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Panel Seasonal Unit Root Test With An Application for Unemployment Data

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Abstract

In this paper the seasonal unit root test of Hylleberg et al. (1990) is generalized to cover a heterogenous panel. The procedure follows the work of Im, Pesaran and Shin (2002). Test statistics are proposed and critical values are obtained by simulations. Moreover, the properties of the tests are analyzed for different deterministic and dynamic specifications. Evidence is presented that for a small time dimension the power is slow even for increasing cross section dimension. Therefore, it seems necessary to have a higher time dimension than cross section dimension. The new test is applied for unemployment behaviour in industrialized countries. In some cases seasonal unit roots are detected. However, the null hypotheses of panel seasonal unit roots are rejected. The null hypothesis of a unit root at the zero frequency is not rejected, thereby supporting the presence of hysteresis effects.

Keywords: Panel seasonal unit root test; IPS-approach; Unemployment data.
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1 Introduction

It has become a common practice in macroeconomic analysis to test for unit roots. However, the power of the tests is often very small. It can be increased if the information base is extended by pooling data over individual cross sections (countries, regions, sectors). Therefore, panel unit root tests are proposed (see Banerjee 1999 for a survey).

Usually, the tests concentrate on unit roots at the zero or long run frequency, implying that the analysis is limited to seasonal adjusted data. Strong seasonality can bias the results of these tests. In some cases the seasonal pattern may be described by deterministic seasonal intercepts, or stochastic dynamic effects. However, even the seasonal pattern may be subject to stochastic trends, indicating that the series may be well approximated by seasonal unit roots. These series include additional unit roots at the annual and half yearly frequency. Hylleberg et al. (1990) suggest a test strategy for this problem. The test generalizes the Dickey-Fuller test to cover seasonal frequencies. An extension to the panel framework is clearly recommended.

Therefore, this paper discusses a seasonal unit root test in the line of Hylleberg et al. (1990) for a heterogenous panel. The procedure is build upon the work of Im, Pesaran and Shin (2002). Test statistics are proposed and critical values are obtained by simulations. Moreover, the properties of the tests are analyzed for different deterministic and dynamic specifications. The new test is applied for unemployment behaviour in industrialized countries. In some cases seasonal unit roots are detected. However, the null hypotheses of panel seasonal unit roots are rejected. The null hypothesis of a unit root at the zero frequency is not rejected, thereby supporting the presence of hysteresis effects.

The paper proceeds as follows. The next section (section 2) gives the statistical framework. In section 3 simulations are described and results are presented. The empirical example is discussed in section 4, and section 5 concludes.

2 Statistical framework of seasonal processes

2.1 Seasonal integration HEGY-test

To test the unit root properties of variables with a substantial seasonal pattern Hylleberg et al. (1990) have proposed a generalization to the Dickey-Fuller approach, denoted as HEGY-test and applied in Engle et al. (1993). The procedure is based on the assumption that the individual time series is generated by a finite autoregressive process

$$\phi(B)x_t = \epsilon_t \tag{1}$$

with ϵ_t as a zero mean white noise. The operator B denotes the backshift operator ($Bx_t = x_{t-1}$). If this process x_t is integrated and seasonally integrated then $\phi(z) = 0$ has roots at 1, -1, and $\pm i$, where a maximum integration order of one is imposed. These roots correspond to zero frequency, frequency ω (two cycles a year, biannual), and frequency $\omega/2$ (one cycle a year, annual). Under this hypothesis $\phi(B)$ contains the factors

$$(1-B^4) = (1-B)(1+B)(1+B^2)\,. \tag{2}$$

To analyze the unit roots at all seasonal frequencies and zero frequency the process is rearranged as

$$\phi^\star(B)\Delta_4 x_t = \pi_1 z_{1,t-1} + \pi_2 z_{2,t-1} + \pi_3 z_{3,t-2} + \pi_4 z_{3,t-1} + \epsilon_t \tag{3}$$

where

$$\begin{aligned} z_{1,t} &= (1+B+B^2+B^3)x_t \\ z_{2,t} &= -(1-B+B^2-B^3)x_t \\ z_{3,t} &= -(1-B^2)x_t \\ \Delta_4 x_t &= (1-B^4)x_t \end{aligned}$$

