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Working Paper

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School of Economics Discussion Papers, No. 1322

Provided in Cooperation with:

University of Kent, School of Economics

Suggested Citation: Heinlein, Reinhold; Krolzig, Hans-Martin (2013) : Global stochastic trends in growth, interest and inflation. Is the post-Bretton-Woods era driven by the Volcker disinflation?, School of Economics Discussion Papers, No. 1322, University of Kent, School of Economics, Canterbury

This Version is available at:

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December 2013

KDPE 1321



Global stochastic trends in growth, interest and inflation. Is the post-Bretton-Woods era driven by the Volcker disinflation?

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December 2013

Abstract

This note aims to identify the stable long-run relationships as well as unstable driving forces of the world economy using an aggregated approach involving the four largest currency blocks. The small global macro model encompasses aggregated quarterly US, UK, Japanese and Euro Area data for the post-Bretton-Woods era. Three stable long-run relationships are found: output growth, the global term spread and an inflation climate measure. The common stochastic trend of the global economy is found to be dominated by real short-term interest rate shocks, reflecting the strong increase of the global real rates during the Volcker disinflation period as a dominating event of the last 40 years of macro history.

Keywords: Cointegration; Real interest rates; Volcker disinflation; Multi-country model; Divisia index.

JEL classification: C32; C50; C82.

1 Introduction

Certain time periods have a long lasting impact on macroeconomic history. Due to the non-stationarity of macroeconomic variables a shock has not only an impact when it occurs but has a permanent effect. An epoch which exerted a long lasting influence on the history of the world economy was surely the Volcker disinflation period. The rigorous monetary policy action of the Fed chairman Paul Volcker led to an increase of the world real interest rates, which has been reversed very slowly over several decades. [Blanchard et al. \(1984\)](#) discussed in their paper ‘Perspectives on High World Real Interest Rates’ the level shift of real rates at the end of the 1970s and beginning of the 1980s and found a mix of fiscal policy and tight money as a probable cause. [Goodfriend and King \(2005\)](#) refer to this historic episode as the ‘The Incredible Volcker Disinflation’. In our paper we derive the global driving trend and find it to be accumulated shocks to the real short-term interest rate. The immense level shift in the real rate during the

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Volcker disinflation, reversing only very gradually, makes the real interest rate the driving trend of the world economy. These results are puzzling as they contradict one of the key pillars of macroeconomics, the stylised fact of [Kaldor \(1957\)](#) suggesting the rate of return on capital should be stable over a long time period.

The Cointegrated Vector Autoregression (CVAR) model in the spirit of [Johansen \(1995\)](#) and [Juselius \(2006\)](#) is an approach allowing to structure the information embedded in the data along pulling and pushing forces. The pulling forces are the long-run stable cointegration relationships bringing the economy after an unanticipated shock back to the steady state. The pushing forces are the common stochastic trends driving the the evolving macroeconomy. Deriving the common trends is important for understanding the economic system and for developing and improving economic theory. Additionally the detected stochastic trend can be used for further modelling, in analogy to the global factor in a dynamic factor model.

The approach of aggregating a large data set to a global scale and using the Granger representation of a cointegrated VAR model to derive the common driving trends, is an alternative to using disaggregated variables and a factor model. The advantage of our approach is that it is feasible for non-stationary data, while e.g. a principle component analysis is not. See [Stock and Watson \(2002\)](#) using common factors of 215 variables of monthly US data for forecasting.

The structure of the paper is as follows. In §2 we introduce the data set. The CVAR model is presented in §3. Having derived the moving average representation, we identify the common stochastic trend in §4 and analyse its relation to the Volcker disinflation period. Finally §5 concludes.

2 Data aggregation

The aggregation of the US, the UK, Japanese and the Euro Area data to a measure of the global economy is performed using the Divisia index. The continuous time aggregation of quantities with changing prices was originally proposed by [Divisia \(1925\)](#). For each variable, aggregation is performed by accumulation of the countries growth rates weighted by their GDP shares.

