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Nonlinear inflationary persistence and growth:

theory and comparative empirical analysis

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Abstract

The paper focuses on the relationship between inflation persistence and economic growth. A bilinear model of non-systematic inflation is used for obtaining decomposition of total inflation persistence into the linear and nonlinear parts. On the basis of this decomposition, new measures of persistence are proposed. The hypothesis is that the nonlinear component of the inflation persistence results from a technological shock and might positively contribute to economic growth. The microfoundations are derived from an assumption of Calvo pricing and sticky-information neo-Keynesian Phillips curve. The hypothesis is evaluated empirically with the use of monthly data series of inflation for 141 countries. Linear and nonlinear (bilinear) inflation persistence measures have been estimated on the basis of a bilinear autoregressive moving average model. Further on, correlation analysis has been performed to detect a relationship between economic growth and linear and nonlinear persistence. The paper concludes that the nonlinear inflation persistence contributes positively to economic growth after 2000.

1. Introduction

It appears that a long-standing discussion on the relations between inflation and economic growth has recently reached a conclusion. After decades of arguing (for a review of early literature and arguments see e.g. Bruno and Easterley, 1996), the current seems to be that the relation is negative, e.g. high inflation is usually associated with negative growth (see e.g. Barro, 1995, Gillman, Harris and Mátyás, 2002). While not disputing this result, this paper argues that some components of inflation and, in particular, the nonlinear component of non-steady-state inflation persistence, resulting from the dynamic price-setting behaviour, might be positively related to growth.

The subject of dynamic price-setting behaviour and its consequences have substantially gained on popularity within last decade. It has resulted in a stream of papers on the staggered price theory, monetary policy commitments, dynamic policy optimisation, foundation of the new Keynesian Phillips curve, further development of the dynamic stochastic equilibrium models, etc.. In applications of most of these theories, the crucial place is taken by the problem of estimation and interpretation of inflation persistence, understood as the speed in which inflation converges to equilibrium after a shock (e.g. Willis, 2003). Regardless of their groundings, the empirical measures are similar here (for their reviews see e.g. Dias and Marques, 2005, Pivetta and Reis, 2007). Their common feature is the linear nature of the model they are developed and hence an impossibility of identification of the linear and nonlinear inflationary persistence.

It is hypothesised in this paper that the source and outcome of nonlinear inflationary persistence is substantially different from the linear one. In particular, the nonlinear component of total persistence is more likely to be related to the economic growth than the linear component. The paper provides a microeconomic reasoning for this assertion and supports it by some empirical findings showing significant correlation of growth with the nonlinear component of inflation persistence.

2. Linear and nonlinear inflation persistence

In the literature (see e.g. Granger and Anderson, 1978 and, in economic context, Peel and Davidson, 1998) a process y_t is described as bilinear if it can be expressed as:

$$y_t = \sum_{j=1}^{p} a_j y_{t-j} + \sum_{j=0}^{r} c_j \varepsilon_{t-j} + \sum_{l_1=1}^{m} \sum_{l_2=1}^{k} b_{l_1 l_2} y_{t-l_1} \varepsilon_{t-l_2} \quad ,$$

where a_j , c_j and $b_{l_1 l_2}$ are parameters and $\{\varepsilon_t\}$ is a sequence of *i.i.d.* random variables with zero expected value, variance σ_ε^2 and finite higher moments. In a compact notation, the process is denoted as a *BL(p, r, m, k)*. Here we assume that π_t, that is a deviation of the observed (headline) inflation from its systematic (core) component at time *t*, *t* = 0, 1,…,*T*, is described by a simple diagonal case of the above process:

$$\pi_t = \sum_{j=1}^{p} a_j \pi_{t-j} + \sum_{i=1}^{k} b_i \varepsilon_{t-i} \pi_{t-i} + \varepsilon_t \quad , \tag{1}$$

that is, by *BL(p, 0, 1, k)* with the coefficient $c_1=1$. The stationarity condition for (1) is complicated and, in general form, computationally awkward. However, for the case where $k = 1$, formula (1) coincides with a special case of a slightly different model of Subba Rao (1981), for which the stationarity condition is:

$$\rho[A \otimes A + B \otimes B \sigma_\varepsilon^2] < 1 \quad . \tag{2}$$

In (2) $\rho[X]$ denotes a maximum absolute value of eigenvalues of matrix *X*, $\otimes$ is a Kronecker product and matrices *A* and *B* are defined as:

$$A = \begin{bmatrix} \overline{a} \\ I_{p-1} \quad 0_{p-1,1} \end{bmatrix} \quad , \quad B = \begin{bmatrix} \overline{b} \\ 0_{p-1,p} \end{bmatrix} \quad ,$$

where $\overline{a}$ is $1 \times p$ matrix of autoregressive coefficients in (1), $\overline{b}$ is $1 \times p$ vector with b_1 being the first element and zeros elsewhere, I_{p-1} is (*p*-1) identity matrix and $0_{n,m}$ denotes $n \times m$ matrix of nulls. By analogy with the linear case, where the persistence is measured by the largest (in absolute value) root of the autoregressive polynomial, we regard the left-hand side of (2) as a generalised measure of total persistence. We denote it here as *TP*1.

Among numerous measures of persistence, for a linear case, that is when in (1) all b_i's are equal to zero, we consider here the simplest measure, being the sum of autoregressive coefficients in a linear *AR(p)* model. Its straightforward bilinear generalisation is:

$$TP2 = \sum_{j=1}^{p} a_j + \sum_{i=1}^{k} |b_i| \quad .$$

Both *TP*1 and *TP*2 can be decomposed into the linear and nonlinear parts. In particular, the linear persistence measure in *TP*1, denoted as *LP*1 can be obtained from (2) by setting $B = 0$, and the nonlinear persistence in *TP*1, *NP*1, is obtained from (2) by setting $A = 0$. It should be noticed, however, that *LP*1, based on the eigenvalues of $A \otimes A$, does not give the same numerical values as the usual measure of persistence in a linear model, based on the eigenvalues of *A*. In stationary models, the largest, in absolute value, eigenvalue of $A \otimes A$ is smaller that that of *A*. Analogously, we can derive the linear and nonlinear persistence measures from *TP*2 as:

$$LP2 = \sum_{j=1}^{p} a_j \quad \text{and} \quad NP2 = \sum_{i=1}^{k} |b_i| \quad .$$

The *TP*1 and *TP*2 measures of persistence are somewhat arbitrary and can be subject of criticisms, as their linear counterparts (see Dias and Marques, 2005, Pivetta and Reis, 2007). In brief, *TP*1 ignores the effects of the eigenvalues other than first, while *TP*2 distorts the general image of persistence if the elements of *TP*2 with small *j*'s are smaller then those with large *j*'s. This is particularly evident if a_j's are of different signs.