and $\phi^\star(B)$ is a stationary polynomial in the lag operator B. The last transformation eliminates all roots on the unit circle, which correspond to seasonal frequencies and to zero frequency. $\Delta_4 x_t$ is stationary. By contrast, $z_{1,t}$ contains a stochastic trend, as seasonal unit roots have been filtered out. In $z_{2,t}$ the stochastic trend and the roots $\pm i$ are eliminated, whereas in $z_{3,t}$ the roots ± 1 are removed. Hylleberg et al. (1990) suggest the following procedure. Estimate equation (3) by OLS and test the following hypotheses:

i) existence of the root 1 : $\pi_1 = 0$

ii) existence of the root -1 : $\pi_2 = 0$

iii) existence of the roots $\pm i$: $\pi_3 = \pi_4 = 0$

The alternative hypothesis is stationarity of the process. It is accepted, if the conditions $\pi_1 < 0$, $\pi_2 < 0$ as well as π_3 and π_4 not both equal to zero are satisfied. The alternative may be augmented by allowing for the possibility of a deterministic component like an intercept (I), linear trend (T), and for seasonal dummies (S) in the test regression. The test statistics of i) and ii) are corresponding to t-values and for iii) an F-test has to be conducted. Hylleberg et al. (1990) compute the appropriate critical values for these tests by Monte Carlo simulations.

2.2 Panel seasonal integration test

Assuming that there are N cross-sectional units for which the test equation (3) is applied. The Im Pesaran Shin (IPS) panel unit root test is based on the null of non-stationarity ($\pi_{1i} = 0 \forall i$) against the alternative of no unit root ($\pi_{1i} < 0 \forall i$). The IPS test does not assume that all cross-sectional units converge towards the equilibrium value at the same speed under the alternative. Instead, the speed may be different. Following Im, Pesaran and Shin (2002) it is assumed that the ϵ_{it}, $i = 1, \cdots, N$, $t = 1, \cdots, T$ in (3) are independently and identically distributed random variables for all i and t with zero means and finite heterogeneous variances σ_i^2. For the zero frequency the IPS test is based on the standardized t-bar statistic as follows:

$$\Gamma_{1t} = \frac{\sqrt{N}(\bar{t}_{1NT} - N^{-1}\sum_1^N E\{t_{1iT}(p_i)|\pi_{1i} = 0\})}{\sqrt{N^{-1}\sum_1^N Var\{t_{1iT}(p_i)|\pi_{1i} = 0\}}} \sim N(0,1), \tag{4}$$

where $\bar{t}_{1NT}$ is the average of the N cross-section ADF(p_i) t-statistics, $E\{t_{1iT}(p_i)|\pi_{1i} = 0\}$ and $Var\{t_{1iT}(p_i)|\pi_{1i} = 0\}$ are the mean and variance respectively of the average ADF(p_i) statistics under the null for the zero frequency. The values are tabulated by Im et al. (2002, Tables 3) for different T and lag orders p_i. They show that under the null of a unit root Γ_{1t} is distributed as $N(0,1)$.

For the bi-annual frequency the same procedure is adopted. The test statistic is:

$$\Gamma_{2t} = \frac{\sqrt{N}(\bar{t}_{2NT} - N^{-1}\sum_1^N E\{t_{2iT}(p_i)|\pi_{2i} = 0\})}{\sqrt{N^{-1}\sum_1^N Var\{t_{2iT}(p_i)|\pi_{2i} = 0\}}} \sim N(0,1), \tag{5}$$

where $\bar{t}_{2NT}$ is the average of the N cross-section ADF(p_i) t-statistics, $E\{t_{2iT}(p_i)|\pi_{2i} = 0\}$ and $Var\{t_{2iT}(p_i)|\pi_{2i} = 0\}$ are the mean and variance respectively of the average ADF(p_i) statistics under the null for the bi-annual frequency. Since HEGY show that the test statistic for the zero and the bi-annual frequency have the same asymptotic distribution the identical values of the mean and variance are used.