Our small macroeconometric global model is designed to capturing the dynamic interaction of inflation, economic growth, short- and long-term interest rates over the sample period 1972Q4 to 2011Q4, involves a total of 157 quarterly observations. The data are taken from the OECD for GDP and its deflator and Reuters for the 3 month deposit, 10 year government benchmarks and nominal exchange rates. For the aggregation of the country variables we use time-varying GDP weights throughout. The full-sample average weights are for the US 42%, for the Euro Area 33%, for Japan 18% and for the UK 7%.

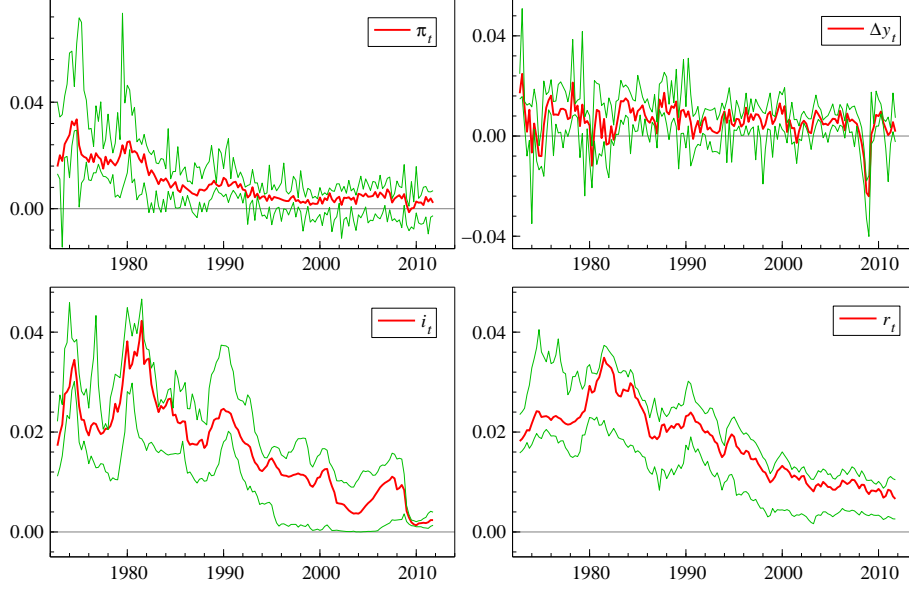


Figure 1 Global time series and the maxima and minima of the country series.

3 The global cointegrated vector autoregression

3.1 Methodology

We commence from a Vector Autoregressive (VAR) model of order p and dimension K , without any equation-specific restrictions, to capture the characteristics of the data:

$$\mathbf{y}_t = \boldsymbol{\mu}_0 + \boldsymbol{\mu}_1 t + \sum_{j=1}^p \mathbf{A}_j \mathbf{y}_{t-j} + \boldsymbol{\varepsilon}_t, \quad (1)$$

where $\boldsymbol{\varepsilon}_t \sim \text{NID}(\mathbf{0}, \boldsymbol{\Sigma})$ is a Gaussian white noise process.

The Johansen procedure for determining the cointegration rank, r , is then applied to the VAR in (1) mapped to its Vector Equilibrium Correction Mechanism (VECM) representation:

$$\Delta \mathbf{y}_t = \boldsymbol{\mu}_0 + \boldsymbol{\mu}_1 t + \boldsymbol{\Pi} \mathbf{y}_{t-1} + \sum_{j=1}^{p-1} \boldsymbol{\Gamma}_j \Delta \mathbf{y}_{t-j} + \boldsymbol{\varepsilon}_t. \quad (2)$$

For a cointegrated vector process, the reduced-rank matrix, $\boldsymbol{\Pi}$, can be decomposed into the $K \times r$ dimensional loading matrix, $\boldsymbol{\alpha}$, and $K \times r$ cointegration matrix, $\boldsymbol{\beta}$, containing the information of the long-run structure of the model, i.e. $\boldsymbol{\Pi} = \boldsymbol{\alpha} \boldsymbol{\beta}'$. The trend is restricted to the cointegration space, so that $\boldsymbol{\mu}_1 = \boldsymbol{\alpha} \boldsymbol{\delta}$, where $\boldsymbol{\delta}$ is r dimensional. The Johansen procedure delivers unique estimates of $\boldsymbol{\alpha}$ and $\boldsymbol{\beta}$ as a result of requiring $\boldsymbol{\beta}$ to be orthogonal and normalized. These estimates provide a value for the unrestricted log-likelihood function to be compared to the log-likelihood under economically meaningful overidentifying restrictions, $\boldsymbol{\beta}^r$:

$$\Delta \mathbf{y}_t = \boldsymbol{\mu}_0 + \boldsymbol{\alpha} (\boldsymbol{\beta}^{r'} \mathbf{y}_{t-1} + \boldsymbol{\delta} t) + \sum_{j=1}^{p-1} \boldsymbol{\Gamma}_j \Delta \mathbf{y}_{t-j} + \boldsymbol{\varepsilon}_t. \quad (3)$$

The empirical modeling procedure for finding the cointegration relations follows Juselius (2006).

3.2 Empirical findings

In the following, we analyse the dynamics of a global macro model of inflation, output growth, and short- and long-term interest rates, $\mathbf{y}_t = (\pi_t, \Delta y_t, i_t, r_t)'$, fitting a VAR(5) with an unrestricted constant and a linear trend restricted to the cointegration space.¹ The Johansen (1995) test for $I(1)$ cointegration, see Table 1, shows a rank of 3. Thus there is only one unit root in the system.

Table 1 Johansen likelihood ratio trace test of $H_0 : \text{rank} \leq r$.
VAR(5) with constant and trend

r	eigenvalue	trace test	prob
0	0.270	110.65 **	[0.000]
1	0.193	61.24 **	[0.000]
2	0.122	27.56 *	[0.028]
3	0.045	7.17	[0.337]

** significant at 1% level, * significant at 5% level.

As a preliminary analysis we test standard economic relations as cointegration relationships, like the Fisher hypothesis or the term spread, see Figure 2. The level shift 1981, during the Volcker disinflation, seems too large to accept the real rates as cointegrating vectors. On the other hand a shift dummy at this point in time seems not to be appropriate to solve this non-stationarity, because the upward shift occurs during a period of three years and the downward shift is a very slow decline taking place up to the end of the sample. The term spread together with a trend is a possible cointegrating vector.

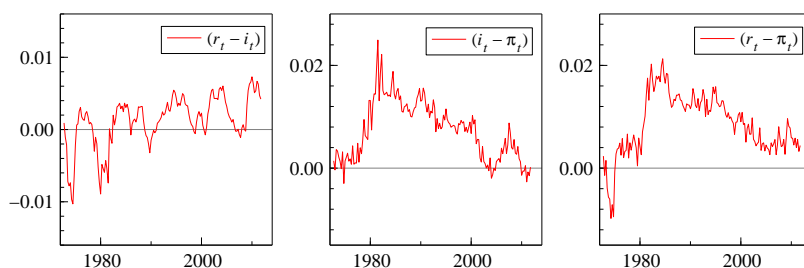


Figure 2 Global term spread and real short- and long-term interest rates.

The cointegration relationships are found by checking statistical acceptability and agreeability with economic theory. The following cointegrating vectors were identified:

(i) *Output growth.*

$$\Delta y_t + 0.00003t \sim I(0). \quad (4)$$

The first cointegrating vector is trend stationary global output growth rate. The negative trend of the global output growth is partly due to large negative growth rates during the Great Recession.

¹A shorter lag order would not change the result of the following Johansen rank test but would lead to autocorrelation in the residuals.

(ii) *Term spread average.*

$$r_t - i_t - 0.00003t \sim I(0). \quad (5)$$

The second cointegrating vector is the stationary global spread between long and short-term interest rates. The positive trend of the term spread can be explained to a certain extent with the accommodating monetary policy during the Great Recession.

(iii) *Inflation climate.*

$$0.5(\pi_t + r_t) + 0.00013t \sim I(0). \quad (6)$$

The final vector reflects the global inflation climate as a linear combination of current inflation and future inflation expectations, where the later is measured by the nominal bond yield in spirit of the Fisher hypothesis. The secular downward trend in the inflation climate from ‘Great Inflation’ to ‘Great Moderation’ to ‘Great Recession’ is captured by the deterministic trend.

