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Trends, unit roots, structural changes, and time-varying asymmetries in U.S. macroeconomic data: the Stock and Watson data re-examined

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ABSTRACT

This article considers simple least squares based unit root tests in time series models accommodating nonlinear trends and time-varying deepness and steepness in the dynamic law. The unit root tests are applied to 214 U.S. post-war macroeconomic time series (the same data set as in Stock and Watson, 1999 and Lundbergh, Teräsvirta, and van Dijk, 2003), and the overall rejection rate allowing for a linear (nonlinear) trend specification is 50% (67%). The highest rejection rate by an individual test is 40% (53%) and it arises from a time-varying steepness model. The lowest rejection rate of an individual test is the one by the ADF test and equals 12% (19%).

The steps of unit root testing and model building are illustrated in more detail for U.S. unemployment rates. The unit root hypothesis is rejected for this series, and successive specification tests and estimation results yield evidence in favor of a stable TV-MSTAR model with more momentum in unemployments increases than in unemployment decreases.

1. Introduction

Research on the dynamic behavior of macroeconomic variables over phases of the business cycles has been much in focus during the last three decades or so.[1] Nowadays, there is an abundance of work showing that the law of dynamics is asymmetric and related to recessions and expansions and gives rise to a regime dependent type of behavior.

Two types of asymmetries that have received considerable attention in the literature are deepness, where troughs are further below trend than what peaks are above trend, and steepness, with cycles in which recessions are steeper than expansions (Sichel, 1993 p. 224) (when the opposite relationships hold, we will refer to reversed deepness and steepness; typical for countercyclical series). Such asymmetries are, for example, studied by: Neftci (1984, U.S. unemployment rates), Falk (1986, U.S. GNP, investments, productivity, and industrial production abroad), Sichel (1993, U.S. unemployment, industrial production, and GNP), Teräsvirta and Anderson (1992, production 'Europe' and 13 countries), Potter (1995, U.S. GNP), van Dijk and Franses (1999, U.S. GNP), Sarantis (1999, exchange rates for the G10 countries), Taylor et al. (2001, exchange rates U.S., U.K., Germany, France, and Japan), van Dijk et al. (2002, U.S. unemployment), Clements and Krolzig (2003, U.S. GNP, investment, and consumption), and Bec et al., (2004, exchange rates Canada, U.K., Germany, France, Italy, Belgium, and Spain) to mention a few.

Another phenomenon that is frequently reported in major economic time series is dynamics that are subject to structural changes (or parameter instability). Rather than a state dependent law for the dynamics, this yields time periods of various lengths (where the length may be determined by the date of some exogenous events) characterized by linear dynamics, but the dynamics in different time periods are not necessarily the same. Empirical evidence of structural changes includes: Stock and Watson (1996, 1999, overwhelming evidence in a large number of U.S. post war macroeconomic time series), Lin and Teräsvirta (1994, Dutch industrial production) and Jansen and Teräsvirta (1996, Norwegian income and expenditures) among others.

More recently, a joint modeling of asymmetries and structural changes in the dynamics have been in focus. This implies that the behavior of the asymmetries may change over time and it is a natural generalization since the parameter constancy assumption in asymmetric models may be questioned if the time series at hand span over a long time period. Empirical evidence of joint asymmetries and structural changes can be found in: Lütkepohl et al. (1999, German money demand), Kim and Nelson (1999, U.S. GDP), Luginbuhl and De Vos (1999, U.S. GDP), Skalin and Teräsvirta (2002, quarterly unemployment rates of a number of developed countries) and Lundbergh et al. (2003, overwhelming evidence in a large number of U.S. post-war macroeconomic time series) among many others.

Different types of business cycles associated with the features in the data discussed above are illustrated in Fig. 1. Panel (a) shows a cycle with no asymmetries. Panel (b) displays time-varying deepness such that the last two peaks are more above the trend (central line; dashed line) than the first two but yet in such a way that the deepness property is preserved. In panel (c), a cycle with time-varying steepness is shown

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[1] But it is interestingly noticed that the economic theory on business cycle asymmetries can be traced back already to Mitchell (1927, pp. 330–334 and 407–412), Keynes (1936, p. 314), and Hicks (1950).

