ARTICLE IN PRESS
ECMODE-03658; No of Pages 11
Economic Modelling xxx (2015) xxx–xxx
Contents lists available at ScienceDirect
Economic Modelling
journal homepage: www.elsevier.com/locate/ecmod

Long-run monetary neutrality under stochastic and deterministic trends☆

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ARTICLE INFO

Article history:
Accepted 8 March 2015
Available online xxxx

Keywords:
Long-run monetary neutrality
LHR
Trending variables
Structural breaks

ABSTRACT

This paper studies long-run monetary neutrality when long-horizon regressions (LHR) are used as a vehicle to test it. We assume that money and/or output can be generated according to widely used persistent models. We combine these specifications and study the divergence rate of the *t*-statistic as an indication of a spurious relationship between money and output, and show that the presence of spurious evidence of non-neutrality is highly likely. We then propose a correct inferential procedure for testing the null hypothesis of no relationship in a LHR (finite-sample and asymptotic evidence supports the procedure). The latter is then applied to an international data set on money and output in order to test for long-run monetary neutrality. We find that neutrality holds for all countries.

1. Introduction

A central tenet of macroeconomics is the monetary neutrality proposition, which states that there should be no long-run real effects of an unanticipated, permanent change in the level of money. One of the main tools for testing this key macro proposition is the non-structural test devised by Fisher and Seater (1993, FS in what follows). This test depends on the time series properties of both money and output, and uses as the testing vehicle a long-horizon regression (Valkanov, 2003).

The rationale behind these regressions is that long-horizon variables (obtained as a rolling sum of the original variable, over a fraction of the sample) allow predictability to increase with the length of the horizon (Rossi, 2007), while strengthening the signal, and reducing the noise (Lee, 2007 and Valkanov, 2003). Three types of LHRs that have been used in the empirical literature are the following:

$$\sum_{j=0}^{k-1} y_{t+j+1} = \alpha_k + \delta_k x_t + \varepsilon_{kt}, \tag{1}$$

$$\left[\sum_{j=0}^{k-1} y_{t+j+1}\right] = \alpha_k + \delta_k \left[\sum_{j=0}^{k-1} x_{t+j}\right] + \varepsilon_{kt}, \tag{2}$$

$$\left[\sum_{j=1}^{k} y_{t-j+1}\right] = \alpha_k + \delta_k \left[\sum_{j=1}^{k} x_{t-j+1}\right] + \varepsilon_{kt}. \tag{3}$$

The LHR model in Eq. (1) has been used by Fama and French (1988), Campbell and Shiller (1988), Lanne (2002), and Torous et al. (2004), in the analysis of dividend yields and expected stock returns. The LHR in Eq. (2) has been used in the context of the Fisher effect test by Mishkin (1992) and Boudoukh and Richardson (1993), and a variant of this LHR, presented in Eq. (3), has been used in several studies of the Long-Run Monetary Neutrality (LRN) proposition, beginning with the work of FS, and continuing with Boschen and Otrok (1994), Serletis and Krause (1996), Haug and Lucas (1997), Wallace (1999), Bae and Ratti (2000), Coe and Nason (2003, 2004), and Noriega (2004), among others. This version of the LHR was also used by Chen and Chou (2010), to study exchange rates and fundamentals.

Valkanov (2003) found that Ordinary Least Squares (OLS) applied to the LHR regression model (1) yields an inconsistent estimator of the slope parameter, that is $\hat{\delta}_k$ does not converge to δ_k as the sample size grows. On the other hand, for the LHR model (2), OLS produce a super-consistent estimator of δ_k ($\hat{\delta}_k$ converges to δ_k at rate T). He also found that $t_{\hat{\delta}_k}$ from (2) diverges, even when both variables are generated independently of each other. A similar divergent behavior of the *t*-statistic is reported in Lee (2007) for the case of independent fractionally integrated processes. This has potentially important implications for statistical inference in areas of economics in which LHRs have been used. Consider the time-series approach for testing LRN, put forward by FS, which is based on the time series properties of money and output, and on the *t*-statistic $t_{\hat{\delta}_k}$ in a long-horizon regression model, as that in

