding economic data are the realizations of such process, an ineluctable question is from the data we confront it can be easily found circumstances that some events significantly change the mean or trend in various kinds of ways no matter whether we consider them as purely exogenous or contingently endogenous shocks, the events behind which can be categorized into a wider concept of structural changes. The frequently appeared structural changes in economic data blur the distinct differences between a unit root and a trend stationary process, and once a single or some of the potential structural changes are ignored, the statistical inferences based on naïve unit root tests may be lured to type Ⅰ or type Ⅱ errors. Leybourne *et al*. (1998a), Leybourne and Newbold (2000), Cook and Manning (2004) among others have elaborated the bias that would occur under neglect: generally, overlooking breaks under the null would lead to over-rejection, or size distortion, a jargon preferred by some econometricians; overlooking breaks under the alternative would result in non-rejection when the exogenous shock is slightly persistent, namely the low test power. The standard ADF is a good case in point with respect to the latter circumstance. Even the GLS unit root test (ADF-GLS) proposed by Elliot *et al*. (1996) doesn't help much in raising test power under potential break neglect. Succinctly, structural changes are common properties in time series, many stochastic or significant events may exert occasional or persistent breaks on the data generating process, it is in this sense the notion that the absolute majority of macroeconomic series are integrated of order one or two may not be an appropriate delineation of the unobserved DGP of the real world, and this paper sets out with the idea that any desired investigations of the series' stochastic or deterministic trend property can only be obtained via a fit-like-a-glove approximation of structural changes.

The reason why such an investigation is important also lies in the fact that unit root hypothesis bears direct relationship with the evolution of economic theories. If macroeconomic series were indeed dominated by stochastic trend after incorporating the structural break effects, we should then perceive the world with the theories based on or implying unit root hypothesis so that it would help us gain more reliable insights into the realities. Such theories include discussion about stock prices made by Samuelson (1973), velocity of money by Gould and Nelson (1974), consumption by Hall (1978), and Blanchard and Summers for employment (1986). Au contraire, if these series were dominated de facto by stationary trend after precluding the effect of structural changes, then models of fluctuations should no longer regard the random disturbances induced by some real forces as the core substance in the modeling whereas innovations such as monetary shocks should be treated as temporary volatilities or at most somehow persistent (as opposed to permanent) disturbances, since in this way more accurate forecasts might yield. In the aspects of theoretical econometrics, the unit root hypothesis catalyzes co-integration theory of Engle and Granger (1987) and multivariate system of Stock and Watson (1988). It is confidently foreseeable that the structural change stationarity investigation is of undoubted help for the burgeoning of structural change co-integration or co-breaking theory as well as the development of structural change multivariate system.

After thirty years of spectacular growth, the biggest problems China's economy confronts nowadays are transitions and structural reforms. How the government is supposed to intervene and what role the government is expected to play during these transitions are problems worthy of in-depth discussion. Thus another generic point of reality to make is that if the majority of macroeconomic variables, especially the real output, are structural break unit root processes, then the government initiated structural reform is of limited value since government's effect may probably be canceled by other shocks. On the other hand, if macro variables or real output is trend stationary or trend stationary with structural changes, the logical implication is that government is capable of substantive contribution on the balanced growth path provided the shocks are large enough. So the structural change investigation of stationarity is of both theoretical value and policy implications from either the perspective of economic theory or the Chinese economy.

2. Literature Review and Comments

Basically, structural changes can be categorized in two varieties: threshold breaks and smooth transitions. Threshold refers to sudden change in mean or slope at a certain point(s) whereas the model's systematic properties do not have substantive difference before or after the point(s). Smooth transition, by definition, refers to gradual change that happens smoothly in some periods. There have been applications for both types in unit root / stationary testing but there are still slight differences in terms of comprehension with respect to how the structural changes are generated. If the breaks, no matter thresholds or smooth transitions, are regarded as exogenously given, the implication is that instead of adding artificial procedure to gain to gain better fit of the data, such corresponding structural effect can be removed for analysis by extracting it from the noise functions.[1] If structural changes are supposed to be endogenous however, the implication is that one needs to give descriptive approximation to the data realization process according to some specific rules which commonly take whether the data are fitted sufficient as a usual starting point.

[1] This is in the same spirit with the intervention analysis proposed by Box and Tiao (1975).

Thus the literature of structural change unit root / stationary tests can be generally sorted into four varieties according to the type of changes and our ways of comprehension: exogenous threshold breaks, endogenous threshold breaks, exogenous smooth transitions, and endogenous smooth transitions.

The seminal studies of Perron (1989, 1990) unfold the research of structural break unit root tests, while Perron (1990) supplements the former paper and focuses on structural changes in mean. The core idea of Perron (1989) originates from the fact that the great crash in 1929 significantly changed the means of many macroeconomic variables and the oil price shock in 1973 evidently slowed down the growth rate thereafter, if such big events are regarded as exogenous shocks instead of realizations of time-invariant stochastic process of the various series, then it is more appropriate to model most macroeconomic time series as trend stationary process. Specifically, based on ADF methods, Perron (1989) constructs unit root tests with the null allowing one-time structural break at an exogenously given date, his simulation reveals that the stronger the magnitude of a break is, the closer to one the cumulative distribution of AR(1) coefficient estimator stays, therefore rejecting the null is almost impossible though the DGP is actually a deterministic trend but with one structural break. Overlooking the structural change leads to the fallacy that the shocks are of perpetual effect whereas it is factually the one-time break that is responsible for the alteration of its long-run behavior. For the sake of comparability, Perron (1989) reexamine the Nelson and Plosser (1982) data and rejects the null hypothesis of eleven variables out of fourteen with high confidence level.[2] And further points out that "Only the events associated with the Great Depression and the oil price shock significantly altered the long run behavior of the series" (Perron, 1989, p.1389). Be that as it may, this corollary is incomplete because although the matter in essence is that overlooking the large shocks of such events is inappropriate, one cannot guarantee other less famous events do not pose similar effects for some specific series, thus the choice of break date is inevitably controversial and subjective. On the other hand, although historical events are usually helpful in pinpointing the break dates no matter what the series are, the lags needed for a full unleashing of the effects may also lead to imprecise break date choices. Simulations made by Hecq and Urbain (1993) indicate that there will be simultaneous size distortions and loss of power in Perron's (1990) structural break in mean test if the pre-specified break date does not conform to the real one, though Montañés (1997) shows this effect disappears in large samples, Montañés and Olloqui (1999) further point out the problem of low test power cannot be eliminated even asymptotically if the break date misspecification happens in Perron (1989)'s trend breaking models. Such essential limitations of exogenous breaks give rise to endogenously determined break points as the next destined direction.

Endogenous breaks are nothing more than constructing selection criteria for events so that the latent shocks capable of structural change effects could be justifiably singled out, such criteria include minimal sequential t statistics, minimal summed squared residuals, and maximized F statistics, etc. Perron's (1989) tests as well as its simulated critical values are only valid for single break circumstance, once the breaks are endogenously determined, the tolerance can be easily extended to multiple breaks. Similar research that construct endogenous but one structural break include Christiano (1992), Banerjee *et al*. (1992), Perron (1997), and the most representative Zivot

[2] N-P data end by 1970. Perron (1989) in addition uses quarterly data of U.S. post war real GDP (1947:Ⅰ-1986:Ⅲ) to perform the test with 1973:Ⅰ as the break date of oil shock and the null of a unit root is also rejected. Here all that I want to say are that Perron's (1989) tests admit merely single break point.

and Andrews (1992) whose null hypotheses are unit root without break and the alternatives are trend stationary with one structural change. Their intention is straightforward: the result favors a unit root process if the estimated point is not the real break, thus the optimal break should be the date corresponding to the minimal t statistics under the circumstance of rejecting the null. Vogelsang and Perron (1998) discuss the difference of asymptotical invariance as for the structural change in mean and structural change in trend in the above mentioned unit root statistics; Lumsdaine and Papell (1997) as well as Ohara (1999) extend Zivot and Andrews' (1992) model to accommodate two and even more breaks. However, the universal problem existing in this discipline of construction is that a break is not allowed under the null whereas merely allowed under the alternative, such an asymmetric treatment is convenient for establishing test procedures, yet brings about several undesirable properties. Firstly, the information about structural change is not fully explored. Secondly, the problems of size distortion and low test power may simultaneously present. Thirdly, the composition of asymmetric break is not consistent with the initial motivation of Perron (1989), who aims in establishing tests independent of the magnitude of change in mean or slope, and such a motivation can only be achieved by allowing breaks both under the null and alternative hypothesis. Although Perron's (1989) purely exogenous break receives much criticism and the emerging endogenous-break tests thereafter have not found much evidence for the argument of structural break trend stationarity, these do not mean Perron's (1989) tests are undesirably flawed, rather the succeeding aforementioned methods are not satisfactory.

It can be summarized from the above line of research that Perron's (1989, 1990) initiations are still the most desirable with respect to the parametric invariance of the trend function as well as the test size and power providing the break date is specified correctly. For the sake of endogenous breaks, apart from allowing dual presence of breaks under both the null and the alternative, we can gain improvement on the test power meanwhile maintain the correct size if the test statistics have the same asymptotic distributions as Perron's (1989, 1990) exogenous cases. This is what Kim and Perron (2009) think and technically they propose a sufficient condition so that the asymptotic distributions of the test statistics equal the distributions under a known break date. When this sufficient condition fails to hold Kim and Perron (2009) just trim the data to acquire increased convergence rate of the estimated parameters in order to give rise resemblance distributions. Though Kim and Perron's (2009) method is immune to the absence-of-a-break-under-the-null problems, their discussion is still mainly applicable to the single break cases, both the critical values as well as the associated test power under multiple breaks still need further sharpening.