For the annual frequency the null of $\pi_{i3} = \pi_{i4} = 0 \forall i$ is tested by a F-test, which is used in the panel approach.

$$\Gamma_{3t} = \frac{\sqrt{N}(\bar{F}_{NT} - N^{-1}\sum_1^N E\{F_{iT}(p_i)|\pi_{3i} = \pi_{4i} = 0\})}{\sqrt{N^{-1}\sum_1^N Var\{F_{iT}(p_i)|\pi_{3i} = \pi_{4i} = 0\}}} \sim N(0,1), \tag{6}$$

where $\bar{F}_{NT}$ is the average of the N cross-section ADF(p_i) F-statistics, $E\{F_{iT}(p_i)|\pi_{3i} = \pi_{4i} = 0\}$ and $Var\{F_{iT}(p_i)|\pi_{3i} = \pi_{4i} = 0\}$ are the mean and variance respectively of the average F(p_i) statistics under the null for the annual frequency.

3 Simulation

3.1 Simulation experiments

In this section we use Monte Carlo experiments to examine finite sample properties of the panel-based seasonal unit root tests. The experiment adopts that of Im et al. (2002). The first set focuses on the benchmark model

$$y_{it} = (1 - \phi_i)\mu_i + \phi_i y_{i,t-4} + \epsilon_{it},\ t = 1, \cdots, T;\ i = 1, \cdots, N, \tag{7}$$

where $\epsilon_{it} \sim N(0, \sigma_i^2)$. The second set of experiments allows for the presence of positive (heterogeneous) AR(1) serial correlations in ϵ_{it},

$$\epsilon_{it} = \rho_i \epsilon_{i,t-1} + e_{it}, \; t = 1, \cdots, T; \; i = 1, \cdots, N, \tag{8}$$

where $e_{it} \sim N(0, \sigma_i^2)$, $\rho_i \sim U[0.2, 0.4]$, U denotes a uniform distribution and ρ_i's are generated independently of e_{it}. The next sets of experiments allow for seasonal dummies, a linear trend and seasonal dummies as well as a linear trend in estimation of the HEGY regressions using the same data generating process employed in the first two sets of experiments.

In all of the experiments e_{it} (or ϵ_{it} are generated as *iid* normal variates with zero means and heterogeneous variances, σ_i^2. The parameters μ_i and σ_i^2 are generated according to

$$\mu_i \sim N(0, 1), \; \sigma_i^2 \sim U[0.5, 1.5], \; i = 1, \cdots, N, \tag{9}$$

Under the null $\phi_i = 1$ for all i (denoted as set 1), while $\phi_i = 0.8$ for all i under the alternative hypothesis (denoted as set 2, the case with AR-errors is denoted set 3). All of the parameter values such as μ_i, σ_i^2 or ρ_i are generated independently of ϵ_{it} once and the fixed throughout replications. The first set of experiments are carried out for $N = 5, 10, 20, 40, 100$ and $T = 20, 32, 40, 60, 100$. The other experiments (sets 2 and 3) are conducted for $N = 5, 10, 20, 40, 100$, $T = 20, 32, 40, 60, 100$ and $p = 0, 1, 2, 3, 4, 5$. We used 2000 replications to compute empirical size and power of the tests at the 5% nominal level.

3.2 Simulation results

The simulated critical values at the 5 percent significance level are given in the tables 1 to 5. Table 1 shows that the critical values for Γ_1, Γ_2 and Γ_3 decrease with an increasing sample size T independent of the deterministic specification. The critical values of Γ_1 are different from Γ_2 if the regression equation includes an intercept or an intercept and a linear trend. They are more or less the same if an intercept and seasonal dummies are included. Accounting for a linear trend decreases the critical values for Γ_1. The specification of seasonal dummies does not influence the values of Γ_1. It affects the values of Γ_2. Moreover, if the panel dimension is increased (see Tables 2 to 5) it does not change these observations. If the critical values of a higher panel dimension are compared with the critical values for $N = 5$, where the deterministic specification is identical, it is apparent that the critical values are higher (lower) for Γ_1 and Γ_2 (Γ_3).

In Tables 6 to 10 the means and standard deviations of the corresponding distributions are presented. For example in Table 6 the panel dimension is $N = 5$. In the first cell the sample size is $T = 20$, such that the mean is -1.3498 and the standard deviation is in parentheses (.3912). These results correspond to the distribution of Γ_1, where the critical value of -1.9898 is given in Table 1 first cell. The values in Tables 6 to 10 are used to test for seasonal unit roots.