Although similar in interpretation, both types of total persistence measures represent different balance between the linear and nonlinear parts. This is illustrated by Figure 1, which plots *TP*1, *LP*1, *TP*2 and *LP*2 against α_1 in:

$$\pi_t = \alpha_1 \pi_{t-1} + 0.25 \pi_{t-2} + 0.5 \varepsilon_{t-1} \pi_{t-1} + \varepsilon_t \quad ,$$

where ε_t has a unitary variance and $\alpha_1 = 0.1, 0.11, \cdots, 1$. The figure shows that, with the increase of persistence due to a change in α_1, *TP*1 rises faster than *TP*2. For both measures the relations between total and linear persistence are kept constant, which indicates that, as expected, the nonlinear persistence is not changing. Nevertheless, the ratio of linear to nonlinear persistence in *TP*1 is smaller than in *TP*2. When it comes to evaluation of the weight of nonlinear persistence in total, both measures might give different results and hence are not directly comparable.

Figure 1: Persistence measures in a *BL*(2, 0 ,1 ,1) model

Persistence measures
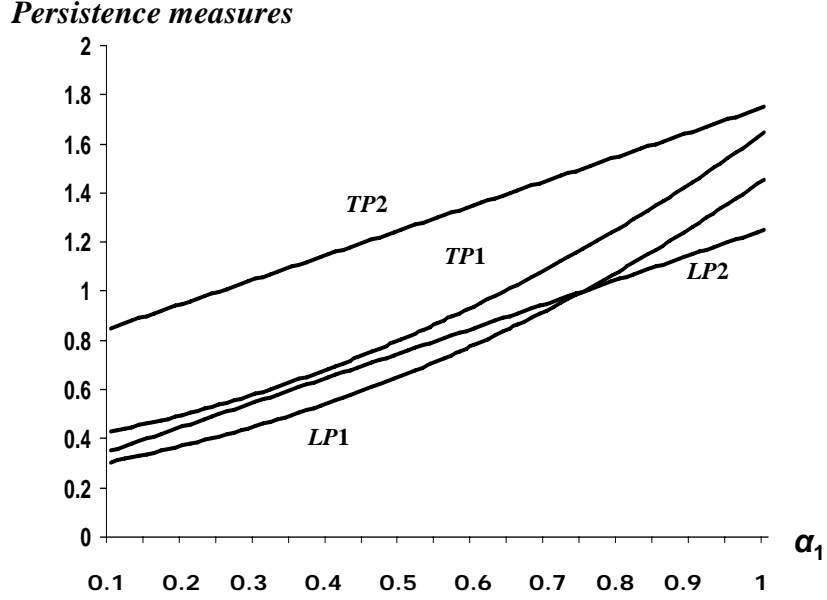
3   Elementary microfoundations

Microfoundations for the applied dynamic scheme which confirm the rational of assessing the nonlinear persistence with economic growth can be derived as a simple generalization of a variety of staggered-price models. For the sake of argument we have chosen here the Christiano, Eichenbaum and Evans (2005, CEE afterwards) model, due to its widespread popularity, numerous extensions and discussions.

As in most contemporary staggered-price models, it is assumed here that one final consumption good is produced in time *t*, under perfect competition, with the use of a continuum of intermediate goods. Other relevant assumptions are:

(i) In consistence with Calvo (1983) pricing mechanism, firms reoptimise their prices with a constant probability $1-\xi$.

(ii) The resulting price is $\tilde{P}_t$, so that they all choose the same price.

(iii)Those firms which do not reoptimise, set their prices by indexation their last period price by the inflation rate. This leads to the reformulation of the pricing formula as:

$$P_t = [(1 - \xi)(\tilde{P}_t)^{1/(1-\lambda)} + \xi(\frac{P_{t-1}}{P_{t-2}} \tilde{P}_t)^{1/(1-\lambda)}]^{1-\lambda} \quad . \tag{3}$$

where P_t is the price of the final good and λ is the elasticity of substitution, assumed to be constant.

(iv) The price optimising firms, in their profit maximization problem, are facing the following log-linearised, around the steady-state, first-order condition:

$$p_t = s_t + E_t \left[\sum_{l=1}^{\infty} (\beta\xi)^l (s_{t+l} - s_{t+l-1}) + \sum_{l=1}^{\infty} (\beta\xi)^l (\pi_{t+l} - \pi_{t+l-1}) \right] \quad ,$$

where p_t denotes the logarithm of price, s_t is the real marginal cost, β is the discount factor and π_t is the inflation rate.

In CEE it is shown show that, under certain regularity conditions, (3) leads to the expected inflation equation:

$$\pi_t^e = \pi_{t-1} + \vartheta_t \quad , \tag{4}$$

where: $\vartheta_t = \frac{(1-\beta\xi)(1-\xi)}{\xi} E_{t-1} \sum_{j=0}^{\infty} \beta^j s_{t+j}$

The term ϑ_t shows the dependence of inflation on expected future real costs adjusted by the Calvo's firms' reoptimising probability. Clearly, the greater ξ is, the smaller is impact of the expected marginal costs on current inflation and, consequently, inflation persistence is greater. Since the real marginal costs are, in the CEE model, a function of interest rate, real wage and rental cost of capital services, the expected costs must be, analogously, a function of expectations of these variables.

One of the disadvantages of the above specification, which makes the empirical analysis awkward, is the assumption that, unless ϑ_t depends negatively on earlier inflation. Taking into account (4), inflation is described by a nonstationary $I(1)$ process which, in the light of current findings, is highly disputable (see e.g. Charemza, Hristova and Burridge, 2005). In order to relax this problem, it is assumed here that firms develop an inflationary mean reversion perception, so that a positive deviation of inflation from its steady-state causes the expected real costs to decline. Symmetrically, inflation being below the steady state causes

the expected real costs to increase. These changes, however, are not linear. They additionally depend on a monetary shock in time *t*-1 in that sense that a positive shock adjusts negatively the speed of inflationary mean reversion and *vice versa*. We are assuming here that the only cause of the expectations error is a monetary shock g_t, so that $\varepsilon_t = g_t$. With the above assumptions, we can approximate ϑ_t as:

$$\vartheta_t = C_t + \theta_t \pi_{t-1} \quad ,$$

and $\theta_t = -a + bg_{t-1}$, where $a > 0$ and *b* are the parameters and C_t represents a deterministic component of the expected marginal costs. Combining the above with (4), the following inflation expectations equation:

$$\pi_t^e = C_t + [(1-a) + bg_{t-1}]\pi_{t-1} \quad , \tag{5}$$

provides the rationale for the empirical bilinear inflation used in this paper. In the light of the CEE model, equation (5) has also an interesting interpretation, which leads to our working hypothesis that inflation persistence and, in particular, its nonlinear component, might affect growth. If, in (5), $a = b = 0$, π_t becomes a linear *I*(1) process. If $0 < a < 1$ and $b = 0$, π_t becomes a more realistic *I*(0) process (recall that π_t denotes deviations from the steady state). However, the most interesting situation is where $b \neq 0$. In this case a positive monetary shock directly affects expected inflation by either increasing, or decreasing the speed of adjustment, depending whether $b > 0$ or $b < 0$. Since the probability of firms' reoptimising, $1 - \xi$, is usually smaller than one, such temporary change in the speed of adjustment is directly affecting the expected real costs and, as the result, contribute to growth.