Threshold structural changes, as reviewed above, typically characterize themselves by introducing dummy variables or slope dummies to account for the break effects. In many circumstances however, when researchers are uncertain about the stationarity of the series, they presumably also lack reliable ex ante information as to the latent form of structural changes. Besides, it takes time for influential events to fully unleash their impacts, even the 1929 Great Crashes and 1973 oil price shock considered by Perron (1989) are thought to have durations of three to five years. Although the statistical data, once garnered, are always discrete, structural change quite possibly take on the form of gradual change as the data's frequency increases (from yearly to monthly, for instance), these are all reasons to bear in mind smooth transitions. One typical methodology in sharpening smooth transitions is to introduce the cross product of an autoregressive term and a smooth transitional function in the autoregression functions, which is called smooth transition auto regression (STAR). Usually the smooth transition functions are

Logistic density functions (LSTAR) which are designed for monotonic transformation or Exponential density functions (ESTAR) which are prepared for U-shaped transformation, an additional parameter is used in both cases to adjust transition speed. Luukkonen *et al*. (1988), Leybourne *et al*. (1998b), Saikkonen and Lütkephol (2002), Lanne *et al*. (2002) and Kapetanios *et al*. (2003) establish smooth transition unit root tests containing a single changing point. Harvey and Mills (2004) propose a stationarity test that endogenously determines the break location. Yet the common problems of these research are: firstly, the number of breaks and modes of transition must be pre-specified, the actual nature of structural change, however is generally unknown. Inappropriate specification of break numbers or transition modes has basically no difference from completely overlooking structural changes. Secondly, the test powers of the above research are higher than the standard ADF if the DGP is indeed smooth transition process; but if otherwise, their test powers are not comparable with those of the ADF. Thus the above line of investigation lacks a rigorous identification on nonlinearities.

We learn from the retrospection of literature that smooth transition is preferable than threshold break for the real world, especially the low frequency, data. In the branch of smooth transitions, the problem is not fitting the data but to get rid of the unconscious assumptions about the unknown number of breaks and the type of changes. One exciting development in this aspect is to approximate the deterministic component of the series by Fourier expansion with appropriate frequency, which may also be understood as replacing the STAR with Fourier functions. Fourier transformation is initially brought about in time series analysis by Gallant (1981). Gallant (1984), Davies (1987), Gallant and Souza (1991) and Becker *et al*. (2004) prove the iteration of sinusoidal components can capture the trend of an unknown function well irrespective of the periodicity of the function itself, which brings hope of relaxing a pre-specified number and type of breaks.

Employing the idea of Fourier approximation, Bierens (1997), Enders and Lee (2004, 2012), Rodrigues and Taylor (2012) propose unit root tests and Becker *et al*. (2006) come up with a stationarity test. Although Fourier approximation serves well to threshold breaks, their applications to gradual changes are more satisfactory, and higher test power is associated with it no matter for the monotonic or U-shaped transformation or even for the breaks locate near the end of a series, as we will probe deeply into it later. This paper intends to make a formal sharpening on the evidence of stochastic trend for China's main macroeconomic time series by employing the discipline of Fourier approximation.

Existing discussions about the stochastic trend of China's economy, such as Li (2000) and Smyth and Inder (2003), mainly focus on the perspective of threshold breaks with respect to aggregate GDP as well as its provincial levels, with highly mixed results though. One possible reason for such ambiguous results, besides the latent methodological problems articulated above, is that GDP series are highly persistent, and tests with a null of a unit root are inclined to gesture toward a low test power in application for highly persistent yet stationary data. Thus this paper unfolds its investigation under Fourier approximation by inviting stationarity as its null and proceeds with the test according to LM principle as suggested by Becker *et al*. (2006), meanwhile we will further corroborate the results by employing a Fourier unit root test as suggested by Enders and Lee (2012). In addition, this paper singles out a set of much-handled economic series that are comparable to Nelson and Plosser (1982)'s in terms of coverage, so as to contribute to the cross country comparison in this realm by providing a comprehensive evidence with respect to China.

3. Principles of Fourier Approximation and the Test

Contrary to the idea of estimating the latent number of breaks and specific type of changes, for the maneuver of endogenous breaks, Fourier approximation is not to estimate these specific features of structural changes but to transfer the problem into choosing the appropriate frequency when fitting the latent breaks via iterations of sinusoidal functions. The tradeoff of the optimal frequency that appropriately fits the data without overplaying its hand is the core of Fourier approximation and its corresponding test.

3.1. Principle and method of Fourier approximation

For any given function *f(t)* approximated via Fourier expansions:

$$f(t) \doteq c_0 + \sum_{\omega=1}^{k} a_\omega \sin\left(\frac{2\pi\omega t}{T}\right) + \sum_{\omega=1}^{k} b_\omega \cos\left(\frac{2\pi\omega t}{T}\right); \quad k < \frac{T}{2}.$$

f(t) can be approximated to any degree of accuracy provided the series is sufficiently long, no matter how many or what type of breaks *f(t)* incorporates, where ω is some specific frequency, k is the number of frequencies and T represents the sample size. The degree of approximation accuracy increases as k becomes larger. Structural changes are captured by sinusoidal terms, when this idea is applied to regressive fitness problem it is natural to add iterative sine and cosine components in the regression function:

$$f(t) = c_0 + \beta t + \sum_{\omega=1}^{k} a_\omega \sin\left(\frac{2\pi\omega t}{T}\right) + \sum_{\omega=1}^{k} b_\omega \cos\left(\frac{2\pi\omega t}{T}\right) + \varepsilon_t.$$

Where amplitude $a_\omega = b_\omega = 0$ ($\omega = 1, \cdots, k$) means there is no nonlinearity in the function, contrarily, if there is nonlinearity, it must correspond to one particular frequency. Too many frequencies deplete degrees of freedom quickly and lead to the over-fitting problem pointed out by Enders and Lee (2004). Sinusoidal components which are used here to capture the structural changes lead to the fact that it is best to apply Fourier approximation to gradual process, and the smoother the process is, the less necessarily higher frequency is needed. It can be proved that structural changes shift the spectral density towards frequency zero, thus the optimal frequency for a break locates most probably at the low end of the spectrum. Becker *et al*. (2004) further show that high frequencies are prone to bring about stochastic variability of parameters, and the common sense up to now is that ω can best be chosen from the integer interval of [1, 5], actually single frequency $\omega=1$ (or $\omega=2$) is sufficient for the delineation of a majority of breaks. Consider the following data generating process:

$$\begin{gathered} y_t = X_t'\beta + Z_t'\gamma + u_t + \varepsilon_t, \\ u_t = u_{t-1} + v_t, \quad v_t \sim WN\left(0, \sigma_v^2\right). \end{gathered} \tag{1}$$

Where ε_t are stationary disturbances allowing for heterogeneity, u_t are random walks with v_t are white noise processes and the variance is σ_v^2. Furthermore, $X_t=[1]$ is used for level series of y_t and $X_t=[1, t]'$ for processes with trend. $Z_t=[\sin(2\pi\omega t/T), \cos(2\pi\omega t/T)]'$ capture the breaks in deterministic trend (or other forms of nonlinearity) and $\gamma=[\gamma_1, \gamma_2]'$ measures the amplitude. The null of σ_v^2=0 corresponds to y_t is a $I(0)$ process with structural changes. If Z_t is absent, equation (1) degenerates into standard KPSS stationarity test.

One favorable property of Fourier approximation in capturing the breaks is that for a given size and duration the location of a break does not affect the fitness of the data. To be concrete, consider the following two DGPs: suppose the sample size T=100, y_t=1.5 when 33≤ t ≤66 and y_t=2 otherwise, as charted in figure (1.1). Another DGP has the identical break size and duration except that the break happens at the low end of the sample for 12≤ t ≤45 as in figure (1.2). Dashed lines are Fourier approximations with ω=1 and the selection criterion for ω is the integer frequency from the interval [1, 5] that minimizes the SSR. Then the Fourier regressions for each DGP are:

$$y_t = 1.830 - 0.009\sin\left(\frac{2\pi t}{T}\right) + 0.279\cos\left(\frac{2\pi t}{T}\right) + u_t,\ \ SSR = 1.7184,\ R^2 = 0.6937 \qquad (1.1)$$

$$y_t = 1.830 - 0.273\sin\left(\frac{2\pi t}{T}\right) + 0.061\cos\left(\frac{2\pi t}{T}\right) + u_t,\ \ SSR = 1.7184,\ R^2 = 0.6937 \qquad (1.2)$$

Evidently the location of the break only affects the trigonometric estimator γ but does not change the value of the sum of squared residuals in each of the model. The importance of such property is

[Insert Figure (1.1) about Here] [Insert Figure (1.2) about Here]

twofold: Firstly, it guarantees breaks near the end of the series do not fester into test power.[3] Secondly, it can be proved (see Enders and Lee, 2004 and Becker *et al.*, 2006) that test maintains invariance with regards to the value of β and γ yet depends merely upon the frequency ω, which avoids spurious inferences lured by some paradoxical breaks which themselves are highly subject to negligence.

The construction of structural change stationarity test statistics from equation (1) is based on the standard KPSS statistics, denote $\hat{e}_t$ as the OLS residuals from the following regression (1.3) or (1.4):

$$y_t = c_0 + \gamma_1 \sin\left(\frac{2\pi\omega t}{T}\right) + \gamma_2 \cos\left(\frac{2\pi\omega t}{T}\right) + \varepsilon_t \qquad (1.3)$$

$$y_t = c_0 + \beta t + \gamma_1 \sin\left(\frac{2\pi\omega t}{T}\right) + \gamma_2 \cos\left(\frac{2\pi\omega t}{T}\right) + \varepsilon_t \qquad (1.4)$$

And the test statistics is:

$$\tau_i(\omega) = \frac{1}{T^2}\frac{\sum_{t=1}^{T} S_t^2(\omega)}{\sigma^2}, \quad i = \mu, \tau. \qquad (2)$$

Let $\tau_\mu(\omega)$ denote the test statistics for the level equation (1.3) and $\tau_\tau(\omega)$ for the trend equation (1.4). $S_t(\omega)$ itself is the sum of cumulative residuals from period 1 to t, different from the standard KPSS is that S_t now relies upon frequency ω; σ^2 is the long run population variance and its sample counterpart can be figured out via nonparametric method as the standard KPSS does. Specifically,

3 Some tests, for instance Bai and Perron (1998), have little power when a break happens near the end of a series.

truncate the sample and choose the weight w_j, $\tilde{\gamma}_j$ is the jth autocovariance of the sample residuals and l is the truncation lag. Then the sample counterpart of $S_t(\omega)$ and σ^2 can be calculated according to the following (2.1) and (2.2):

$$\hat{S}_t(\omega) = \sum_{j=1}^{t} \hat{e}_j \tag{2.1}$$

$$\hat{\sigma}^2 = \tilde{\gamma}_0 + 2\sum_{j=1}^{l} w_j \tilde{\gamma}_j . \tag{2.2}$$

$\tau_i(\omega)$ do not follow the usual probabilistic distribution but due to the test invariance with regards to the parameter β and γ, the DGP for the simulation of critical values can be set with $\beta=\gamma=0$,[4] Becker *et al*. (2006, p.389) give the Monte Carlo simulated critical values on the frequencies [1, 5].