The next step is to analyze the nominal values of the tests if the data generating processes have different covariances. The covariances are drawn from a uniform distribution in the range of 0.5 to 1.5. The nominal value of the tests is the 5 percent level, hence, the critical value is -1.64486. In this experiment the number of cases is counted, where the test value is lower than the critical value. The Tables 11 to 15 gives these frequencies, where the number should be close to the 5 percent. Table 11 presents the results for the panel dimension $N = 5$. The first block of Table 11 exhibits the specification, which corresponds to the regression that is used to generate the critical values. The next block includes the result if the test regression contains one lag of the endogenous variable. In other words these equations are overfitted. The limits of the values to be in line with the nominal value can be determined by $\sqrt{p(1-p)/2000}$, where p indicates the nominal significance level. The two error bounds are 4 and 6 for $p = 5$. At first, if the test regression includes an intercept, the test statistic Γ_1 is well sized. Γ_2 is to some extent undersized whereas Γ_3 is oversized for the different sample sizes. The small overfitting (lag = 1 or 2) does not destroy this evidence. Turning to the trend specification the evidence for the Γ_1 or Γ_2 test statistic do not change. However, the Γ_3 test statistic is undersized for sample sizes of from $T = 20$ to $T = 60$ and a lag length of one or two.

If the panel dimension is increased (see Table 12 to 15) the results for Γ_1, Γ_2 and Γ_3 become better if the test regression only includes an intercept and no lags. If a lag of unity is specified the test statistics Γ_1 and Γ_2 are undersized for $N = 100$ and $T = 100$. The same is found if seasonal dummies and a linear trend are specified. In general if the test regression is well specified the tests work good. A misspecification of test regression destroy the nominal size of the tests.

The power results are given in Tables 16 to 25. For $N = 5$ the null hypothesis of no unit root at the null frequency is rarely rejected for small sample sizes (first row in Table 16) if the test regression only includes an intercept. The two other tests have a higher power in such situation. It is nearly 100 percent for $T = 100$ (see also Figure 1 upper left panel). A lag specification reduces the power. If the test regression additionally contains a linear trend results of the Γ_1 and Γ_2 test do not change substantially. The Γ_3 test looses power. Specifying seasonally dummies reduces the power of Γ_1 and Γ_2 (see Figure 1 middle right panel).

It is worth noting that the power of the tests grows if the panel dimension increases for the cases of no linear trend and no seasonal dummies. The power of the tests is high if the correct specification is selected (see Figure 1 upper row and middle left panel). However, in cases of a linear trend and seasonal dummies and lags the power of the tests is low as long as the dimension is small ($T \leq 40$) (see Table 20). This evidence is also found if the autoregressive errors are considered (see Table 21 to 25, Figure 1 lower row). An underfitting of the test equation (lag = 0) substantially reduces the power of the Γ_1 test. In such cases the test has no power even if the panel dimension is $N = 100$ and the time dimension less than 60. For Γ_2 and Γ_3 better results are presented (see Table 21 for example).

4 Application

According to the insider-outsider theory of the labour market, hysteresis may arise as a consequence of the division between insiders, who are employed, and outsiders, who are unemployed (Blanchard and Summers 1986). If union's expectations depend on past employment autoregressive components are included. Provided that former employment fully affects the expectations, the employment series contain a random walk. Under the assumption that labour supply is stationary umemployment will include a random walk. Leon-Ledesma (2000) tests this hypothesis for the unemployment rate of 51 US states and 12 EU countries for the period 1985-1999 with quarterly data. He uses the IPS-tests and finds mixed results for the US states and EU countries. For the EU countries the null hypothesis of nonstationary unemployment series is not rejected. For the US states he presents evidence of nonstationarity if he do not control for correlation in the series. For the adjusted series the null hypothesis is rejected. Moreover, Smyth (2003) presents evidence in favour of hysteresis for Australia performing panel unit root tests based on data of Australian regions.

In this paper the nonstationarity hypothesis is tested for zero frequency and for the seasonal frequencies for the unemployment rate in member countries of the European Union which are at least 9 nine years member of the EU except of Greece. Additionally, Japan and the United States are considered. We use original data, which is not seasonally adjusted. The data are from the OECD data base of the period 1983.1 to 2003.4.