The three over-identifying restrictions on the cointegration space are accepted by the likelihood ratio (LR) test with $\chi^2(3) = 2.64$ and a p-value of 0.45. The three cointegrating relations are shown in Figure 3. These are the pulling forces ensuring the partial reversal of the economy to the steady state. The deterministic trends are moving these steady states.

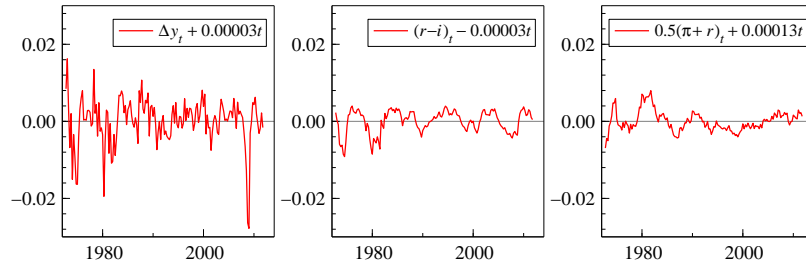


Figure 3 *The three cointegrating vectors.*

Table 2 *Cointegration vectors and loadings, t-values in brackets*

	Cointegration vectors			Loadings		
	β_1	β_2	β_3	α_1	α_2	α_3
π_t	0	0	0.5	0.032 (0.61)	-0.038 (-0.45)	-0.285** (-3.89)
Δy_t	1	0	0	-0.667** (-4.77)	0.607** (2.70)	-0.498* (-2.52)
i_t	0	-1	0	0.112* (2.43)	0.021 (0.28)	-0.095 (-1.45)
r_t	0	1	0.5	0.002 (0.10)	-0.112** (-2.73)	-0.076* (-2.10)
<i>trend</i>	0.000034** (3.14)	-0.000033** (-4.00)	0.000134** (14.2)			

** significant at 1% level, * significant at 5% level.

3.3 The Granger representation of the model

After identifying the long-run equilibrium of our model, we are going to analyse the cumulated residuals and derive the global common trend.² Following Engle and Granger (1987) a VAR model with $I(1)$ variables and cointegration between the variables can be expressed in a moving average representation. The Granger representation is a trend-cycle decomposition of the system in (3):

$$\mathbf{y}_t = \tilde{\beta}_\perp^r \alpha_\perp' \sum_{i=1}^t \varepsilon_i + \tau_1 t + \tau_0 + \rho_t, \quad (7)$$

where $\tilde{\beta}_\perp^r = \beta_\perp^r (\alpha_\perp' \Gamma \beta_\perp^r)^{-1}$ and $\Gamma = \mathbf{I} - \Gamma_1 - \dots - \Gamma_{k-1}$. The first term is the contribution of the stochastic trend in the decomposition. We can define $\xi_t = \alpha_\perp' \sum_{i=1}^t \varepsilon_i$, with ε_i being the residuals of the restricted VECM in (3), as the stochastic trend of the system, so that $\tilde{\beta}_\perp^r$ can be interpreted as a loading matrix linking the stochastic trend to each individual variable, see Johansen (1995). The second term is a deterministic trend, the third term the influence of the initial values and the final term ρ_t is a stationary component, which can be interpreted as the cycle of the process. The orthogonal complement matrix of α , denoted α_\perp , is defined such that $\alpha' \alpha_\perp = \mathbf{0}$ and $\text{rank}(\alpha, \alpha_\perp) = K$. With the parameter matrices α, β and Γ_i given, $\tilde{\beta}_\perp^r$ and α_\perp are as follows with the variable ordering $(\pi_t, \Delta y_t, i_t, r_t)'$:

$$\tilde{\beta}_\perp^r = \begin{pmatrix} -1 \\ 0 \\ 1 \\ 1 \end{pmatrix} \quad \text{and} \quad \alpha_\perp = \begin{pmatrix} -0.226 \\ 0.034 \\ 0.257 \\ 0.309 \end{pmatrix}.$$

The normalised loading matrix $\tilde{\beta}_\perp^r$, which links the stochastic trend to each individual variable, shows that an increase in the stochastic trend leads to a decrease in inflation and an increase in the interest rates. The global common stochastic trend calculated with α_\perp and the system residuals can be seen in Figure 4. As a robustness check, two model alternatives are displayed: The unrestricted CVAR model and the restricted CVAR where additionally the insignificant parameters of the α matrix are restricted to zero.³ The common stochastic trends of all three model options are very similar. In other words, the results are robust with regard to the restrictions imposed on the cointegration relationships.