3.2. Frequency selection

Frequency plays the crux of the test and there are logically three strategies of selecting the frequency component(s) in the test: single frequency, cumulative frequencies and endogenous frequency. The selection criterion is still based on the rationale that the candidate yields highest power and sound size. Single frequency means a pre-specified ω=1 (or ω=2) is sufficient to replicate the essentials of many a break. It can be verified via simulation, however, once the real latent frequency is higher than 2, under valued frequency often leads to severe over-sized problem.[5] So there is risk in utilizing ω=1 (or ω=2) without exception since researchers usually do not have definite information about frequency.

Gallant (1984) and Bierens (1997) recommend cumulative frequencies and the reason is straightforward: if ω=1 captures an unknown functional form well, then a compound of ω=1 and ω=2 can do better. Under the circumstances of cumulative frequencies, test statistics still depend on the frequencies used because of the orthogonality of the trigonometric components on each frequency. Only the critical values and the distributions move much towards the origin as the frequency dimension increases.

No matter for the single frequency or cumulative frequencies, the frequency component(s) need(s) to be specified a priori, whereas endogenous frequency, although confines to an estimation of merely one frequency, estimates the unknown frequency and thus is a data-driven method. The estimation is usually conducted by choosing the very frequency that minimizes SSR within $\omega \in [1, 5]$. This is because comparing with other principles, such as t or F tests of related coefficient(s), the convergence speed of the test statistics has not been fully investigated whereas the consistency and convergence speed of those based on the minimization of SSR can be guaranteed from the discussion of Davies (1987), Hatanaka and Yamada (1999) as well as Perron and Zhu (2005). Becker *et al*.'s (2006) critical value simulated for single frequency can still be used in case of estimated frequency since the estimation of frequency is consistent.

Test for the optimal cumulative frequencies is not feasible according to this line since adding one more frequency undoubtedly decreases SSR. There are also over-sized problems if the compound frequencies used deviate from the real ones. The SSR frequency, however, also subjects

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[4] Simulation results are actually the same for the other β and γ.

[5] Namely over-reject the null.

to a mild size distortion in small γ and T circumstances, which is due to the lack of precision for the estimation of frequency. It needs to be pointed out the cumulative frequencies still maintain reasonable test size if there's no break at all but SSR frequency suffers size distortion. As for the test power, prior single frequency rates the highest followed by SSR frequency, and cumulative frequencies sustain the minimum, which is because the endogenous method contains a procedure of searching the optimal frequency and this may lead to a none-rejecting-the-null-bias, with its power still higher than cumulative frequencies though. The comparisons between cumulative frequencies and SSR are thus straightforward: the former is latent for the risk of specification bias but is capable of sound test size even if there's no break; the latter sustains conservative test size but maintains higher power. Evidently there is tradeoff between cumulative frequencies and endogenous frequency as far as the frequency selection is concerned. Since cumulative frequencies are not results of some objective selection criteria, whereas endogenous frequency is also not so confident for the allegation that the real optimal frequency must be some single one on the interval [1, 5], thus there's nothing of a universal rule for the optimal frequency selection. And I believe when researchers have no prior information about the appropriate frequency, SSR strategy is a reasonable starting point because less parameters need to be estimated, cumulative frequencies readily extend to higher frequencies at the price of reducing the test power. For the two extreme circumstances when the magnitude of break is too big or too insignificant but still justify structural changes, then much reliable results are likely to come from the cumulative frequencies rather than SSR method because of more sufficient fitness, thus cumulative frequencies should be used even if there is risk.

3.3. Test the break components

One thing that cannot be neglected is the null H_0: $\sigma_v^2=0$ and the alternative hypothesis H_1: $\sigma_v^2>0$ of the test in equation (1) have not specified there must be structural changes in the DGP. If the DGP doesn't contain any breaks, standard KPSS guarantees better test power. So it is necessary to test whether there are break components (nonlinearities in general) in the series, which equals to whether equation (1) contains some specific frequency. When a single frequency is used the null hypothesis is H_0: $\gamma_1=\gamma_2=0$ and H_1 corresponds to some form of structural changes under the frequency used. Such a test can be performed according to the usual F statistics:

$$F_i(\omega)=\frac{\left[SSR_R-SSR_U(\omega)\right]/2}{SSR_U(\omega)/\left(T-k\right)}, \quad i=\mu,\tau. \tag{3}$$

Where k is the number of regressors, SSR_R is the restricted sum of squared residuals with its unrestricted counterpart denoted SSR_U which is dependent upon the frequency, so the F statistics also depends on the frequency. Equation (3) applies only when ω is given, if ω is unknown—— thus appears in the test as an unidentified nuisance parameter, the regular critical values of F test cannot be used even though ω can be figured out via minimization of SSR. In this case the F statistics is specified as follows:

$$\begin{gathered} F_i\left(\hat{\omega}\right)=\max_{\omega} F\left(\omega\right), \quad i=\mu,\tau. \\ \hat{\omega}=\arg\inf_{\omega} SSR_i\left(\omega\right) \end{gathered} \tag{4}$$

Namely the frequency is obtained by minimization of SSR of the equation (1.3) or (1.4). Becker *et* *al*. (2006, p.389) also give the critical values of the *F* statistics under such circumstances and further indicate that the test power is very low for the non-stationary series, that is, the test is defected for its inclination for the absence of nonlinearity under the unit root circumstances whereas there is indeed nonlinearity. So this paper only makes use of this *F* test that justifies existence of breaks when the null of a stationarity is not rejected.

3.4. Corroboration from a Fourier unit root test

The major maneuver we employ takes stationarity as its null hypothesis, concrete as the evidence from a stationarity test could be, it is better to attest the result further by a unit root test which takes the null of a unit root against a stationary process.[6] For this purpose this paper utilizes the Fourier unit root test proposed by Enders and Lee (2012) who introduce Fourier series to approximate structural breaks on an ADF basis.[7] With the above articulation, it is handy and beneficial to take a glance at this test principle which is based on the LM regularity.

Take the single frequency as a case in point, if the data-generating process is represented by equation (1.4), regressing it using the first order differences yields:

$$\Delta y_t = \alpha_0 + \alpha_1 \Delta \sin\left(\frac{2\pi\omega t}{T}\right) + \alpha_2 \Delta \cos\left(\frac{2\pi\omega t}{T}\right) + u_t .$$

Denote $\hat{\alpha}_0$, $\hat{a}_1$ and $\hat{\alpha}_2$ the estimated coefficients, a detrended series has been constructed by Enders and Lee using these coefficients:

$$\xi_t = y_t - y_1 + \hat{\alpha}_0 (1-t) + \hat{\alpha}_1 \left[\sin\left(\frac{2\pi\omega}{T}\right) - \sin\left(\frac{2\pi\omega t}{T}\right) \right] + \hat{\alpha}_2 \left[\cos\left(\frac{2\pi\omega}{T}\right) - \cos\left(\frac{2\pi\omega t}{T}\right) \right],$$

where y_1 is the first observation of y_t . The test is based on regressing first differences of y on the detrended series as well as first differences of the trigonometric components:

$$\Delta y_t = \theta_0 + \phi \xi_{t-1} + \theta_1 \Delta \sin\left(\frac{2\pi\omega t}{T}\right) + \theta_2 \Delta \cos\left(\frac{2\pi\omega t}{T}\right) + \sum_{i=1}^{k} \phi_i \Delta \xi_{t-i} + \eta_t .$$

Non-stationarity corresponds to $H_0 : \phi = 0$, and the LM test statistic is naturally the t-statistic for this null hypothesis.[8] Lagged values of $\Delta\xi_{t-i}$ is used to correct for serial correlation.

Like Becker *et al*. (2006), Enders and Lee (2012) also recommend lower frequencies that don't exceed 5 in approximating the breaks out of the same reason, and a data-driven method of minimizing SSR in selecting the optimal frequency. Furthermore, they use the same max F

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6 I'm grateful to the referee for these refinements.

7 Rodrigues and Taylor (2012) also come up with a unit root test using a Fourier series to approximate smooth breaks on an ADF basis. The difference is their test statistics is established according to the DF-GLS method while Ender and Lee construct their test statistics according to the LM principle. Though DF-GLS is associated with higher test power for non-structural settings, the penalty of sticking to this idea in Fourier approximated breaks is for the test statistics to suffer from asymptotically rank deficiency.

8 Please refer to Enders and Lee (2012, p. 580; p. 582) for critical values under single frequency and cumulated frequencies.

statistic to verify the existence of nonlinearities. So the optimal frequency singled out and the max F test are valid for both the Fourier stationarity as well as the unit root test, with the latter serves as a robustness check for the results obtained from the major stationarity approach.

4. Fourier Approximation Tests and Analysis of China's Macroeconomic Time Series

This part moves to an exposition and discussion of China's macroeconomic time series, the following rests on the general assumption that China's entire macroeconomic system is a stochastic process that follows a certain distribution. This paper singles out 15 commonly used variables which cover a wide range of output, employment, price, exchange rates, money, security and trade. All the variables are in logarithms, detailed information and data sources are summarized in Table (1). Because this data set is reusable for future methodologies, put aside the idea this paper is trying to argue for, this data set itself could contribute to a canonical set from which, like Nelson and Plosser (1982)'s, cross country comparison might come.

[Insert Table (1) about Here]

Since non-stationary series are cumulated disturbances based on one period ahead value of each date, an obvious property of a non-stationary series is that their autocorrelation coefficients decay to zero pretty slowly. Detrending the series either according to equation (1.3) or equation (1.4) reveals that only the NEER, REER and stock prices have a speed of decay analogous to that of a random walk. Other series decay to zero much quickly,[9] which forms an implicit manifestation of a property other than a unit root.