The HEGY approach is adopted to test for individual seasonal unit roots and unit roots at the zero frequency. To control for autocorrelation in the equations at most a lag of 5 is considered. Following the general-to-specific approach significant lags are selected. The specification of the test equations are given in Table 26. It is apparent that in some countries the null hypothesis of no unit root is rejected. In most countries the sample includes seasonal unit roots. Turning to the panel the evidence of seasonal unit roots vanish. Overall, we find no evidence of seasonal unit roots. It is worth noting that the evidence is same if seasonal dummies are specified in the test regression, However, we present strong evidence of a unit roots at the zero frequency. This result is in favour of the hypothesis that hysteresis exist in industrial countries.

5 Conclusion

In this paper the seasonal unit root of Hylleberg et al. (1990) is generalized for to cover a heterogenous panel. The procedure is along the lines of Im, Pesaran and Shin (2002). Test statistics are proposed and critical values are obtained by simulations. The properties of the tests are analyzed for different deterministic and dynamic specifications. Evidence is presented that for a small time dimension the power is slow even for increasing cross section dimension. Therefore, it seems necessary to have a higher time dimension than cross section dimension. This result is in line with Phillips and Moon (1999) who require that the ratio N/T converges to zero for N and T go to infinity. Moreover, a misspecification of the test regression, either due to an inappropriate lag order or deterministic component, reduces the power of the test.

At the end of paper the new test is applied to analyze unemployment behaviour in industrialized countries. In some countries seasonal unit roots are detected. However, the null hypotheses of panel seasonal unit roots are rejected. The null hypothesis of a unit root at the zero frequency is not rejected, thereby supporting the presence of hysteresis effects.

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Table 1: Simulated critical values for the panel dimension of $N = 5$.

Specification	Statistic	Number of observations $T = 20$	$T = 32$	$T = 40$	$T = 60$	$T = 100$
c	Γ_1	-1.9898	-2.0467	-2.0694	-2.0900	-2.1156
	Γ_2	-1.0087	-1.0537	-1.0660	-1.0883	-1.1065
	Γ_3	1.9424	1.8586	1.8712	1.8627	1.8894
c,t	Γ_1	-2.5519	-2.6189	-2.6429	-2.6707	-2.7038
	Γ_2	-1.0014	-1.0554	-1.0714	-1.0938	-1.1112
	Γ_3	2.6822	2.2032	2.1342	2.0220	1.9798
c,S	Γ_1	-1.9436	-2.0140	-2.0415	-2.0654	-2.0996
	Γ_2	-1.9523	-2.0203	-2.0444	-2.0708	-2.0934
	Γ_3	7.5251	5.9055	5.5410	5.1279	4.8635
c,S,t	Γ_1	-2.5103	-2.5843	-2.6197	-2.6491	-2.6886
	Γ_2	-1.9509	-2.0221	-2.0462	-2.0740	-2.0938
	Γ_3	8.1211	6.0798	5.6642	5.1864	4.8948

c: Test regression includes an intercept; t: Test regression includes a linear trend; S: Test regression includes three seasonal dummies.

Table 2: Simulated critical values for the panel dimension of $N = 10$.

Specification	Statistic	Number of observations $T = 20$	$T = 32$	$T = 40$	$T = 60$	$T = 100$
c	Γ_1	-1.8031	-1.8669	-1.8879	-1.9185	-1.9353
	Γ_2	-0.8044	-0.8499	-0.8644	-0.8875	-0.9043
	Γ_3	1.6417	1.5998	1.5967	1.5995	1.6151
c,t	Γ_1	-2.3696	-2.4456	-2.4722	-2.5077	-2.5353
	Γ_2	-0.8069	-0.8559	-0.8704	-0.8947	-0.9089
	Γ_3	2.2703	1.8961	1.8246	1.7387	1.6982
c,S	Γ_1	-1.7633	-1.8376	-1.8644	-1.8992	-1.9218
	Γ_2	-1.7611	-1.8411	-1.8611	-1.8964	-1.9229
	Γ_3	6.5892	5.2184	4.9210	4.5743	4.3513
c,S,t	Γ_1	-2.3198	-2.4106	-2.4473	-2.4898	-2.5212
	Γ_2	-1.7662	-1.8441	-1.8656	-1.9017	-1.9247
	Γ_3	7.1012	5.2789	5.0266	4.6323	4.3817

c: Test regression includes an intercept; t: Test regression includes a linear trend; S: Test regression includes three seasonal dummies.