The interpretation above differs form alternative explanations of persistence in the CEE model (see Smets and Wouters, 2003, Woodford, 2007). Our proposition is, to some extent, a 'hybrid' one, since it is not possible to identify clearly the consequences of the assumption of the invariant and independent Calvo probabilities from other causes of price inertia. In this respect our concept is closer to the generalisations of Goodfriend and King (1997) and Wolman (1999), developed further by Mash (2004) and Sheedy (2005).

4   Empirical results

The empirical analysis uses a panel of monthly time series of annual inflation rates (that is, on the basis of the corresponding month of the previous year) for a wide number of countries have been used. The data are taken from the *International Monetary Fund* database (see http://www.imfstatistics.org/imf). Out of the data set for 182 countries, series for 141 countries have been selected. The series which were incomplete, with a substantial number of missing or systematically repeated observations, have been eliminated. For the remaining series, in a few obvious cases infrequent missing values have been interpolated and some obvious mistakes in data corrected. The data set covers the period from August 1957 to May 2005, but for most countries the series have been shorter. The data length varies from 103 observations for Ireland to 584 for Venezuela. The data are not seasonally adjusted and outliers greater than 5 standard deviations of the series have been truncated (there were very few of them).

The systematic (steady-state) part of inflation has been eliminated by smoothing the data by the Hodrick-Prescott filter with the smoothing constant equal to 16,000. This is evidently a highly arbitrary way of dealing with a systematic core component of inflation. At initial stages of the research some alternative measures of core inflation were tentatively applied, leading to similar results. Two versions of equation (1) have been used, with the different lag restriction on the bilinear part. If the lag length for the bilinear part of (1) is restricted to 1, so that $k = 1$, the full set of persistence measures described in Section 2 above, that is $TP1$, $LP1$, $NP1$, $TP2$, $LP2$ and $NP2$ can be used. However, if we allow longer lags for the bilinear part, the persistence measures $TP1$, $LP1$ and $NP1$ cannot be computed. Hence we have decided to set $p = 3$ and $k = 1$, for which all the persistence measures can be computed and, additionally, $p = 3$ and $k = 3$, where we can only compute $TP2$, $LP2$ and $NP2$. For each country the parameters of equation (1) have been estimated by the maximum likelihood method applied to the steady-state representation of (1). While setting $p = 3$ and $k = 1$, the maximum likelihood function converged to a maximum for 141 countries and, for $p = 3$ and $k = 1$, for 134 countries. In the remaining cases the computations failed.

The Appendix contains the evaluations of the persistence measures for individual countries. In Table A1 the measures for $p = 3$ and $k = 1$ are given and Table A2 contains the results for $p = 3$ and $k = 3$ and also the differences between $TP2$, $LP2$ and $NP2$ obtained for k

= 1 and $k = 3$. These differences give an idea of a possible bias of all measures due to the misspecification of the lag length in the bilinear term of the model. These differences are for most cases positive (especially for the total linear persistence measures), suggesting possible downward bias of the appropriate measures computed for $p = 3$ and $k = 1$. List of codes and names of countries is given in Table A3 in Appendix.

Since, according to most sources, the year 2000 constituted a threshold in the world development, it has been decided, following the World bank convention, to apply the average rate of growth computed for the period 1990-2000 and, separately, for 2000-2005. For countries for which data match was possible (that is, where there were both growth data available and convergence of the maximum likelihood estimates was achieved), simple correlation was computed between the average GDP and total, linear and nonlinear persistence. There are 120 such countries for the estimates obtained for $p = 3$ and $k = 1$ and 113 for $p = 3$ and $k = 3$.

Table 1: Correlation coefficients for average growth and persistence measures

	Time periods		
	1990-2000	2000-2004	1990-2004
	$p = 3$, $k = 1$		
*TP*1	-0.166	0.276	-0.047
*LP*1	-0.168	0.258	-0.0562
*NP*1	-0.076	0.258	-0.056
*TP*2	-0.092	0.312	0.043
*LP*2	-0.077	0.212	0.015
*NP*2	-0.0749	0.390	0.0927
	$p = 3$, $k = 3$		
*TP*2	-0.046	0.253	0.064
*LP*2	0.003	0.124	0.057
*NP*2	-0.136	0.384	0.029

The results given in Table 1 show no signs of correlation between growth and persistence of any kind, where the growth rate is averaged for 1990-2004 and also for 1990-2000. There are even some indications of a negative relationship for this period. However, for the years 2000-2004 the picture is different. All the persistence measures computed are markedly and

positively correlated with average growth. In particular, it is evident that nonlinear persistence correlates with growth much stronger, than the linear one.

The above result, albeit not strong in the statistical sense, is reasonably robust to outliers. This is illustrated by Figures 2 and 3. Figure 2 represents correlation diagram of *NP*2 computed for $p = 3$, $k = 3$ with the GDP data for 2000-2004, where data with negligible nonlinearity have been discarded, that is such where $0 < NP2 < 0.0005$. Overall there were 47 countries with such small nonlinear persistence. Clear outlier here are Armenia and Chad, both countries with a high growth rate and contrastingly different nonlinear persistence. Other outliers with high nonlinear persistence, but relatively moderate growth are Ireland and Estonia. For these all countries, however, inflation persistence have been estimated with the use of relatively short data series, so that these estimates might not be very reliable.