Nine of the fifteen concerned series take on obvious trend in the entire sample; still four of the series present trends within some specific subsamples, these series are tested according to equation (1.4) that allows for trend. Since economic theory does not suppose deterministic trend in stock prices, Shanghai composite index and Shenzhen component index are performed under equation (1.3).

[Insert Table (2) about Here]

The first six columns of Table (2) summarize the main analytical results. Figure (2.1)-(2.4) plot the outputs of China with Fourier approximations are in dashed lines. Similarly, it is interesting to notice the optimal frequency that fits these various output indexes best are all ω=1. While most of the parts look relatively smooth in real GDP, real per capita GDP and real industrial production, the period of 1960-1962 in contrast corresponds to evident downward transitions which are not so evident in the non-inflation adjusted nominal GDP though. Every Chinese can instantly recognize them as the result of the Great Leap Forward and the following Great Famine which has been attributed to the three years of natural disasters, a term preferred by official announcements and mandated in textbooks even today. The Great Leap Forward was an ideologically pathological national movement whose aim was to jog into Communism, when an enthusiasm had been roused as every political campaign would be capable of, local officials were twisted with an incentive of overstating the crop productions under dictatorship. In a haste of showing devotion or allegiance

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9 Such an informal demonstration is available upon request.

lower echelons had a fondness of raising the ante of the output volume sequentially in a single-direction hierarchical system. Since tax was proportional to output, the more was produced or was assumed to be produced, exactly speaking, the more was collected by the country. And when the overstatement was rolled down to a preposterous exaggeration, peasants were expected to hand over not only all the yields but nearly everything including the necessary amount of food for maintaining sustenance and the seeds for sowing. That's how demagoguery results in the Great Famine during 1959 to 1962, it is estimated 37.55 million Chinese people starve to death,[10] an estimation that is in close accordance with the population reduction inferred from demographic records. So the ups in output correspond to intense devotion of the Great Leap Forward, the downs in output correspond to the starvation and the hindrances to reproduction. That's enough for the background.

Test results show non-rejections at the significance of 5% unanimously, which means although the Great Famine exert significant shocks towards the latent data generating process of China's GDP, there are still evidence indicate that the growth of Chinese economy follows a tractable trend. Such a trend may not be properly handled by simple linear or quadratic trends due the various and infinite randomness of the entire economic system, all the significance this paper intends to address methodologically is that delineating the trend nonlinearly by the thought of Fourier approximation may yield a better exposition. Based on these observations, it is more pervasive to regard China's GDP as trend stationary process with structural changes of smooth transitions, even the shocks as large as three years of nationwide starvation could not lead the economy to deviate from its Fourier trend for a long time, business cycles in this sense are just fluctuations around this smooth trend with some drastic yet gradual ups and downs. Finally, all the *max F* tests for nonlinearity in outputs reject the null of $\gamma_1=\gamma_2=0$ significantly, which justifies the obvious feature of gradual changes. Omitting the breaks or detrending the series by simple trend may easily yield the inference of a unit root about China's GDP.

[Insert Figure (2.1)-(3.3) about Here]

There is a little bit subtlety in employment and money supply, although the two variables reject the null at 5% significance level, they both fail to reject when the significance level tightens up to 1%. Under this condition, graphs once again help to recognize the problem or build confidence in the results. Figure (2.5) shows an upsurge and down of the employment during the year 1957 to 1960, the Great Leap Forward enhances employment initially but the following Great Famine drags it down. A large "N-shape" fluctuation emerges during 1989-1992, the growth rate whereafter slows down, which is presumably a result of the reform of state-owned enterprises (SOEs). Even though the Open-up reform has started as early as 1978, the SOEs have taken dominance in nearly all industries by the end of 1980s. Then a relative fierce reform of SOEs was initiated in many industries to give rise to privatization which brought about a large amount of unemployment in the beginning, since SOEs were redundant inefficient it wasn't uncommon at that time in cities that an former SOEs' employee had become an laid off worker at his/her thirties or fourties. The effects of the two volatile deviations cannot be cancelled, which I suppose may account for the rejection at 5% significance level. But the rest of the processes other than the two breaks are comparatively stationary, including the slow down after 1992. Thus it is feasible to

[10] Source (In Chinese): http://jiuliyougancheng.blogchina.com/1373459.html

consider China's employment as trend stationary with structural changes. Figure (2.6) offers just another case, mere eye glances can hardly distinguish between Fourier fit and money supply. This is due to the small variance of China's monetary supply, there is not any recognizable fluctuations since 1996; besides, it is ponderable from the graph that China's monetary supply of each period may considerably take into account of the amount issued one period ahead or even earlier and thus takes on the effect of intensive persistency. Small variance as well as intensive persistency exerts an effect that a small deviation is actually a large shock, which give rise to the inclination for a unit root inference. The amazing straightforward trend, however, still locks the inference of a trend stationary at 1% significance level, and as witnessed, there are reasons in such an inference.

The case of CPI is a bit more complicated yet illustrative about the focal point. China's CPI reaches its peak as high as 24.1% in 1994,[11] and still suffers an annual average of 17.1% and 8.3% separately in 1995 and 1996 though alleviated gradually. Because the monthly data this paper utilized are available only since February 1995 on which is also the data based, so there is an obvious price increasing trend during 1995 to 1996, as plotted in figure (3.1)-(3.3). Since then China steps into mild deflation during 1997-2002 and the fixed base CPI somewhat goes down. The entire shift from inflation to deflation stands prominently as a smooth transition process with distinctive growth rates on each period and neat stationarities on each trend. If CPI is fitted with the single optimal frequency ω=1, as plotted in Figure (3.1), distinctive change of growth rates results in insufficient approximation for single frequency and the test rejects the null at 1% significance and is in favor of a unit root inference. But the approximation improves when cumulative frequencies ω=1 and ω=2 are employed, as plotted in Figure (3.2), the test now rejects the null at 5% significance level but fails to reject at 1%. One more step further, if a compound frequencies of ω=1, ω=2 and ω=3 are fitted in the equation, the approximation improves yet again and the test result listed in Table (3) shows the null of a stationarity is not rejected even at 10% significance level. The fact revealed in the investigation of CPI is that insufficient fit makes possible rooms for size distortion, which is prone to be favorable for a unit root inference. A reasonable inference is conditional on sufficient fit (to the exclusion of over fit, of course) whereas there is still lack of a universal rule to differentiate the circumscription between sufficient and insufficient fit. And the distinction between the two, under many circumstances, depends on the meticulous command of the researchers to a substantial extent. For this reason, it makes sense to deem the monthly fixed base CPI as trend stationary process with smooth transitions.

[Insert Figure (4.1)-(4.2) about Here]

The same problem appears in the nominal exchange rate of Renminbi against US dollar. Because commodity prices were controlled under planned economy for a long term, the same commodity might have a drastically different world price compared to its domestic market, which caused international trade to be in a red. At that time the State Council of China presumed this to be the fact that the RMB exchange rate could not cater both the non-trade aspect and the

[11] Chinese economy is an investment driven economy up until today. Investment, irrespective of private or public, rather than consumption plays a determinant role in economic growth. In 1992, Mr. Deng Xiaoping, the former chairman of the CPC, made one of his most cited speeches in south China whose content was to encourage the existence of private economy for the sake of efficiency. The speech instigated an upsurge of investments and the inflation during 1993-1996 was brought about by this round excessive investing.

international trade aspect simultaneously, so a double regime of RMB exchange rate was designed and put to application until 1994. That is, a new exchange rate of RMB which, 1 USD = 2.80 RMB initially, is designated for trade settlement is established, meanwhile the old official RMB exchange rate which is approximately 1 USD = 1.50 RMB served the so called non-trade settlement. Later as the trade regime gravely depreciated to 1 USD in exchange of nearly eight RMB Yuan, together with the prevalence of exchange rate arbitrage in the black market, those strength finally forced the merger of official rate and the trade regime rate in 1994. As graphed, the RMB exchange rate firmly pegged USD at the level of 8.27 from the fourth quarter of 1996 to the second quarter of 2005. And this exchange rate is undoubtedly stationary if the sample is confined within this period. However if the period falls to be the subset of the entire sample, such an embarrassing tranquility only helps to boost pseudo-inference. The test rejects the null at 5% but fails to reject at 1% if the single optimal frequency $\omega=1$ is used to fit the data (Figure (4.1)). If the frequencies are relaxed to a compound of $\omega=1$ and $\omega=2$ altogether (Figure (4.2)), the test does not reject the null even at 10% besides fitness improvement. Although the break points on the corresponding quarters of 1995, 2005 and 2008 are by no means smooth, there is still evidence to treat RMB exchange rate against USD as trend stationary with structural changes.

[Insert Figure (5.1)-(6.2) about Here]

The Nominal Effective Exchange Rate (NEER) and Real Effective Exchange Rate (REER) of RMB primarily undergo a long way of persistent devaluation before 1994 and appreciate in fluctuations ever since (Figure (5.1)-(5.2)). Exchange rate reforms in 1994 once again dovetail with the stylized facts of structural changes. The optimal frequency for NEER and REER are both $\omega=1$ and the tests reject the null both at 1% significance level. So NEER and REER of RMB are inclined to be inferred as unit root processes with structural changes. Shanghai composite index and Shenzhen component index corresponds separately to Figure (6.1) and Figure (6.2), with the former initiated on January 1992 and the latter on January 1995. The optimal frequencies for the stock prices represented by the two indexes are both $\omega=2$ and the null hypotheses are rejected significantly. It is necessary to make clear that economic theory does not provide much evidence to back up the viewpoint that stock prices have long term growth trend, thus the tests are performed according to equation (1.3) that precludes the trend. The results conform to the commonly acknowledged perception that financial prices are generally processes of random walk.