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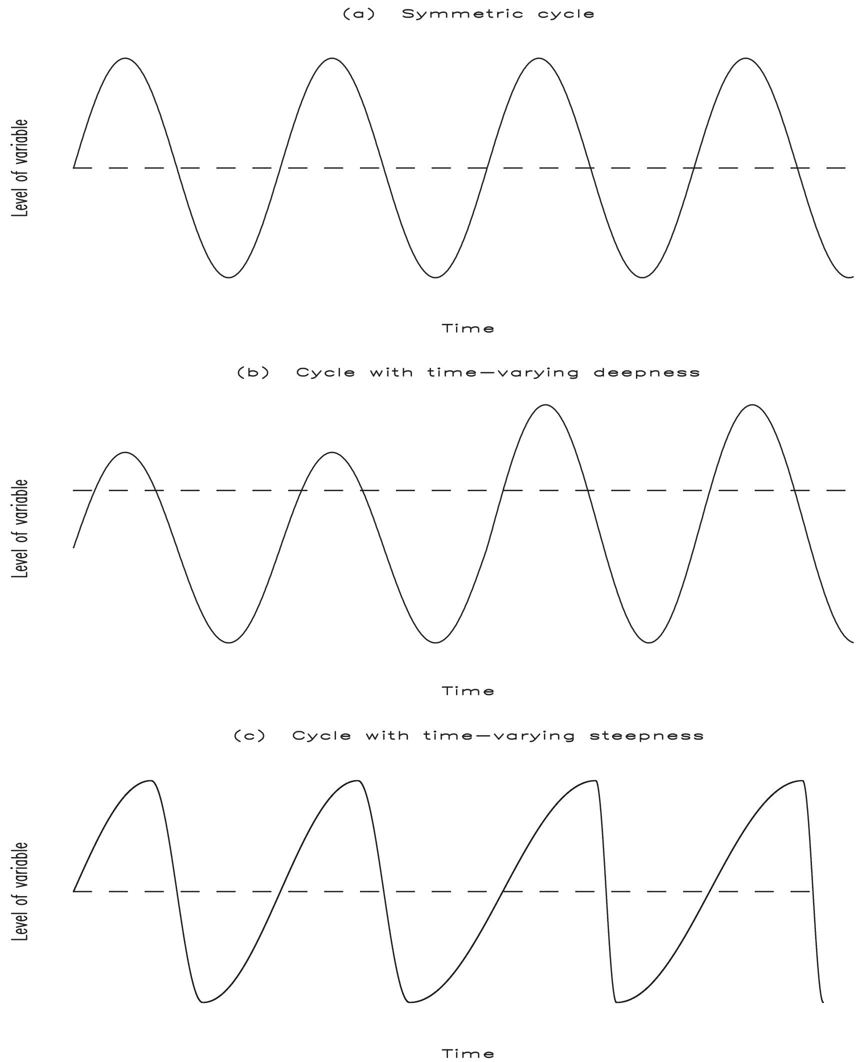

Fig. 1. Time-varying deepness and steepness around a central line.

where the last two expansions and recessions are less and more steep, respectively, than the first two.

All aforementioned findings on asymmetries and structural changes presumed stationarity of the data. However, it is important, and as argued by (Bec et al., 2004), to answer the questions

(1) are data stationary?
(2) is the model linear?

in the correct order. That is, stationarity should be established before testing for asymmetries and structural changes. The reason for this is simply that the distribution of most linearity tests is standard under the null hypothesis of a stationary process and non-standard under the null hypothesis of a unit root. In this context, Kiliç (2004) and Sandberg (2008) demonstrate that a linearity hypothesis can be rejected in up to 31% of the cases (at a 5% significance level) erroneously presuming stationarity of data. In practice, it is therefore not uncommon to test the linearity hypothesis on both detrended and first-difference data (see, e.g., Lundbergh et al., 2003). But of course, this is not necessarily an efficient method, and it may lead to (conflicting) results that are hard to interpret. Another common approach is to let a unit root pre-test dictate if the researcher should work with levels or first-differences. A potential problem here is that existent unit root tests do not necessarily direct satisfactory power against time series with time-varying deepness or steepness properties (evidence of the former claim can be found in He and Sandberg, 2006). This may lead to first-differences being used too often and that asymmetries and features of structural changes are potentially weakened.[2] More subtle is that if deepness (levels) is of original interest, the focus changes to steepness (first-differences); an argument that will be transparent by the below definitions of deepness and steepness.

Keeping the above dynamic properties of major economic time series and the requirements of stationarity in mind, a main goal of this work is to derive unit root tests in time series models accommodating time-varying deepness and steepness in the dynamics. Such tests are lacking in the literature. To accomplish this, we model the dynamic law by a time-varying smooth transition (TV-STR) type of model (see, e.g., van Dijk et al., 2002 and Lundbergh et al., 2003) where lagged dependent variables in levels and first-differences (to yield aspects of

[2] To take a simple example, assume that the true process is a mean zero first-order threshold autoregressive process defined by: $Y_t = \phi_1 Y_{t-1} + \varepsilon_t$ if $t \le c$ and $Y_t = \phi_2 Y_{t-1} + \varepsilon_t$ if $t > c$ ($t = 1, \ldots, T$) where ϕ_i ($i = 1, 2$) is a dynamic root satisfying $|\phi_i| < 1$, ε_t is a well-behaved disturbance term, and c is a location parameter. Now, 'erroneously' taking first-differences of this series, it follows that the dynamic roots corresponding to the two regimes change, and it is straightforward to show that they equal $(\phi_i - 1)/2$. Hence, taking first-differences alters the original dynamic properties of the process. It also follows that a structural change feature is weakened in the sense that the (absolute) difference in dynamics for level series $|\phi_1 - \phi_2|$ is larger than the (absolute) difference in dynamics for difference series $|(\phi_1 - \phi_2)/2|$.
This may cause linearity tests on the first-difference series not to be as powerful as linearity tests based on the level of the series.