☆ With thanks to Carlos Capistrán, Daniel Chiquiar, Russell Davidson, and seminar participants at Banco de México, CIMAT, 16th Conference on Computing in Economics and Finance, Instituto de Matemáticas at UNAM, Universidad de Guanajuato, and to Mario Alberto Oliva for excellent research assistance. The opinions in this paper correspond to the authors and do not necessarily reflect the point of view of Banco de México.
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http://dx.doi.org/10.1016/j.econmod.2015.03.010
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Eq. (3). In this context, divergence of the t-statistic would indicate, with probability approaching one as the sample size grows to infinity, a long-run relationship between money and output, i.e., rejection of the (long-run) monetary neutrality proposition, considered as a tenet of macroeconomics.

In this paper, we study the asymptotic behavior of the t-statistic in the long-horizon regression (3), under different *DGPs* for y and x. In particular, we study the consequences on inference, of allowing the variables to follow different types of stochastic and deterministic trends, including linear trends, linear trends with breaks, and unit root processes (there is a variety of empirical models in the literature that support different types of long-run nonstationary behavior, with linear trends, linear trends with breaks and unit roots being very popular ones). This has not been explored before in the literature of long-horizon regressions, and has important inferential implications in applied work in macroeconomics.

Our results show that the asymptotic spurious long-horizon regression phenomenon depends on the assumed data generating process for both the dependent and the explanatory variables. For instance, we corroborate Valkanov's (2003) findings when both variables follow a unit root, but we also find that when the explanatory variable follows a unit root while the dependent follows a linear trend, then the t-statistic does not diverge. On the other hand, when both variables follow a broken trend model, the t-statistic diverges, spuriously rejecting the null of no relationship (between independent variables). We arrive at such conclusion from the calculation of the order in probability for the t-statistic in a long-horizon regression.

In general, we find that a spurious long-horizon regression problem will arise whenever the dependent variable, the explanatory variable, or both, are hit by a permanent shock, which could be of a stochastic or deterministic nature. In order to alleviate this problem, we introduce a procedure that asymptotically guarantees correct inference, whether the variables have a long-run relationship or not. Under this procedure, when the variables are independent, the null of no relationship will not be rejected, while when the variables are cointegrated, the null will be rejected, correctly indicating a long-run relationship.

We then relate these results to the problem of testing for LRN of money. In particular, we present new evidence on monetary neutrality for the international data set analyzed in Noriega (2004) and Noriega et al. (2008, NSV hereafter), which comprises money and output data for Australia, Argentina, Brazil, Canada, Italy, Mexico, Sweden, and the UK. Based on our asymptotic results, we test for Long-Run Monetary Neutrality by rescaling a bootstrapped t-statistic in a long-horizon regression for each country, using output and money data generated from models identified by NSV. Our results indicate that, in all cases, monetary neutrality cannot be rejected.

We discuss in Section 2 the issue of the trending mechanisms for the variables. Section 3 presents the asymptotic results, which we derive both under the null of no long-run relationship between the variables, and under the alternative of cointegration. The finite sample counterpart of our limit theory is analyzed in Section 4 via simulations. Section 5 presents the empirical application of testing for monetary neutrality. The final section concludes.

2. Trending mechanisms for the data

Since the early 1980s, a great deal of effort has been devoted to uncover the trending nature of economic time series (see, for example, Nelson and Plosser, 1982; Perron, 1989, 1992, 1997; Murray and Nelson, 2000; Cook, 2005; Assaf, 2008; Maslyuk and Smyth, 2008; Rahman and Saadi, 2008 and Kim and Perron, 2009). However, the issue has not been resolved yet, and while there are authors who favor the use of stochastic trends for macro data, there are others in favor of deterministic ones. Some have even argued that data can be uninformative as to whether the long-run trend is better described as deterministic or stochastic.[1]