[Insert Figure (7.1)-(7.6) about Here]

China's foreign trade statistical data provide excellent material for the comprehension of smooth transition stationarity test. The bygone subprime crisis leaves an impressive scent at the terminal end of each of the sample in Figure (7.1)-(7.6), also it can be found from a comparison between Figure (7.3) and Figure (7.5) that the crisis strikes the import heavier than the export. Since Fourier approximation maintains fitness invariance as for the break position within the detrended series, a break located at the end of the sample will not lead to severe size distortion. If the data are fitted by optimal single frequency $\omega=1$, then total trade, the export and the import all reject the null at 1% without exception and are in favor of unit root inferences. But when cumulative frequencies $\omega=1$ and $\omega=2$ are utilized, the tests unanimously fail to reject the null at

10% without exception. Reasons do not lie in the subprime shocks at the terminal ends, whether the marked parts in the middle of the sample are regarded as smooth transition processes as lined out in Figure (7.2), (7.4) and (7.6) is the one that really counts. Compare each graph with their counterpart under ω=1 situations, the intermediate sessions do not stand prominently as smooth transition processes under single frequency, thus the test itself regards them as realizations of purely stochastic trend, which is the reason that leads to unit root inferences. But under cumulative frequencies, along the traces following the approximated dashed lines are clearly sluggish then revived growth rates, though nothing changes in the original data plots but only the Fourier approximations. For the total trade data, this intermediate part presumably corresponds to July, 1997-June, 2000; and July, 1997-February, 2001 for the export and February, 1996-December, 2000 for the import. The very historical event these periods coincide with is the Southeast Asian Financial Crisis! So it justifies considering these sessions as smooth transitions rather than the results of purely stochastic trend. And within the scope of gradual changes, the more persuading inference for China's trade data should be trend stationary with smooth transitions.

5. Robustness check: Corroborations and Comparisons

Since non-rejection of the null undertakes a probability of making mistakes which is hard to tell, for the sake of robustness we corroborate our results with a Fourier unit root test of Enders and Lee (2012) which has been briefly exposited in subsection 3.4. The attesting results are shown in table (2) under the column labeled with "Fourier UR". The fact that the optimal frequency, as well as the max *F* test statistic, applies to both Fourier stationarity and unit root tests greatly facilitate the cross reference. Besides all the exchange rates and stock prices, other variables unanimously reject the null at the 1% significance level in favor of the conclusion that all these variables are stationary. Except for the bilateral RMB/USD exchange rate, all our former conclusions under the stationarity test can be cross attested by this Fourier unit root test under the same trend type and frequency specification.

For further demonstration of test size and power, table (2) also incorporates the test results obtained from the standard KPSS, DF-GLS, the Logistic Smooth Transition Auto-Regressive (LSTAR) unit root test suggested by Saikkonen and Lütkephol (2002), and finally the Zivot and Andrews' (1992) test that uses dummy variables but allows for the endogenously determined break date. The situations can be quite different when the breaks are not catered or the nonlinearities are not controlled for by trigonometric components. The standard KPSS just significantly rejects the null of a stationary process to all except for the real industrial production, DF-GLS, the one that is considered to be of the highest power under no break circumstances, fails to reject all except for the bilateral RMB/USD exchange rate.[12] Without due consideration of the structural breaks, nearly every variable we got is prone to be concluded as a unit root process. Yet even considering approximation using a smooth transitional function suffers from low test power, because LSTAR test rejects none of the null hypotheses of all the variables.[13] Finally, we can compare the results with the traditional method using dummies to account for breaks, as indicated in the Zivot and Andrews' test,[14] only the real industrial production, CPI, and the bilateral

[12] Here in the table the DF-GLS test only reports among others the test statistic of the optimal lag selected by Ng-Perron sequential *t* statistics.
[13] The initial transition parameter is set to 10 for LSTAR estimation.
[14] 5% percent data trimming is used.

exchange rate could reject the null of a unit root, even though the real GDP and GDP per capita resemble the real industrial production largely, as can be seen from the figures.

6. Concluding Remarks and Discussion

This paper aims to give an investigation on the stochastic trend that possibly lurks within China's macroeconomic system from the perspective of structural changes. Since the initiation of Perron (1989), research in this realm are flourishing yet still short of satisfaction, it is thus necessary to base this investigation on the detailed comments and comparisons among the former literature to reduce the possibility of pseudo-inferences to a maximum extent. And detailed treatment of the development in this realm leads to the observation that Fourier approximation intrigues the investigation in two aspects: Firstly, it shifts the determination of number of breaks and modes of changes into the appropriate frequency selection problem and thus enables a short cut over the incessant dispute on the specific properties of the structural changes. Secondly, a Fourier detrended series maintains the fitness invariance as for the break locations so breaks near the end of a series do not encroach on the inferences. For these reasons, this paper explores Fourier principles and tests suggested by Becker *et al*. (2006) to investigate the structural change stationarity of the fifteen variables chosen from China's macroeconomic system. The results are further corroborated by the Fourier unit root test of Enders and Lee (2012) and are compared with other parallel methodologies. We believe that only the stock prices, the nominal effective exchange rates and the real effective exchange rates are dominated significantly by stochastic trend, it is more appropriate to model these variables according to structural change unit root processes; other variables, including the real GDP and foreign trade, however, are dominated by deterministic trend, and modeling them according to trend stationary processes with smooth transitions yields more accurate forecasts and perceptions.

We do not implement tests to cherish the intention of labeling a particular series with an $I(0)$ or $I(1)$ tag, we implement tests to gain improved epistemic grasp on how we should comprehend the latent data generating process of the true economy. Take the real GDP for instance, if it was inferred to be a unit root process irrespective of the smooth transitions, this implies what happens during 1960-1962 are three years of succeedingly large outliers which are due to the fat tail of the time-invariant probabilistic distribution that the latent DGP follows. Whereas if the real GDP was inferred to be a trend stationary process with smooth transitions as this paper believes, then 1960-1962 should be comprehended as the shocks of the Great Leap Forward as well as the Great Famine changed the probabilistic distribution that the DGP follows during this period, nonetheless, either the distribution before or after these shocks remains stationary. It is the impactive events that the smooth transition processes correspond to rather than the entire noise processes are of permanent effect. The same implications of perception apply to the other series, such as the Southeast Asia Financial Crisis for trade and the shift from inflation to deflation for CPI. The results of this paper, in terms of policy implications, back up the effect of government initiated structural reforms, because they cannot be easily offset by other noisy disturbances. Such interventions should either be of powerful intensity or be able to maintain transitional persistency institutionally.

As the problem all the hypothesis tests confront, of course, rejecting the null in a unit root test does not mean an instantaneous acceptance of a particular alternative, but for the purpose that tests are designed to raise power against a specific class of alternatives, forecast precision may gain improvement by comparing among the close alternatives and modeling according to a particular one. Analogously, failing to reject the null in a stationarity test does not mean adhering to this specific null hypothesis even seriously, but for the purpose that tests are developed to maintain reasonable test size, it helps to confine the forecast errors within reasonable ranges when modeling according to this null. However neither the structural change unit root tests nor structural change stationarity tests settle the problem of observational equivalence well in finite samples. Metaphorically, a trend stationary process with one break but same slopes and zero variance in the errors is observationally equivalent to a unit root process with drift but errors are zero with a high probability and nonzero occasionally. Namely nonzero but finite variances correspond to fat-tail distributed errors of a unit root, it is hard to differentiate the two kinds of models once the nonzero variance sprang out, or put it equivalently, such a differentiation is only feasible on the infinite horizons. For more general cases, any trend stationary processes are almost observationally equivalent to unit root processes with strong mean reversion.[15] The fact of non-rejection after approximating the smooth transitions with Fourier series as this paper does has an implication in this term that the disturbances must present strong mean reversion if the data are actually dominated by stochastic trend. Although for any given finite sample series, a representative can be found from either class of processes that are capable of delineating the observed features of the data, there are still good reasons justify the distinction between the two classes of models. The first involves a trade-off between efficiency and consistency. If a restriction (a structural change trend stationarity, in this paper's context) is true, imposing it in the estimation yields more efficient estimates and more accurate predictions. If the restriction is false, the estimates are unreliable and the inconsistency cannot be wiped out even asymptotically. Besides the familiar trade-off between efficiency and consistency, two classes of models also correspond with different data perceptions. Whether a particular class of models should be used depends not only upon the data themselves but also upon the rationality of the perception. If a unit root is employed, there must be justifications to guarantee the realizations of fat tailed disturbances. But for the major representative variables of real macro economy, described as hereinbefore, such justifications are seldom sufficient. Thus it is more reasonable to employ trend stationarity with structural changes (smooth transitions), which is all that this paper means.

[15] Consider the stationary process $y_t = \varepsilon_t$ and the unit root process $(1-L)y_t = (1+\theta L)\varepsilon_t$ where $|\theta| < 1$, the observable implications are virtually the same as θ goes to -1. Again, the unit root process $y_t = y_{t-1} + \varepsilon_t$ and the stationary process $y_t = \rho y_{t-1} + \varepsilon_t$ under $|\rho| < 1$, it is also difficult to distinguish the two when ρ is close to 1 at finite time horizons.

References

Bai, J. and P. Perron, 1998, "Estimating and Testing Linear Models with Multiple Structural Changes," *Econometrica*, 66(1), pp.47-78.

Banerjee, A., R.L. Lumsdaine and J.H. Stock, 1992, "Recursive and Sequential Tests of the Unit-Root and Trend Break Hypothesis: Theory and International Evidence," *Journal of Business and Economic Statistics*, 10(3), pp.271-87.

Barro, R., 1976, "Rational Expectations and the Role of Monetary Policy," *Journal of Monetary Economics*, 2(1), pp.1-32.

Becker, R., W. Enders and S. Hurn, 2004, "A General Tests for Time Dependence in Parameters," *Journal of Applied Econometrics*, 19(7), pp.899-906.

Becker, R., W. Enders and J. Lee, 2006, "A Stationarity Test in the Presence of an Unknown Number of Smooth Breaks," *Journal of Time Series Analysis*, 27(3), pp.381-409.

Bierens, H., 1997, "Testing the Unit Root with Drift Hypothesis against Nonlinear Trend Stationarity, with an Application to the US Price Level and Interest Rate," *Journal of Econometrics*, 81(1), pp.29-64.

Blanchard, O.J., 1981, "What Is Left of the Multiplier Accelerator?" *American Economic Review*, 71(2), pp.150-4.

Blanchard, O.J. and L.H. Summers, 1986, "Hysteresis and the European Unemployment Problem," NBER Working Papers, No.1950.

Box, G.E.P. and G.C. Tiao, 1975, "Intervention Analysis with Applications to Economic and Environmental Problems," *Journal of the American Statistical Association*, 70(349), pp.70-9.

Christiano, L.J., 1992, "Searching for a Break in GNP," *Journal of Business and Economic Statistics*, 10(3), pp.237-50.