Figure 2: Correlation of NP2 and growth for countries with non-negligible nonlinear persistence
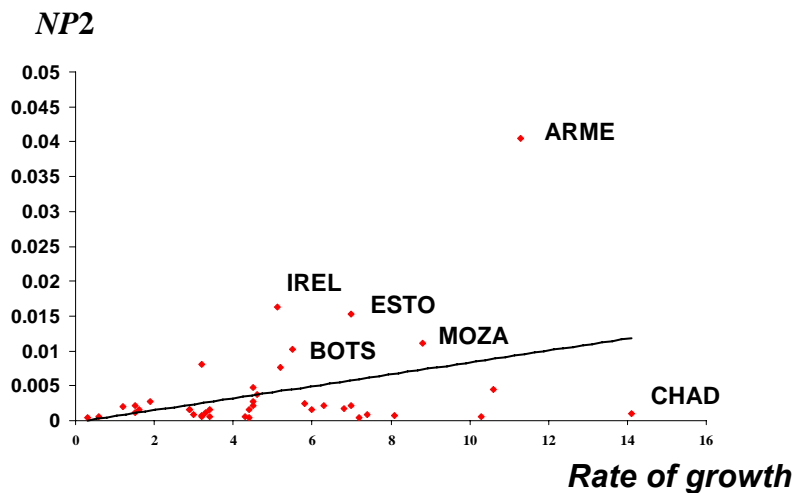
Figure 3 shows a correlation diagram based on the same data, where all the outliers marked in Figure 1 have been eliminated. Here the second group of non-typical countries can be identified. They are Azerbaijan ad Kazakhstan; two countries of post-communist economies, from a similar region, but with different nonlinear persistence, and also Slovenia, Mongolia and Croatia (all also post-communist economies), where nonlinear persistence have been

high, relatively to economic growth. Nevertheless, even with outliers eliminated, the positive relationship between growth and nonlinear persistence, albeit weaker, can still be visible.

Figure 3: Correlation of NP2 and growth with outliers removed
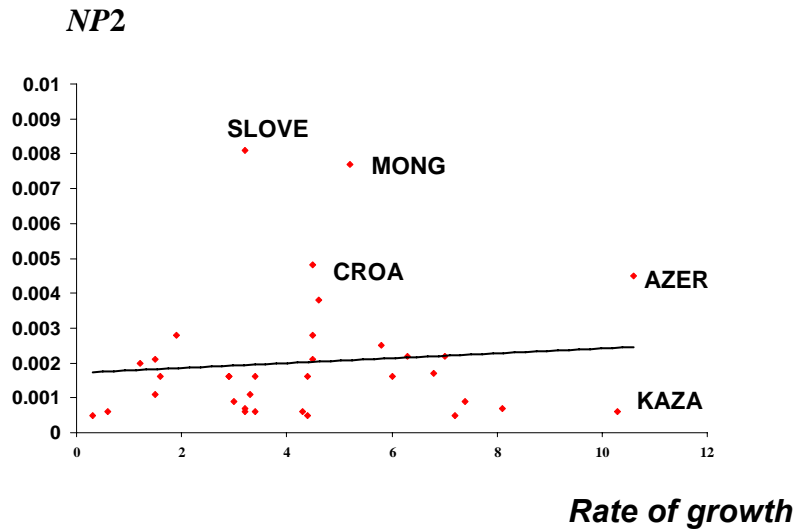
2. Concluding remarks

The hypothesis discussed is of a positive relationship between inflationary persistence and growth and its relation to the non-constant speed of adjustment varying with the changes in expected marginal costs. It turned out to be statistically supported, albeit not strongly. Much depend here on the quality of data and the econometric procedures applied. In particular, it is not clear whether the unusual behaviour of a number of post-communist economies is an economic or a statistical fact. The statistical problems might be caused by the fact that either the data series were too short, or there were measurements error in inflation and/or GDP growth data, or by the numerical inaccuracy of the applied econometric estimator. Hence, the only clear conclusion seem to be that studies of the problem should continue.

Appendix A

Table A1: Persistence measures, $p = 3$, $k = 1$

country	No.obs	*TP*1	*LP*1	*NP*1	*TP*2	*LP*2	*NP*2
ALBA	161	0.4297	0.4289	0.0002	0.8061	0.7932	0.0129
ALGE	352	0.3962	0.3962	0.0000	0.6369	0.6308	0.0061
ANGO	164	0.5080	0.4994	0.0007	0.9088	0.8827	0.0261
ARGE	573	0.3683	0.3589	0.0002	0.8851	0.8719	0.0132
ARME	141	1.2080	1.1420	0.0405	1.2522	1.0510	0.2012
ARUB	236	0.5009	0.5009	0.0000	0.8044	0.8008	0.0036
AUST	571	0.2431	0.2378	0.0020	0.6556	0.6104	0.0452
AZER	160	0.7525	0.7437	0.0045	0.9632	0.8964	0.0667
BAHA	397	0.6217	0.6210	0.0006	0.8143	0.7892	0.0251
BAHR	306	0.4303	0.4303	0.0000	0.5873	0.5873	0.0000
BARB	461	0.3309	0.3306	0.0000	0.7268	0.7206	0.0063
BELA	152	0.6091	0.5882	0.0017	0.9551	0.9138	0.0413
BELG	573	0.4325	0.4324	0.0000	0.7508	0.7471	0.0036
BENI	145	0.4300	0.4299	0.0001	0.7311	0.7222	0.0089
BOLI	571	0.7821	0.7821	0.0000	0.9075	0.9039	0.0036
BOTS	362	0.4087	0.2989	0.0102	0.8536	0.7525	0.1010
BRAZ	297	0.7467	0.7467	0.0000	0.9277	0.9258	0.0020
BULG	165	0.7368	0.7367	0.0001	0.8750	0.8646	0.0104
BURK	539	0.4888	0.4887	0.0001	0.7054	0.6972	0.0081
BURU	378	0.4631	0.4628	0.0003	0.7007	0.6841	0.0166
CAMB	119	0.4458	0.4457	0.0001	0.6867	0.6752	0.0115
CAME	403	0.5477	0.5420	0.0028	0.8433	0.7904	0.0529
CANA	571	0.3793	0.3784	0.0001	0.7650	0.7555	0.0095
CAPE	163	0.3238	0.3178	0.0015	0.7124	0.6737	0.0387
CENT	279	0.6247	0.6247	0.0000	0.8013	0.7976	0.0037
CHAD	241	0.5766	0.5747	0.0010	0.8377	0.8057	0.0320
CHIL	573	0.5473	0.5471	0.0002	0.7777	0.7649	0.0128
CHIN	220	0.6044	0.6036	0.0002	0.8787	0.8643	0.0144
CHHK	286	0.6103	0.6100	0.0006	0.7519	0.7267	0.0252
COLO	573	0.5703	0.5703	0.0000	0.8800	0.8799	0.0002
CONG	495	0.4785	0.4780	0.0001	0.8604	0.8524	0.0080
COST	370	0.7013	0.7012	0.0000	0.8861	0.8797	0.0063
COTE	528	0.5015	0.5013	0.0002	0.6779	0.6638	0.0141
CROA	225	0.6332	0.6284	0.0048	0.8614	0.7923	0.0691
CYPR	568	0.3809	0.3808	0.0001	0.6792	0.6713	0.0079
CZEC	138	0.5087	0.5085	0.0001	0.8489	0.8414	0.0075
DENM	452	0.4907	0.4907	0.0000	0.7667	0.7662	0.0004
DOMI	467	0.5556	0.5549	0.0014	0.7182	0.6813	0.0370
DOMR	572	0.4780	0.4598	0.0010	0.8778	0.8461	0.0316
EQUA	573	0.4840	0.4822	0.0004	0.8484	0.8295	0.0188
EGYP	572	0.2923	0.2887	0.0016	0.6848	0.6446	0.0402
ELSA	570	0.6785	0.6762	0.0028	0.8619	0.8093	0.0526
ESTO	152	0.8719	0.8588	0.0153	1.0460	0.9222	0.1238
ETHI	445	0.5675	0.5667	0.0004	0.8134	0.7927	0.0208
FIJI	426	0.4792	0.4791	0.0000	0.7641	0.7579	0.0061
FINL	573	0.5365	0.5364	0.0000	0.7831	0.7787	0.0044
FRAN	573	0.5833	0.5782	0.0021	0.8683	0.8224	0.0460