4 Identifying the global common stochastic trend

A comparison of the common trend of the baseline model with nominal and real interest rates shows that the real short-term rate mimics the stochastic trend closely, with a correlation of 97%, see Figure 4. Having found this high correlation we test in the following whether the common stochastic trend is determined by shocks to the real short-term interest rate, hence only shocks to the real short-term interest rate are present in the stochastic trend, so α_\perp has the following form:

$$H_o^1 : \alpha_\perp' = (-1, 0, 1, 0). \quad (8)$$

²It is important noticing that, in contrast to cointegration relations, the common stochastic trend is not invariant to the inclusion of additional variables. Focussing here on central macroeconomic variables, we claim to give a good description of a driving trend of the world economy.

³The restrictions passed the likelihood ratio test, after which the model is re-estimated.

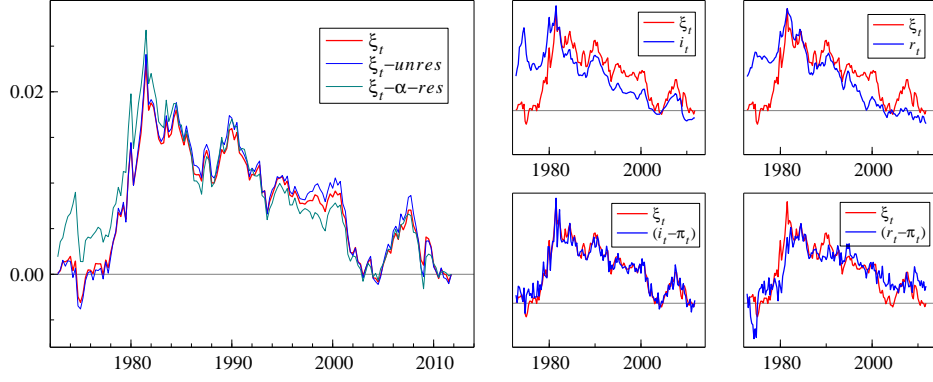


Figure 4 *Left panel: The global common stochastic trend, ξ_t , in three model options: the restricted baseline model, the unrestricted model and the baseline model with restricted α . Right panel: The global common stochastic trend compared to nominal and real short- and long-term interest rates. Series re-scaled for equal means and ranges.*

Recalling how the orthogonal complement is defined, the test of H_o^1 is implemented as a test of the following linear restrictions on α :

$$R\alpha = r \text{ with } R = \alpha'_\perp \text{ and } r = 0. \quad (9)$$

Where in the case of H_o^1 , the test hypotheses are of the form

$$-\alpha_{1,i} + \alpha_{3,i} = 0 \text{ for all } i = 1, \dots, r. \quad (10)$$

Under preservation of the cointegration rank and the full rank of (α, α_\perp) , the LR test statistic is $\chi^2(r)$. For the baseline model, with a test result of $\chi^2(3) = 5.456$ and a p-value of 0.141, the hypothesis can not be rejected. Finally we check on this restricted model that the rank condition for α_\perp , $\text{rank}(\alpha, \alpha_\perp) = K$ is not violated:

$$H_o^2 : (\alpha_{21}, \dots, \alpha_{2r}) = 0 \text{ and } H_o^3 : (\alpha_{41}, \dots, \alpha_{4r}) = 0. \quad (11)$$

Both hypothesis can clearly be rejected, H_o^2 with a test result of $\chi^2(3) = 33.12$ and a p-value of 0.000 and H_o^3 with a test result of $\chi^2(3) = 18.72$ and a p-value of also 0.000.