Cook, S. and N. Manning, 2004, "The Disappointing Properties of GLS-Based Unit Root Tests in the Presence of Structural Breaks," Communications in Statistics-Simulation and Computation, 33(3), pp.585-96.

Cochrane, J.H., 1988, "How Big is the Random Walk in GNP," *Journal of Political Economy*, 96(5), pp.893-920.

Davies, R.B., 1987, "Hypothesis Testing When a Nuisance Parameter Is Present Only Identified under the Alternative," *Biometrika*, 74(1), pp.33-43.

Diebold, F.X. and L. Kilian, 2000, "Unit-Root Tests Are Useful for Selecting Forecasting Models," *Journal of Business & Economic Statistics*, 18(3), pp.265-73.

Elliot, G., T.J. Rothenberg and J.H. Stock, 1996, "Efficient Tests for an Autoregressive Unit Root," *Econometrica*, 64(4), pp.813-36.

Enders, W. and J. Lee, 2004, "Testing for a Unit-Root with a Nonlinear Fourier Function," Econometric Society 2004 Far Eastern Meetings, No.457, http://www.nd.edu/~meg/MEG2004/Lee-Junsoo.pdf.

Enders, W. and J. Lee, 2012, "A Unit Root Test Using a Fourier Series to Approximate Smooth Breaks," *Oxford Bulletin of Economics and Statistics*, 74(4), pp.574-99.

Engle, R.F. and C.W. Granger, 1987, "Co-Integration and Error Correction: Representation, Estimation and Testing," *Econometrica*, 55(2), pp.251-76.

Gallant, A.R., 1981, "On the Bias in Flexible Functional Forms and an Essentially Unbiased Form: The Fourier Flexible Form," *Journal of Econometrics*, 15(2), pp.211-45.

Gallant, A.R., 1984, "The Fourier Flexible Form," *American Journal of Agricultural Economics*, 66(2), pp.204-8.

Gallant, A.R. and G. Souza, 1991, "On the Asymptotic Normality of Fourier Flexible Form Estimates," *Journal of Econometrics*, 50(3), pp.329-53.

Gould, J.P. and C.R. Nelson, 1974, "The Stochastic Structure of the Velocity of Money," *American Economic Review*, 64(3), pp.405-18.

Granger, C. and P. Newbold, 1974, "Spurious Regressions in Econometrics," *Journal of Econometrics*, 2(2), pp.111-20.

Hall, R.E., 1978, "Stochastic Implication of the Life Cycle-Permanent Income Hypothesis: Theory and Evidence," *Journal of Political Economy*, 86(6), pp.971-87.

Hamilton, J.D. 1994, Time Series Analysis, Princeton, NJ: Princeton University Press.

Harvey, D. and T. Mills, 2003, "Tests for Stationarity in Series with Endogenously Determined Structural Change," *Oxford Bulletin of Economics and Statistics*, 66(5), pp.863-94.

Hatanaka, M. and K. Yamada, 1999, "A Unit Root Test in the Presence of Structural Changes in I(1) and I(0) Models," in Cointegration, Causality, and Forecasting: A Festschrift in Honour of Clive W. J. Granger, ed. By R.F. Engle and H. White, Oxford: Oxford University Press.

Hecq, A. and J.P. Urbain, 1993, "Misspecification Tests, Unit Roots and Level Shifts," *Economics Letters*, 43(2), pp.129-35.

Kapetanios, G., Y. Shin and A. Snell, 2003, "Testing for a Unit Root in the Nonlinear STAR Framework," *Journal of Econometrics*, 112(2), pp.359-79.

Kim, D. and P. Perron, 2009, "Unit Root Tests Allowing for a Break in the Trend Function at an Unknown Time under Both the Null and Alternative Hypotheses," *Journal of Econometrics*, 148(1), pp.1-13.

Kwiatkowski, D., P.C.B. Phillips, P. Schmidt, and Y. Shin, 1992, "Testing the Null Hypothesis of Stationarity against the Alternative of a Unit Root," *Journal of Econometrics*, 54(1-3), pp.159-78.

Kydland, F. and E. Prescott, 1980, "A Competitive Theory of Fluctuations and the Feasibility and Desirability of Stabilization Policy," in Rational Expectations and Economic Policy, ed. by Stanley Fisher. Chicago: University of Chicago Press, pp.169-98.

Lanne, M., H. Lütkephol and P. Saikkonen, 2002, "Comparison of Unit Root Tests for Time Series with Level Shifts," *Journal of Time Series Analysis*, 23(6), pp.667-85.

Lee, J. and M.C. Strazicich, 2001, "Break Point Estimation and Spurious Rejections with Endogenous Unit Root Tests," *Oxford Bulletin of Economics and Statistics*, 63(5), pp.535-58.

Lee, J. and M.C. Strazicich, 2003, "Minimum Lagrange Multiplier Unit Root Test with Two Structural Breaks," *Review of Economics and Statistics*, 85(4), pp.1082-9.

Leybourne, S.J., T.C. Mills and P. Newbold, 1998a, "Spurious Rejections by Dickey-Fuller Tests in the Presence of A Break under the Null," *Journal of Econometrics*, 87, pp.191-203.

Leybourne, S.J., P. Newbold and D. Vougas, 1998b, "Unit Roots and Smooth Transitions," *Journal of Time Series Analysis*, 19(1), pp.83-97.

Leybourne, S.J. and P. Newbold, 2000, "Behavior of the Standard and Symmetric Dickey-Fuller Tests When There Is A Break under the Null Hypothesis," *Econometrics Journal*, 3, pp.1-15.

Li, X.M., 2000, "The Great Leap Forward, Economic Reforms, and the Unit Root Hypothesis: Testing for Breaking Trend Functions in China's GDP Data," *Journal of Comparative Economics*, 28(4), pp.814-27.

Lumsdaine, R.L. and D.H. Papell, 1997, "Multiple Trend Breaks and the Unit Root Hypothesis," *Review of Economics and Statistics*, 79(2), pp.212-8.

Luukkonen, R., P. Saikkonen and T. Terasvirta, 1988, "Testing Linearity against Smooth Transition Autoregressive Models," *Biometrika*, 75(3), pp.491-9.

Montañés, A., 1997, "Level Shifts, Unit Roots and Misspecification of the Breaking Date," *Economics Letters*, 54(1), pp.7-13.

Montañés, A. and I. Olloqui, 1999, "Misspecification of the Breaking Date in Segmented Trend Variables: Effect on the Unit Root Tests," *Economics Letters*, 65(3), pp.301-7.

Nelson, C. and C. Plosser, 1982, "Trends and Random Walks in Macroeconomic Time Series," *Journal of Monetary Economics*, (10), pp.139-62.

Nunes, L.C., P. Newbold and C. Kuan, 1997, "Testing for Unit Root with Breaks: Evidence on the Great Crash and the Unit Root Hypothesis Reconsidered," *Oxford Bulletin of Economics and Statistics*, 59(4), pp.435-48.

Ohara, H.I., 1999, "A Unit Root Test with Multiple Trend Breaks: A Theory and an Application to US and Japanese Macroeconomic Time-Series," *Japanese Economic Review*, 50(3), pp.266-90.

Phillips, P.C.B. and P. Perron, 1988, "Testing for a Unit Root in Time Series Regression," *Biometrika*, 75(2), pp.335-46.

Perron, P., 1989, "The Great Cash, the Oil Price Shock, and the Unit Root Hypothesis," *Econometrica*, 57(6), pp.1361-401.

Perron, P., 1990, "Testing for a Unit Root in a Time Series with a Changing Mean," *Journal of Business and Economic Statistics*, 8(2), pp.153-62.

Perron, P., 1997, "Further Evidence on Breaking Trend Functions in Macroeconomics Variables," *Journal of Econometrics*, 80(2), pp.355-85.

Perron, P. and X. Zhu, 2005, "Structural Breaks with Deterministic and Stochastic Trends," *Journal of Econometrics*, 129(1-2), pp.65-119.

Rodrigues, P. M. M., and A. M. R. Taylor, 2012, "The Flexible Fourier Form and Local Generalized Least Squares De-trended Unit Root Tests," *Oxford Bulletin of Economics and Statistics*, 74(5), pp.736-59.

Saikkonen, P. and H. Lütkephol, 2002, "Testing for a Unit Root in a Time Series with a Level Shift at Unknow Time," *Econometric Theory*, 18(2), pp.313-48.

Samuelson, P.A., 1973, "Proof that Properly Discounted Present Values of Assets Vibrate Randomly", *Bell Journal of Economics and Management Science*, 4(2), pp.369-74.

Stock, J.H. and M.W. Watson, 1988, "Testing for Common Trends," *Journal of the American Statistical Association*, 83(404), pp.1097-107.

Smyth R. and B. Inder, 2003, "Is Chinese Provincial Real GDP per capita Nonstationary? Evidence from Multiple Trend Break Unit Root Tests," *China Economic Review*, 15(1), pp.1-24.

Vogelsang, T.J. and P. Perron, 1998, "Additional Tests for a Unit Root Allowing for a Break in the Trend Function at an Unknown Time," *International Economic Review*, 39(4), pp.1073-100.

Wasserfallen, W., 1986, "Non-Stationarities in Macro-Econometric Time Series-Further Evidence and Implications," *Canadian Journal of Economics*, 19(3), pp.498-510.

Zivot, E. and D.W.K. Andrews, 1992, "Further Evidence on the Great Crash, the Oil Price Shock, and the Unit-Root Hypothesis," *Journal of Business and Economic Statistics*, 10(3), pp.251-70.