Table 3: Simulated critical values for the panel dimension of $N = 20$.

Specification	Statistic	Number of observations				
		$T = 20$	$T = 32$	$T = 40$	$T = 60$	$T = 100$
c	Γ_1	-1.6707	-1.7401	-1.7609	-1.7921	-1.8122
	Γ_2	-0.6585	-0.7038	-0.7183	-0.7432	-0.7543
	Γ_3	1.4411	1.4114	1.4154	1.4241	1.4363
c,t	Γ_1	-2.2398	-2.3250	-2.3534	-2.3898	-2.4197
	Γ_2	-0.6652	-0.7138	-0.7279	-0.7509	-0.7613
	Γ_3	1.9924	1.6758	1.6160	1.5479	1.5056
c,S	Γ_1	-1.6335	-1.7108	-1.7400	-1.7754	-1.8000
	Γ_2	-1.6306	-1.7125	-1.7376	-1.7731	-1.7996
	Γ_3	5.9098	4.7420	4.4945	4.1991	4.0076
c,S,t	Γ_1	-2.1877	-2.2933	-2.3267	-2.3714	-2.4064
	Γ_2	-1.6338	-1.7171	-1.7413	-1.7775	-1.8017
	Γ_3	6.3594	4.8973	4.5892	4.2483	4.0334

c: Test regression includes an intercept; t: Test regression includes a linear trend; S: Test regression includes three seasonal dummies.

Table 4: Simulated critical values for the panel dimension of $N = 40$.

Specification	Statistic	Number of observations				
		$T = 20$	$T = 32$	$T = 40$	$T = 60$	$T = 100$
c	Γ_1	-1.5758	-1.6480	-1.6691	-1.6996	-1.7191
	Γ_2	-0.5577	-0.6036	-0.6153	-0.6387	-0.6561
	Γ_3	1.3035	1.2866	1.2923	1.3012	1.3139
c,t	Γ_1	-2.1461	-2.2378	-2.2687	-2.3087	-2.3386
	Γ_2	-0.5684	-0.6147	-0.6268	-0.6479	-0.6626
	Γ_3	1.7973	1.5243	1.4720	1.4121	1.3776
c,S	Γ_1	-1.5372	-1.6216	-1.6487	-1.6846	-1.7088
	Γ_2	-1.5403	-1.6245	-1.6479	-1.6848	-1.7110
	Γ_3	5.4549	4.4168	4.2042	3.9360	3.7552
c,S,t	Γ_1	-2.0912	-2.2084	-2.2429	-2.2907	-2.3253
	Γ_2	-1.5422	-1.6298	-1.6549	-1.6896	-1.7136
	Γ_3	5.8545	4.5578	4.2898	3.9836	3.7803

c: Test regression includes an intercept; t: Test regression includes a linear trend; S: Test regression includes three seasonal dummies.

Table 5: Simulated critical values for the panel dimension of $N = 100$.

Specifi- cation	Statistic	Number of observations $T = 20$	$T = 32$	$T = 40$	$T = 60$	$T = 100$
c	Γ_1	-1.4931	-1.5653	-1.5884	-1.6191	-1.6416
	Γ_2	-0.4663	-0.5113	-0.5263	-0.5480	-0.5651
	Γ_3	1.1854	1.1787	1.1838	1.1940	1.2079
c,t	Γ_1	-2.0652	-2.1624	-2.1945	-2.2360	-2.2661
	Γ_2	-0.4813	-0.5254	-0.5391	-0.5583	-0.5728
	Γ_3	1.6363	1.3982	1.3489	1.2976	1.2665
c,S	Γ_1	-1.4571	-1.5441	-1.5704	-1.6051	-1.6323
	Γ_2	-1.4584	-1.5437	-1.5703	-1.6067	-1.6327
	Γ_3	5.0491	4.1425	3.9399	3.7037	3.5472
c,S,t	Γ_1	-2.0072	-2.1321	-2.1698	-2.2178	-2.2531
	Γ_2	-1.4605	-1.5512	-1.5771	-1.6118	-1.6356
	Γ_3	5.4121	4.2670	4.0234	3.7487	3.5715

c: Test regression includes an intercept; t: Test regression includes a linear trend; S: Test regression includes three seasonal dummies.