To sum up the global common trend is largely determined by shocks to the real short-term interest rate. Because monetary policy is strongly influencing the real short-term interest rate, it seems to be an ‘unsystematic’ driver of the global economic system. A period when monetary policy had a strong exogenous character was during the Volcker disinflation era. This time period has been outstanding with a very dominant influence on the macro history in the last 40 years. To demonstrate this we remove the effect of the Volcker disinflation period from the common stochastic trend, with the consequence that the stochastic trend loses its property of a stochastic trend and is getting stationary, according to a unit root test. The creation of a centred Volcker step dummy, ζ_t , from 1979Q4 until 1982Q3 follows historical events according to [Goodfriend and King \(2005\)](#). Additionally, we create a cumulation of this dummy, $\sum_{i=1}^t \zeta_i$, with the purpose to capture the long-term dynamics of the period, because of the unit root in the system. An unrestricted dummy, ζ_t , in the VAR representation of the model leads to a term

$\tilde{\beta}'_{\perp} \alpha'_{\perp} \sum_{i=1}^t \zeta_i$ in the Granger moving average representation.

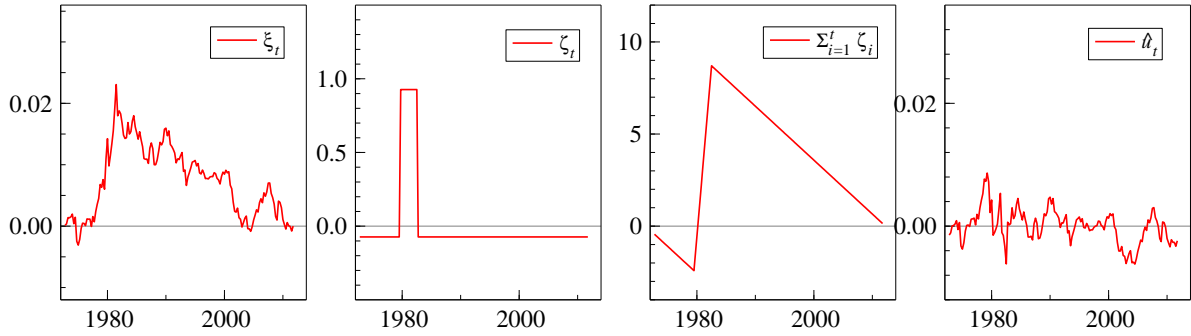


Figure 5 *The common stochastic trend, ξ_t , the centred step dummy, ζ_t , its cumulation, $\sum_{i=1}^t \zeta_i$, and the residuals, \hat{u}_t .*

To remove the effect of the Volcker disinflation from the common stochastic trend we regress the common stochastic trend on a constant and the two dummies, using a Newey-West estimator allowing for up to 5 lags of autocorrelation. The t-values are shown in brackets:

$$\xi_t = 0.0028 + 0.0086 \zeta_t + 0.0014 \sum_{i=1}^t \zeta_i + \hat{u}_t. \quad (12)$$

(3.41) (8.78) (8.76)

The residuals, \hat{u}_t , of this model are plotted in the last panel of Figure 5. When investigating the residuals using an Augmented Dickey-Fuller test with short-run dynamics up to lag four and no deterministic terms (due to zero mean by construction), the hypothesis of a unit root can clearly be rejected with a t-value of -2.87 at a 1% critical value of -2.59, when ignoring a possible detrending effect on the limiting distribution. This result suggests that it is indeed the Volcker disinflation policy that produced the global common stochastic trend in rates of interest and inflation. Note that the major features remaining and now dominating \hat{u}_t are the periods of accommodating monetary policy after September 11, 2001, and the global financial crisis in 2008.

5 Conclusion

The aim of this paper was to shed light on the pulling forces - the cointegration relations - and pushing forces - the common stochastic trend - of the global economy. Three stable long-run relationships emerged: output growth, the term spread and our inflation climate measure. The common driving trend of the global economy turned out to be closely related to the real short-term interest rate, which in turn could be traced back to the stance of monetary policy. The Volcker disinflation emerged as the major macroeconomic event of the post-Bretton-Woods period, forming the global macro-finance common stochastic trend.

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