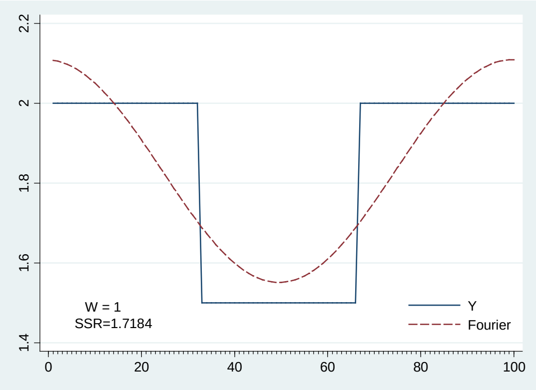


FIGURE (1.1) U-Shaped Break: $33 \le t \le 66$

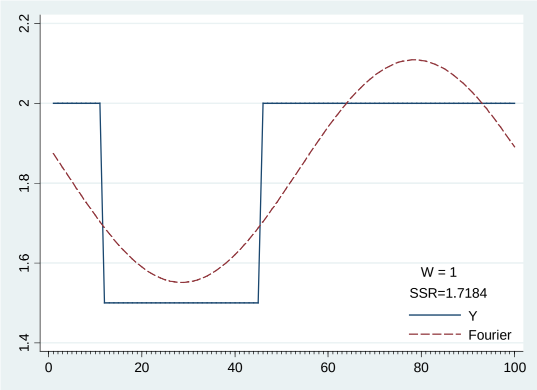


FIGURE (1.2) U-Shaped Break: $12 \le t \le 45$

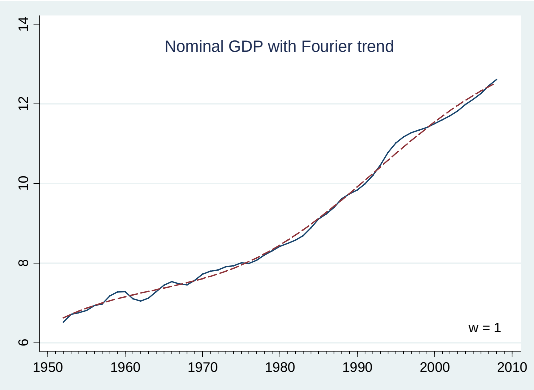


FIGURE (2.1) Nominal GDP

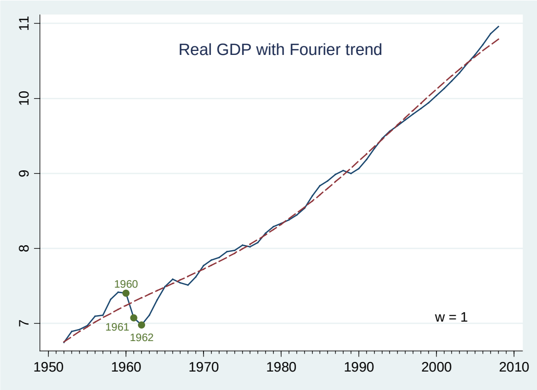


FIGURE (2.2) Real GDP

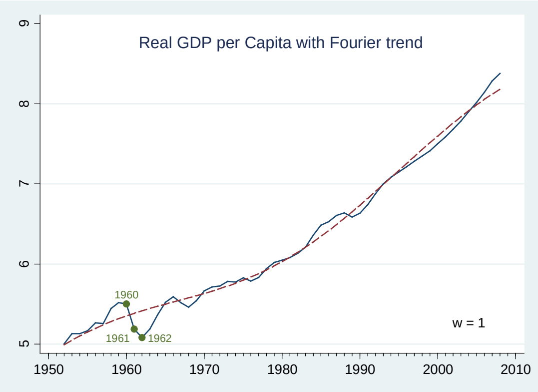


FIGURE (2.3) Real per capita GDP

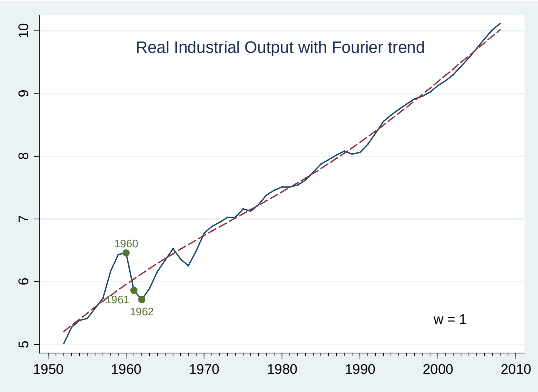


FIGURE (2.4) Real Industrial Production

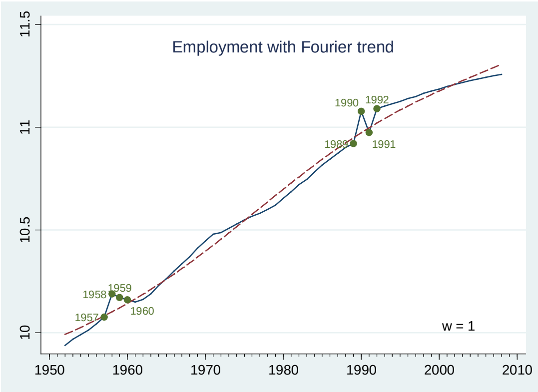


FIGURE (2.5) Employment

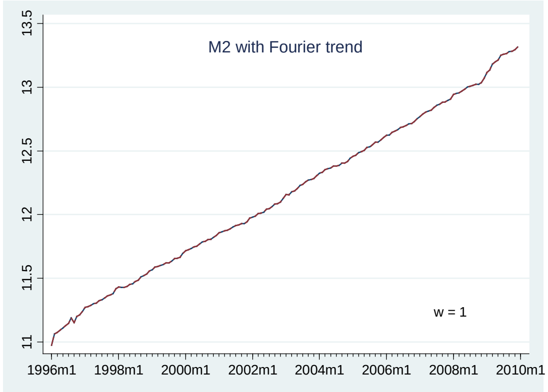


FIGURE (2.6) Money Supply (M2)

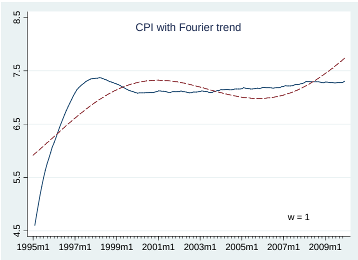


FIGURE (3.1) CPI, ω=1

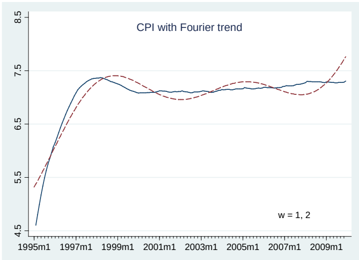


FIGURE (3.2) CPI, ω=1, 2

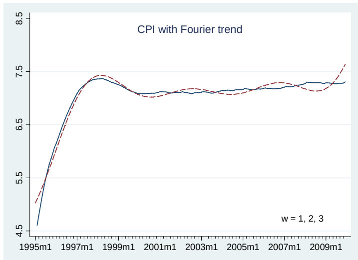
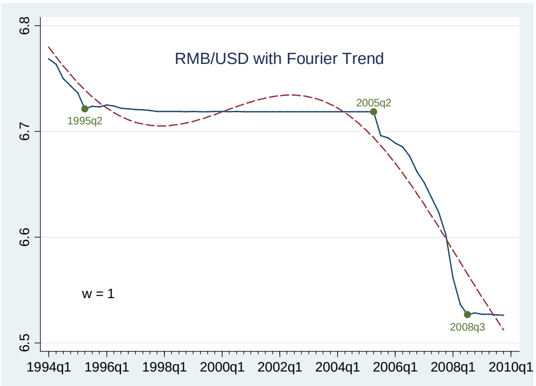


FIGURE (3.3) CPI, ω=1, 2, 3



FITURE (4.1) RMB/USD, ω=1

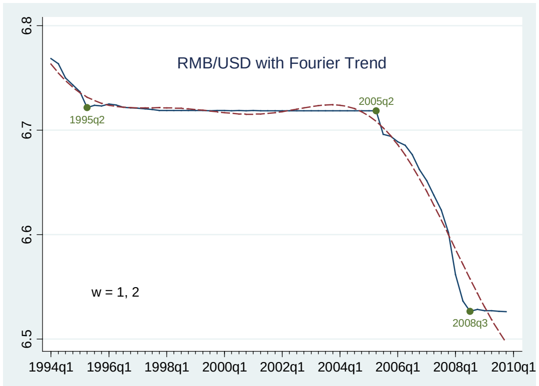


FIGURE (4.2) RMB/USD, ω=1, 2

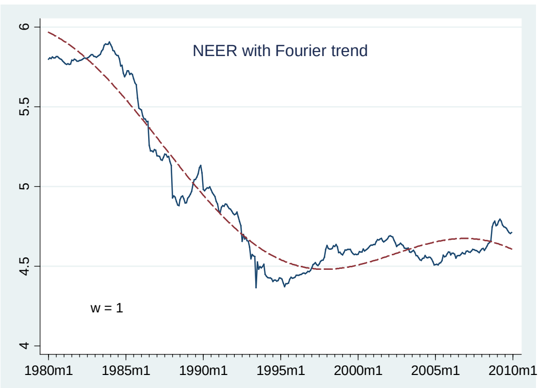


FIGURE (5.1) NEER

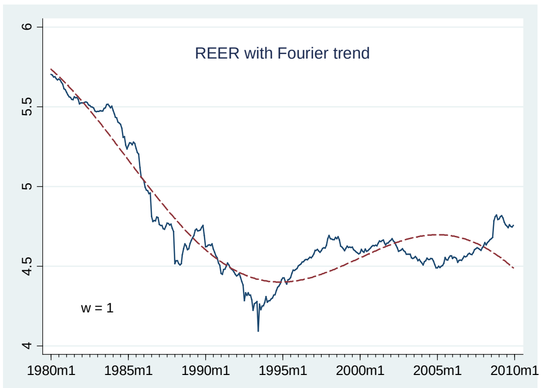
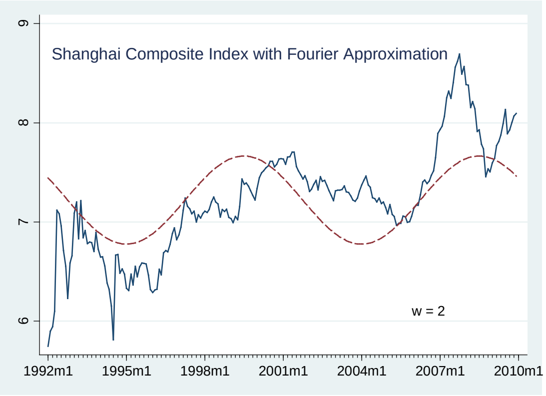