In general, the empirical literature has shown that the long-run behavior of macro data can be well characterized using linear deterministic trends, linear deterministic trends with structural breaks, or stochastic trends. As an example of this set of models, NSV found that for Australia, Sweden and the UK, long-annual data on output and money (referred to as y_t and x_t respectively, hereafter) seem to be well characterized by a Broken Trend Stationary (*BTS*) model. In Australia, y_t was found to behave as a BTS with level breaks in 1891, 1914, and 1928, while x_t can be characterized as a trend stationary process with level breaks in 1891, 1914, 1928 and level and trend breaks in 1941 and 1971. NSV also find that for Canada, y_t seems to follow a linear trend model, while x_t a broken trend one. For Argentina and Mexico, y_t follows a *BTS* model, while x_t a unit root one. For Brazil y_t follows a *BTS* model, while x_t follows a double unit root process. Furthermore, for the US and Denmark, deviations of x_t and y_t from a linear trend seem to reject a unit root, making y_t and x_t trend stationary, or *TS*. Finally, for Italy, a unit root [or $I(1)$] model was most supported by the data for both x_t and y_t.

From the above examples, and indeed from many other examples in the empirical literature, it seems reasonable to assume that linear trends, broken trends, and stochastic trends seem to be capable of adequately representing the long-run behavior of macro data. We therefore study inference on long-horizon regressions (LHRs) under four *DGPs*, described in the following assumption:

Assumption
The *DGPs* for $z = y,x$ are as follows.

Case	Name	Model
1	*TS*	$z_t = \mu_z + \beta_z t + u_{zt}$
2	*BTS*	$z_t = \mu_z + \theta_z DU_{zt} + \beta_z t + \gamma_z DT_{zt} + u_{zt}$
3	$I(1)$	$\Delta z_t = \mu_z + u_{zt}$
4	$I(2)$	$\Delta^2 x_t = u_{xt}$

where u_{yt} and u_{xt} are independent innovations obeying Hamilton's (1994, p. 505) standard assumption,[2] that is:

Assumption 1. Let $z_t = \Psi(L)\epsilon_{zt} = \sum_{j=0}^{\infty}\Psi_{z,j}\epsilon_{z,t-j}$ for $z = e, v$, where $\sum_{j=0}^{\infty} j|\Psi_{z,j}| < \infty$ and $\{\epsilon_{z,t}\}$ is and i.i.d sequence with mean zero, variance σ_z^2, and finite fourth moment.

DU_{zt} and DT_{zt} are dummy variables allowing changes in the trend's level and slope respectively, that is, $DU_{zt} = \mathbf{1}(t > T_{b_z})$ and $DT_{zt} = (t - T_{b_z})\mathbf{1}(t > T_{b_z})$, where $\mathbf{1}(\cdot)$ is the indicator function, and T_{b_z} is the unknown date of the break in z. We denote the break fraction as $\lambda_z = (T_{b_z}/T) \in (0,1)$, where T is the sample size. The *DGPs* include both deterministic and stochastic trending mechanisms, with 12 possible nonstationary combinations of them among the dependent and explanatory variables (the cases of $I(1)$ processes with fractionally integrated processes is studied in Lee, 2007). Note that the $I(2)$ case is restricted to the x_t variable only. This is so because of our particular interest on testing for monetary neutrality. In this regard, empirical evidence suggests that the $I(2)$ case might be relevant for nominal variables in levels, such as the level of monetary aggregates or the price level, but not for data in real terms, or growth rates of nominal data (see for instance Juselius, 1996, 1999; Haldrup, 1998; Muscatelli and Spinelli, 2000; Coenen and Vega, 2001; Nielsen, 2002).

[1] For an analysis on whether the long-run trend function of US real output should be modeled as trend stationary or difference stationary see, among others, Rudebusch (1993), Diebold and Senhadji (1996), Murray and Nelson (2000), Papell and Prodan (2004), Vougas (2007), and Darne (2009).

[2] The derivations in this work could hold under more general data generating processes: Wang and Gulati (2002) show that, by maintaining, (i) $\sum_{j=0}^{\infty} j|\Psi_{z,j}| < \infty$; (ii) $\sum_{j=0}^{\infty}\Psi_{z,j} \neq 0$, and; (iii) $\sum_{j=1}^{\infty} j\Psi_{z,j}^2 < \infty$, the innovations are allowed to follow a stationary martingale difference sequence (which include heteroskedastic variances).

Please cite this article as: Ventosa-Santaulària, D., Noriega, A.E., Long-run monetary neutrality under stochastic and deterministic trends, Econ. Model. (2015), http://dx.doi.org/10.1016/j.econmod.2015.03.010