country	No.obs	*TP*1	*LP*1	*NP*1	*TP*2	*LP*2	*NP*2
GABO	169	0.3855	0.3646	0.0016	0.8376	0.7972	0.0404
GEOR	123	0.6375	0.6375	0.0000	0.7231	0.7190	0.0041
GERM	164	0.3301	0.3294	0.0006	0.6221	0.5969	0.0252
GHAN	493	0.5975	0.5973	0.0001	0.8571	0.8484	0.0087
GREE	573	0.3435	0.3435	0.0000	0.7694	0.7677	0.0017
GREN	311	0.5563	0.5561	0.0002	0.7257	0.7103	0.0154
GUAT	569	0.6006	0.6006	0.0000	0.7804	0.7792	0.0012
GUIN	215	0.6608	0.6599	0.0016	0.8080	0.7683	0.0397
GUYA	126	0.4232	0.4223	0.0016	0.6503	0.6105	0.0398
HAIT	569	0.4887	0.4887	0.0000	0.7121	0.7061	0.0060
HOND	572	0.6372	0.6372	0.0000	0.8238	0.8184	0.0054
HUNG	345	0.4609	0.4609	0.0000	0.7662	0.7657	0.0005
ICEL	261	0.5665	0.5628	0.0007	0.8957	0.8689	0.0268
INDI	566	0.7027	0.7027	0.0000	0.8805	0.8762	0.0043
INDO	441	0.7814	0.7744	0.0038	0.9704	0.9086	0.0618
IRAN	533	0.5473	0.5468	0.0001	0.8367	0.8257	0.0111
IREL	102	0.7787	0.7225	0.0163	1.0408	0.9131	0.1276
ISRA	569	0.7022	0.7018	0.0001	0.9077	0.8955	0.0122
ITAL	572	0.6101	0.6101	0.0000	0.8679	0.8667	0.0012
JAMA	569	0.5846	0.5846	0.0000	0.8911	0.8905	0.0005
JAPA	561	0.4966	0.4965	0.0001	0.7689	0.7605	0.0084
JORD	341	0.4741	0.4736	0.0004	0.7301	0.7106	0.0196
KAZA	140	0.7750	0.7728	0.0006	0.9024	0.8785	0.0239
KENY	451	0.4338	0.4336	0.0000	0.8165	0.8110	0.0055
KORE	428	0.4874	0.4864	0.0003	0.8316	0.8145	0.0171
KYRG	115	0.5214	0.4906	0.0021	0.9031	0.8568	0.0464
LAOP	184	0.5451	0.5388	0.0016	0.8843	0.8449	0.0394
LATV	164	0.6620	0.6613	0.0009	0.8181	0.7883	0.0298
LITH	152	0.7475	0.7461	0.0020	0.8866	0.8420	0.0446
LUXE	571	0.3200	0.3186	0.0003	0.6967	0.6800	0.0167
MACE	133	0.3700	0.3588	0.0002	0.7774	0.7624	0.0150
MADA	487	0.7132	0.7131	0.0001	0.8537	0.8444	0.0093
MALA	295	0.6652	0.6651	0.0001	0.8455	0.8371	0.0084
MALY	566	0.6429	0.6429	0.0000	0.8293	0.8228	0.0065
MALI	192	0.3351	0.3128	0.0022	0.7774	0.7305	0.0469
MALT	564	0.5600	0.5596	0.0006	0.7149	0.6901	0.0248
MAUT	225	0.5031	0.5030	0.0001	0.7067	0.6952	0.0114
MAUR	504	0.4712	0.4687	0.0005	0.8299	0.8085	0.0213
MEXI	572	0.6550	0.6444	0.0011	0.9541	0.9216	0.0325
MOLD	113	0.8260	0.8255	0.0022	0.8671	0.8201	0.0470
MONG	152	0.6497	0.6468	0.0077	0.8036	0.7158	0.0879
MORO	570	0.3244	0.3238	0.0001	0.7365	0.7278	0.0086
MOZA	141	0.4661	0.4452	0.0111	0.8433	0.7382	0.1052
MAYN	420	0.4282	0.4222	0.0015	0.7999	0.7607	0.0392
NANI	168	0.6047	0.6039	0.0003	0.8422	0.8240	0.0182
NEPA	490	0.6685	0.6685	0.0000	0.8190	0.8176	0.0014
NETH	570	0.4651	0.4651	0.0000	0.7028	0.7006	0.0022
NETA	443	0.6983	0.6971	0.0010	0.8845	0.8536	0.0310
NICA	356	0.5939	0.5932	0.0001	0.9008	0.8901	0.0106
NIGE	432	0.3398	0.3375	0.0010	0.6886	0.6577	0.0309
NIGR	533	0.6119	0.6117	0.0001	0.8489	0.8387	0.0102
NORW	578	0.6192	0.6186	0.0004	0.8376	0.8169	0.0207
PAKI	567	0.3979	0.3979	0.0000	0.7850	0.7846	0.0004