FIGURE (5.2) REER



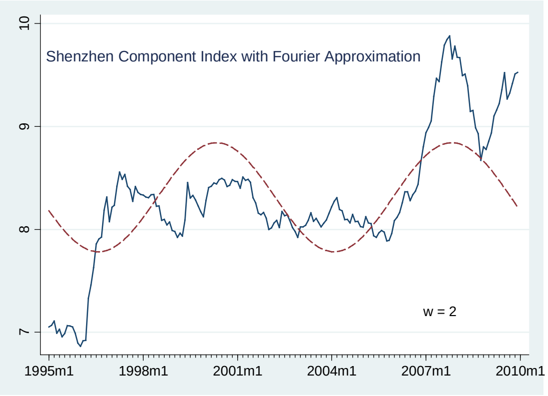
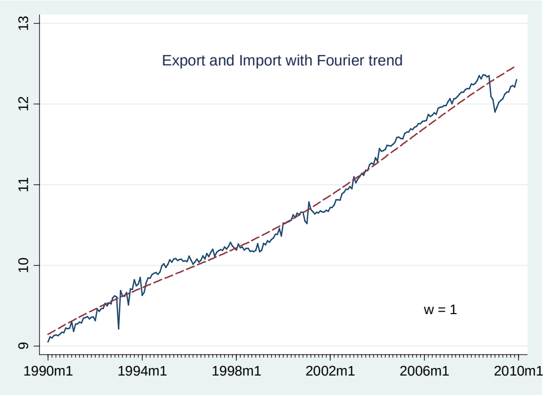


FIGURE (6.1) Shanghai Composite Index

FIGURE (6.2) Shenzhen Component Index



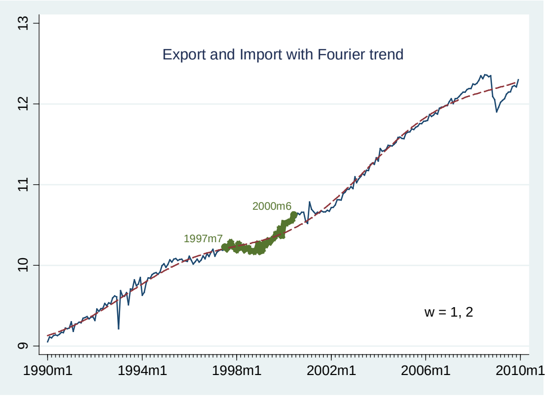
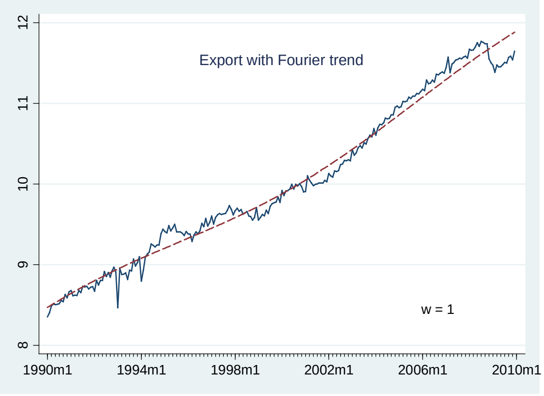


FIGURE (7.1) Export and Import, ω=1

FIGURE (7.2) Export and Import, ω=1, 2



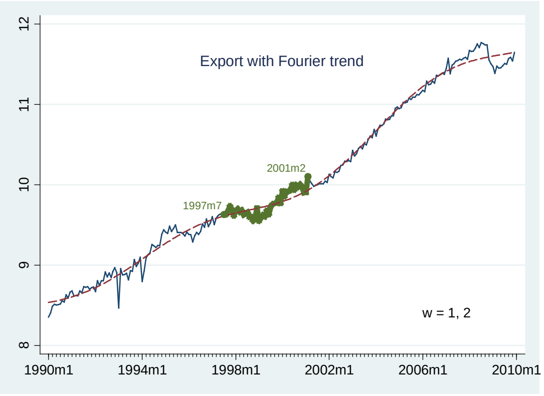


FIGURE (7.3) Export, ω=1

FIGURE (7.4) Export, ω=1, 2

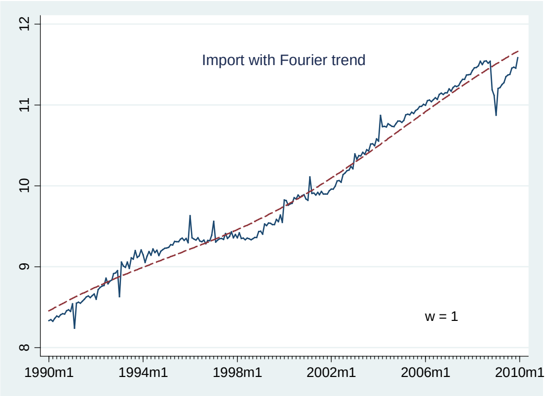


FIGURE (7.5) Import, ω=1

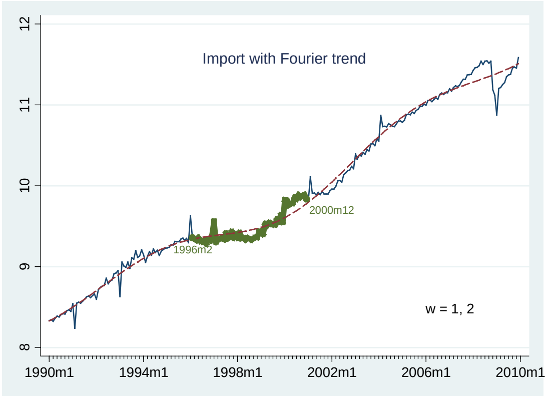


FIGURE (7.6) Import, ω=1, 2

Table (1) Variables and Explanatory Notes

Series	Periods and Remarks	*T*	Data Source
Nominal GDP	Yearly: 1952-2008	57	GTA
Real GDP	Yearly: 1952-2008; Base year=1978	57	GTA (Nominal)
Real per capita GDP	Yearly: 1952-2008; Base year=1978	57	GTA (Nominal)
Real industrial production	Yearly: 1952-2008; Base year=1978	57	GTA (Nominal)
Employment	Yearly: 1952-2008	57	GTA
Money supply (M2)	Monthly: 1996.1-2009.12	168	RESSET
CPI index	Monthly: 1995.2-2009.12; 1995.2=100	179	GTA (Chain Data)
Nominal exchange rate of RMB against USD	Quarterly: 1994.Ⅰ-2009.Ⅳ	64	RESSET
Nominal effective exchange rate (NEER)	Monthly: 1980.1-2009.12	360	IFS
Real effective exchange rate (REER)	Monthly: 1980.1-2009.12; 2000=100	360	IFS
Shanghai composite index	Monthly: 1992.1-2009.12; Closing rate	216	GTA
Shenzhen component index	Monthly: 1995.1-2009.12; Closing rate	180	GTA
Export and import	Monthly: 1990.1-2009.12; Seasonally adjusted	240	RESSET
Export	Monthly: 1990.1-2009.12; Seasonally adjusted	240	RESSET
Import	Monthly: 1990.1-2009.12; Seasonally adjusted	240	RESSET

Note: Obtained from the GTA database are only the nominal values of GDP, per capita GDP and industrial production, the real values of the triple variables are denominated according to the 1978 based price index which come from the *China Statistical Yearbook* of relevant years; the CPI index obtained from the GTA are chain data and they are transformed into fixed base index with February 1995 as their basic month; the real effective exchange rate of RMB is based on the year 2000; Shanghai composite index and Shenzhen component index are closing rate stock prices with different initial date; Export and import from the RESSET database are non-seasonally adjusted data and I remove the seasonal factors using Tramo/Seats method.

Table (2) Tests for stationarity with Corroborations and Comparisons

Series	T	*Type*	ω	$\tau_i(\hat{\omega})$	*max F*	Corroborative and Comparative Tests				
						Fourier UR	KPSS	DF-GLS	LSTAR	Zivot-Andrews
Nominal GDP	57	τ	1	0.0429	393.69	-4.80*	0.53*	-0.45	-3.83	-3.87
Real GDP	57	τ	1	0.0467	63.56	-4.93*	0.45*	-0.36	-4.91	-4.10
Real per capita GDP	57	τ	1	0.0514	104.71	-4.57*	0.49*	-0.40	-4.52	-3.89
Real industrial production	57	τ	1	0.0353	7.84	-4.73*	0.14	-1.52	-4.76	-6.36*
Employment	57	τ	1	0.0660	19.89	-5.35*	0.23*	-1.31	-4.07	-2.86
Money supply (M2)	168	τ	1	0.0678	67.58	-4.77*	0.42*	-2.19	-3.41	-4.27
CPI index	179	τ	1-3	0.0371	448.70	-7.05*	0.43*	-2.73	-2.94	-4.70#
Nominal exchange rate of RMB against USD	64	τ	1-2	0.0275	273.61	-2.38	0.32*	-3.20#	-3.39	-4.89#
Nominal effective exchange rate (NEER)	360	τ	1	0.0874*		-1.88	1.51*	-0.72	-2.57	-3.38
Real effective exchange rate (REER)	360	τ	1	0.1163*		-2.01	1.43*	-1.14	-2.71	-3.79
Shanghai composite index	216	μ	2	1.9163*		-3.75	3.65*	-1.10	-2.65	-4.18
Shenzhen component index	180	μ	2	1.3557*		-1.00	2.31*	-0.06	-1.53	-3.80
Export and import	240	τ	1-2	0.0319	187.14	-7.06*	0.88*	-1.78	-2.99	-2.54
Export	240	τ	1-2	0.0277	167.57	-7.09*	0.83*	-1.98	-1.75	-2.29
Import	240	τ	1-2	0.0327	151.97	-7.81*	0.83*	-2.28	-3.78	-3.27

Note: * denotes rejecting the null at a significance of or higher than 1%, # denotes rejecting the null at 5% significance level. All the single frequencies are endogenously determined optimal ones from the minimizations of SSR, whereas the cumulative frequencies are exogenously appointed. 1% critical values of *max F* statistics for the former six variables under endogenously determined frequency are all 6.873, for the avoidance of spurious inferences that may be induced by low test power, *F* tests are omitted since NEER, REER and stock prices reject the null significantly. DF-GLS reports the test statistics of the optimal lag selected by Ng-Perron sequential t statistics. For LSTAR estimation, the initial transition parameter is set to 10. In Zivot and Andrews' (1992) test, 5% trimming of the data is used.