country	No.obs	*TP*1	*LP*1	*NP*1	*TP*2	*LP*2	*NP*2
PANA	356	0.5313	0.5304	0.0011	0.7426	0.7091	0.0335
PARA	572	0.3601	0.3594	0.0002	0.7384	0.7259	0.0124
PERU	572	0.5265	0.5264	0.0000	0.8292	0.8251	0.0041
PHIL	570	0.5415	0.5415	0.0000	0.8019	0.7994	0.0025
POLA	200	0.6855	0.6855	0.0000	0.9086	0.9079	0.0008
PORT	572	0.5010	0.5000	0.0005	0.7854	0.7626	0.0228
ROMA	168	0.5480	0.5447	0.0002	0.8896	0.8745	0.0152
RUSS	151	0.4847	0.4826	0.0002	0.8887	0.8752	0.0135
SAMO	450	0.6563	0.6562	0.0000	0.8194	0.8138	0.0056
SAUD	291	0.4397	0.4374	0.0006	0.7679	0.7428	0.0251
SENE	443	0.3474	0.3467	0.0002	0.7434	0.7307	0.0127
SEYC	417	0.4912	0.4908	0.0005	0.6922	0.6691	0.0230
SIER	226	0.4522	0.4513	0.0005	0.7385	0.7153	0.0232
SING	516	0.7084	0.7084	0.0000	0.8427	0.8387	0.0040
SLOVA	140	0.4413	0.4412	0.0000	0.7782	0.7739	0.0043
SLOVE	153	0.9451	0.9416	0.0081	1.0459	0.9559	0.0900
SOLO	312	0.5754	0.5754	0.0000	0.7532	0.7525	0.0007
SOUT	572	0.3684	0.3546	0.0007	0.8000	0.7734	0.0266
SPAI	574	0.3886	0.3847	0.0009	0.8045	0.7737	0.0308
SRIL	568	0.3065	0.3065	0.0000	0.7290	0.7270	0.0020
STKI	242	0.3196	0.3166	0.0005	0.6955	0.6739	0.0216
STLU	463	0.6287	0.6278	0.0009	0.8285	0.7993	0.0293
STVI	320	0.1992	0.1990	0.0001	0.5675	0.5569	0.0106
SURI	426	0.6050	0.6048	0.0000	0.8840	0.8774	0.0066
SWAZ	452	0.3446	0.3446	0.0000	0.5884	0.5870	0.0014
SWED	572	0.4590	0.4582	0.0003	0.7704	0.7543	0.0161
SWIT	567	0.3980	0.3978	0.0001	0.7678	0.7596	0.0082
THAI	474	0.6128	0.6113	0.0004	0.8750	0.8543	0.0207
TONG	187	0.3701	0.3637	0.0047	0.7184	0.6499	0.0685
TRIN	569	0.5770	0.5768	0.0001	0.7796	0.7685	0.0111
TUNIS	207	0.5976	0.5963	0.0006	0.8488	0.8243	0.0245
TURK	429	0.4762	0.4760	0.0001	0.8277	0.8206	0.0072
UGAN	283	0.5275	0.5231	0.0025	0.7910	0.7409	0.0501
UKRA	151	0.6438	0.6438	0.0000	0.8585	0.8568	0.0017
UNITK	566	0.6486	0.6484	0.0001	0.8616	0.8519	0.0097
UNITS	573	0.3627	0.3623	0.0001	0.7945	0.7874	0.0071
URUG	573	0.6231	0.6229	0.0001	0.8545	0.8430	0.0115
VENE	583	0.6207	0.6206	0.0000	0.8468	0.8417	0.0051
VIET	114	0.6486	0.6476	0.0003	0.8966	0.8785	0.0180
ZAMBI	235	0.5645	0.5586	0.0016	0.8846	0.8447	0.0399
ZIMB	278	0.5231	0.5231	0.0000	0.7824	0.7804	0.0020

Table A2: Persistence measures, $p = 3$, $k = 3$

country	No.obs	*TP*2	*LP*2	*NP*2	dif*TP*2	dif*LP*2	dif*NP*2
ALBA	161	0,8366	0,8186	0,0180	0,0305	0,0254	0,0051
ALGE	352	0,7241	0,7186	0,0055	0,0872	0,0878	-0,0006
ANGO	164	0,9593	0,9255	0,0338	0,0505	0,0428	0,0077
ARGE	573	0,9233	0,9080	0,0153	0,0382	0,0361	0,0021
ARME	141	1,1357	0,9397	0,1960	-0,1165	-0,1113	-0,0052
ARUB	236	0,8589	0,8344	0,0245	0,0545	0,0336	0,0209
AUST	571	0,7200	0,6719	0,0481	0,0644	0,0615	0,0029
AZER	160	0,9911	0,9270	0,0640	0,0279	0,0306	-0,0027
BAHA	397	0,8135	0,7860	0,0276	-0,0008	-0,0032	0,0025
BAHR	306	0,5468	0,5452	0,0016	-0,0405	-0,0421	0,0016
BARB	461	0,7434	0,7376	0,0058	0,0166	0,0170	-0,0005
BELA	152	0,9497	0,9406	0,0091	-0,0054	0,0268	-0,0322
BELG	573	0,7805	0,7772	0,0033	0,0297	0,0301	-0,0003
BENI	145	0,7953	0,7922	0,0031	0,0642	0,0700	-0,0058
BOLI	571	0,9120	0,9057	0,0063	0,0045	0,0018	0,0027
BOTS	362	0,9121	0,8058	0,1063	0,0585	0,0533	0,0053
BRAZ	297	0,9701	0,9551	0,0150	0,0424	0,0293	0,0130
BULG	165	0,8900	0,8812	0,0088	0,0150	0,0166	-0,0016
BURK	539	0,6854	0,6798	0,0055	-0,0200	-0,0174	-0,0026
BURU	378	0,6980	0,6810	0,0170	-0,0027	-0,0031	0,0004
CAMB	119	0,7079	0,6974	0,0105	0,0212	0,0222	-0,0010
CAME	403	0,8740	0,8180	0,0560	0,0307	0,0276	0,0031
CANA	571	0,8076	0,7967	0,0109	0,0426	0,0412	0,0014
CAPE	163	0,7413	0,7084	0,0330	0,0289	0,0347	-0,0057
CENT	279	0,8029	0,7980	0,0049	0,0016	0,0004	0,0012
CHAD	241	0,8532	0,8323	0,0209	0,0155	0,0266	-0,0111
CHIL	573	0,7860	0,7753	0,0107	0,0083	0,0104	-0,0021
CHIN	220	0,9380	0,9157	0,0224	0,0593	0,0514	0,0080
CHHK	286	0,7134	0,6898	0,0237	-0,0385	-0,0369	-0,0015
COLO	573	0,9178	0,9123	0,0056	0,0378	0,0324	0,0054
CONG	495	0,9095	0,8977	0,0117	0,0491	0,0453	0,0037
COST	370	0,9071	0,9043	0,0028	0,0210	0,0246	-0,0035
COTE	528	0,6552	0,6521	0,0031	-0,0227	-0,0117	-0,0110
CROA	225	0,8604	0,7903	0,0701	-0,0010	-0,0020	0,0010
CYPR	568	0,7002	0,6905	0,0096	0,0210	0,0192	0,0017
CZEC	138	0,8988	0,8893	0,0095	0,0499	0,0479	0,0020
DENM	452	0,8023	0,7954	0,0068	0,0356	0,0292	0,0064
DOMI	467	0,6776	0,6404	0,0373	-0,0406	-0,0409	0,0003
DOMR	572	0,9078	0,8855	0,0223	0,0300	0,0394	-0,0093
EQUA	573	0,8908	0,8757	0,0151	0,0424	0,0462	-0,0037
EGYP	572	0,7088	0,6699	0,0389	0,0240	0,0253	-0,0013
ELSA	570	0,8020	0,7837	0,0183	-0,0599	-0,0256	-0,0343
ESTO	152	0,9079	0,7876	0,1204	-0,1381	-0,1346	-0,0034
ETHI	445	0,8339	0,8128	0,0210	0,0205	0,0201	0,0002
FIJI	426	0,7900	0,7810	0,0090	0,0259	0,0231	0,0029
FRAN	573	0,9238	0,8791	0,0446	0,0555	0,0567	-0,0014
GABO	169	0,8870	0,8445	0,0425	0,0494	0,0473	0,0021
GEOR	123	0,7470	0,7375	0,0095	0,0239	0,0185	0,0054
GERM	164	0,6979	0,6725	0,0254	0,0758	0,0756	0,0002
GHAN	493	0,9116	0,9048	0,0068	0,0545	0,0564	-0,0019
GREE	573	0,8123	0,8100	0,0023	0,0429	0,0423	0,0006

country	No.obs	*TP*2	*LP*2	*NP*2	dif*TP*2	dif*LP*2	dif*NP*2
GREN	311	0,7058	0,6915	0,0143	-0,0199	-0,0188	-0,0011
GUAT	569	0,7832	0,7825	0,0007	0,0028	0,0033	-0,0005
GUIN	215	0,7770	0,7342	0,0427	-0,0310	-0,0341	0,0030
GUYA	126	0,6691	0,6290	0,0401	0,0188	0,0185	0,0003
HOND	572	0,8361	0,8316	0,0045	0,0123	0,0132	-0,0009
ICEL	261	0,8876	0,8687	0,0189	-0,0081	-0,0002	-0,0079
INDI	566	0,9017	0,8959	0,0058	0,0212	0,0197	0,0015
INDO	441	0,9787	0,9228	0,0559	0,0083	0,0142	-0,0059
IRAN	533	0,8621	0,8581	0,0040	0,0254	0,0324	-0,0071
IREL	102	1,0410	0,9303	0,1106	0,0002	0,0172	-0,0170
ISRA	569	0,9152	0,9125	0,0027	0,0075	0,0170	-0,0095
ITAL	572	0,9014	0,8975	0,0039	0,0335	0,0308	0,0027
JAMA	569	0,9243	0,9224	0,0020	0,0332	0,0319	0,0015
JAPA	561	0,7901	0,7864	0,0037	0,0212	0,0259	-0,0047
JORD	341	0,7552	0,7275	0,0276	0,0251	0,0169	0,0080
KAZA	140	0,9483	0,9161	0,0323	0,0459	0,0376	0,0084
KENY	451	0,8551	0,8492	0,0059	0,0386	0,0382	0,0004
KORE	428	0,8862	0,8760	0,0102	0,0546	0,0615	-0,0069
KYRG	115	0,9269	0,8982	0,0287	0,0238	0,0414	-0,0177
LAOP	184	0,9068	0,8739	0,0329	0,0225	0,0290	-0,0065
LATV	164	0,8294	0,7836	0,0459	0,0113	-0,0047	0,0161
LITH	152	0,8773	0,8570	0,0203	-0,0093	0,0150	-0,0243
LUXE	571	0,7323	0,7171	0,0152	0,0356	0,0371	-0,0015
MACE	133	0,8189	0,7970	0,0219	0,0415	0,0346	0,0069
MADA	487	0,8537	0,8444	0,0093	0,0000	0,0000	0,0000
MALA	295	0,8541	0,8494	0,0047	0,0086	0,0123	-0,0037
MALY	566	0,8445	0,8365	0,0080	0,0152	0,0137	0,0015
MALI	192	0,8149	0,7614	0,0536	0,0375	0,0309	0,0067
MALT	564	0,6914	0,6648	0,0266	-0,0235	-0,0253	0,0018
MAUT	225	0,6573	0,6439	0,0134	-0,0494	-0,0513	0,0020
MAUR	504	0,8749	0,8494	0,0254	0,0450	0,0409	0,0041
MEXI	572	0,9413	0,9375	0,0039	-0,0128	0,0159	-0,0286
MOLD	113	0,6783	0,6121	0,0662	-0,1888	-0,2080	0,0192
MONG	152	0,7789	0,6960	0,0829	-0,0247	-0,0198	-0,0050
MORO	570	0,7802	0,7750	0,0052	0,0437	0,0472	-0,0034
MOZA	141	0,8814	0,7921	0,0893	0,0381	0,0539	-0,0159
MAYN	420	0,8422	0,8027	0,0395	0,0423	0,0420	0,0003
NANI	168	0,8509	0,842	0,0089	0,0087	0,0180	-0,0093
NEPA	490	0,819	0,8176	0,0014	0,0000	0,0000	0,0000
NETH	570	0,7143	0,7127	0,0016	0,0115	0,0121	-0,0006
NETA	443	0,9063	0,8678	0,0385	0,0218	0,0142	0,0075
NICA	356	0,9326	0,9294	0,0032	0,0318	0,0393	-0,0074
NIGE	432	0,7179	0,6916	0,0263	0,0293	0,0339	-0,0046
NIGR	533	0,8680	0,8630	0,0050	0,0191	0,0243	-0,0052
NORW	578	0,8510	0,8341	0,0169	0,0134	0,0172	-0,0038
PAKI	567	0,8383	0,8311	0,0072	0,0533	0,0465	0,0068
PANA	356	0,7443	0,7100	0,0343	0,0017	0,0009	0,0008
PARA	572	0,7720	0,7689	0,0031	0,0336	0,0430	-0,0093
PERU	572	0,8849	0,8831	0,0018	0,0557	0,0580	-0,0023
PHIL	570	0,8277	0,8252	0,0025	0,0258	0,0258	0,0000
POLA	200	0,9452	0,9358	0,0094	0,0366	0,0279	0,0086
PORT	572	0,8084	0,7893	0,0191	0,0230	0,0267	-0,0037
ROMA	168	0,9427	0,9090	0,0337	0,0531	0,0345	0,0185

country	No.obs	*TP*2	*LP*2	*NP*2	dif*TP*2	dif*LP*2	dif*NP*2
RUSS	151	0,9471	0,9148	0,0323	0,0584	0,0396	0,0188
SAMO	450	0,8304	0,8197	0,0107	0,0110	0,0059	0,0051
SAUD	291	0,7817	0,7646	0,0171	0,0138	0,0218	-0,0080
SENE	443	0,7740	0,7631	0,0108	0,0306	0,0324	-0,0019
SEYC	417	0,6738	0,6479	0,0259	-0,0184	-0,0212	0,0029
SIER	226	0,7784	0,7509	0,0275	0,0399	0,0356	0,0043
SING	516	0,8370	0,8346	0,0024	-0,0057	-0,0041	-0,0016
SLOVA	140	0,8387	0,8126	0,0261	0,0605	0,0387	0,0218
SLOVE	153	0,9632	0,8024	0,1608	-0,0827	-0,1535	0,0708
SOUT	572	0,8346	0,8091	0,0255	0,0346	0,0357	-0,0011
SPAI	574	0,8536	0,8257	0,0279	0,0491	0,0520	-0,0029
SRIL	568	0,7737	0,7723	0,0015	0,0447	0,0453	-0,0005
STKI	242	0,7712	0,7236	0,0476	0,0757	0,0497	0,0260
STLU	463	0,8343	0,8050	0,0293	0,0058	0,0057	0,0000
STVI	320	0,5976	0,5890	0,0087	0,0301	0,0321	-0,0019
SURI	426	0,9113	0,9068	0,0045	0,0273	0,0294	-0,0021
SWAZ	452	0,5884	0,5870	0,0014	0,0000	0,0000	0,0000
SWED	572	0,8018	0,7854	0,0164	0,0314	0,0311	0,0003
THAI	474	0,9019	0,8835	0,0184	0,0269	0,0292	-0,0023
TONG	187	0,7715	0,7167	0,0548	0,0531	0,0668	-0,0137
TRIN	569	0,7852	0,7748	0,0104	0,0056	0,0063	-0,0007
TUNIS	207	0,8837	0,8535	0,0302	0,0349	0,0292	0,0057
UGAN	283	0,8701	0,8279	0,0422	0,0791	0,0870	-0,0079
UKRA	151	0,9118	0,8941	0,0177	0,0533	0,0373	0,0160
UNITK	566	0,8833	0,8761	0,0072	0,0217	0,0242	-0,0025
UNITS	573	0,8467	0,8400	0,0067	0,0522	0,0526	-0,0004
URUG	573	0,8758	0,8680	0,0078	0,0213	0,0250	-0,0037
VENE	583	0,9121	0,9045	0,0076	0,0653	0,0628	0,0025
ZAMBI	235	0,9362	0,9019	0,0343	0,0516	0,0572	-0,0056
ZIMB	278	0,8133	0,8088	0,0045	0,0309	0,0284	0,0025

Table A3: List of country names and codes

Country name	code	Country name	code	Country name	code
ALBANIA	ALBA	GABON	GABO	NETHERLANDS ANTILLES	NETA
ALGERIA	ALGE	GEORGIA	GEOR	NICARAGUA	NICA
ANGOLA	ANGO	GERMANY	GERM	NIGER	NIGE
ARGENTINA	ARGE	GHANA	GHAN	NIGERIA	NIGR
ARMENIA	ARME	GREECE	GREE	NORWAY	NORW
ARUBA	ARUB	GRENADA	GREN	PAKISTAN	PAKI
AUSTRIA	AUST	GUATEMALA	GUAT	PANAMA	PANA
AZERBAIJAN, REP. OF	AZER	GUINEA-BISSAU	GUIN	PARAGUAY	PARA
BAHAMAS, THE	BAHA	GUYANA	GUYA	PERU	PERU
BAHRAIN, KINGDOM OF	BAHR	HAITI	HAIT	PHILIPPINES	PHIL
BARBADOS	BARB	HONDURAS	HOND	POLAND	POLA
BELARUS	BELA	HUNGARY	HUNG	PORTUGAL	PORT
BELGIUM	BELG	ICELAND	ICEL	ROMANIA	ROMA
BENIN	BENI	INDIA	INDI	RUSSIA	RUSS
BOLIVIA	BOLI	INDONESIA	INDO	SAMOA	SAMO
BOTSWANA	BOTS	IRAN, I.R. OF	IRAN	SAUDI ARABIA	SAUD
BRAZIL	BRAZ	IRELAND	IREL	SENEGAL	SENE
BULGARIA	BULG	ISRAEL	ISRA	SEYCHELLES	SEYC
BURKINA FASO	BURK	ITALY	ITAL	SIERRA LEONE	SIER
BURUNDI	BURU	JAMAICA	JAMA	SINGAPORE	SING
CAMBODIA	CAMB	JAPAN	JAPA	SLOVAK REPUBLIC	SLOA
CAMEROON	CAME	JORDAN	JORD	SLOVENIA	SLOE
CANADA	CANA	KAZAKHSTAN	KAZA	SOLOMON ISLANDS	SOLO
CAPE VERDE	CAPE	KENYA	KENY	SOUTH AFRICA	SOUT
CENTRAL AFRICAN REP.	CENT	KOREA	KORE	SPAIN	SPAI
CHAD	CHAD	KYRGYZ REPUBLIC	KYRG	SRI LANKA	SRIL
CHILE	CHIL	LAO PEOPLE S DEM.REP	LAOP	ST. KITTS AND NEVIS	STKI
CHINA,P.R.: MAINLAND	CHIN	LATVIA	LATV	ST. LUCIA	STLU
CHINA,P.R.:HONG KONG	CHHK	LITHUANIA	LITH	ST. VINCENT & GRENS.	STVI
COLOMBIA	COLO	LUXEMBOURG	LUXE	SURINAME	SURI
CONGO, DEM. REP. OF	CONG	MACEDONIA, FYR	MACE	SWAZILAND	SWAZ
COSTA RICA	COST	MADAGASCAR	MADA	SWEDEN	SWED
COTE D IVOIRE	COTE	MALAWI	MALA	SWITZERLAND	SWIT
CROATIA	CROA	MALAYSIA	MALY	THAILAND	THAI
CYPRUS	CYPR	MALI	MALI	TONGA	TONG
CZECH REPUBLIC	CZEC	MALTA	MALT	TRINIDAD AND TOBAGO	TRIN
DENMARK	DENM	MAURITANIA	MAUT	TUNISIA	TUNI
DOMINICA	DOMI	MAURITIUS	MAUR	TURKEY	TURK
DOMINICAN REPUBLIC	DOMR	MEXICO	MEXI	UGANDA	UGAN
ECUADOR	EQUA	MOLDOVA	MOLD	UKRAINE	UKRA
EGYPT	EGYP	MONGOLIA	MONG	UNITED KINGDOM	UNIK
EL SALVADOR	ELSA	MOROCCO	MORO	UNITED STATES	UNIS
ESTONIA	ESTO	MOZAMBIQUE	MOZA	URUGUAY	URUG
ETHIOPIA	ETHI	MYANMAR	MAYN	VENEZUELA, REP. BOL.	VENE
FIJI	FIJI	NAMIBIA	NANI	VIETNAM	VIET
FINLAND	FINL	NEPAL	NEPA	ZAMBIA	ZAMB
FRANCE	FRAN	NETHERLANDS	NETH	ZIMBABWE	ZIMB

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