Table 6: Mean and standard deviations for the panel test statistics of panel dimension $N = 5$.

Specifi- cation	Stati- stic	Number of observations $T = 20$	$T = 32$	$T = 40$	$T = 60$	$T = 100$
c	Γ_1	-1.3498 (.3912)	-1.4262 (.3813)	-1.4524 (.3802)	-1.4793 (.3780)	-1.5032 (.3762)
	Γ_2	-0.3091 (.4312)	-0.3531 (.4329)	-0.3685 (.4311)	-0.3894 (.4333)	-0.4022 (.4337)
	Γ_3	0.9953 (.5042)	0.9950 (.4672)	1.0092 (.4646)	1.0170 (.4557)	1.0328 (.4607)
c,t	Γ_1	-1.9253 (.3750)	-2.0309 (.3545)	-2.0662 (.3498)	-2.1092 (.3433)	-2.1420 (.3411)
	Γ_2	-0.3299 (.4140)	-0.3705 (.4223)	-0.3839 (.4232)	-0.4014 (.4281)	-0.4107 (.4309)
	Γ_3	1.3698 (.7008)	1.1791 (.5545)	1.1490 (.5299)	1.1037 (.4945)	1.0826 (.4829)
c,S	Γ_1	-1.3167 (.3819)	-1.4071 (.3698)	-1.4374 (.3704)	-1.4681 (.3706)	-1.4954 (.3711)
	Γ_2	-1.3181 (.3821)	-1.4079 (.3745)	-1.4349 (.3710)	-1.4678 (.3724)	-1.4942 (.3695)
	Γ_3	4.3976 (1.700)	3.6813 (1.227)	3.5195 (1.123)	3.3238 (1.018)	3.1885 (.9537)
c,S,t	Γ_1	-1.8678 (.3815)	-2.0018 (.3515)	-2.0435 (.3464)	-2.0928 (.3390)	-2.1303 (.3380)
	Γ_2	-1.3219 (.3767)	-1.4161 (.3701)	-1.4426 (.3673)	-1.4740 (.3695)	-1.4984 (.3677)
	Γ_3	4.6967 (1.870)	3.7909 (1.270)	3.5950 (1.148)	3.3662 (1.028)	3.2102 (.9572)

c: Test regression includes an intercept; t: Test regression includes a linear trend; S: Test regression includes three seasonal dummies.

Table 7: Mean and standard deviations for the panel test statistics of panel dimension $N = 10$.

Specification	Statistic	Number of observations				
		$T = 20$	$T = 32$	$T = 40$	$T = 60$	$T = 100$
c	Γ_1	-1.3503 (.2764)	-1.4265 (.2699)	-1.4512 (.2696)	-1.4807 (.2680)	-1.5032 (.2652)
	Γ_2	-0.3091 (.3043)	-0.3535 (.3051)	-0.3675 (.3049)	-0.3896 (.3073)	-0.4023 (.3073)
	Γ_3	0.9925 (.3549)	.9972 (.3308)	1.0074 (.3277)	1.0172 (.3234)	1.0322 (.3254)
c,t	Γ_1	-1.9262 (.2654)	-2.0313 (.2505)	-2.0669 (.2464)	-2.1093 (.2428)	-2.1405 (.2413)
	Γ_2	-0.3302 (.2923)	-0.3709 (.2976)	-0.3828 (.2992)	-0.4017 (.3036)	-0.4108 (.3054)
	Γ_3	1.3668 (.4930)	1.1816 (.3925)	1.1470 (.3736)	1.1044 (.3515)	1.0825 (.3414)
c,S	Γ_1	-1.3173 (.2703)	-1.4076 (.2618)	-1.4361 (.2628)	-1.4695 (.2628)	-1.4954 (.2615)
	Γ_2	-1.3163 (.2705)	-1.4082 (.2646)	-1.4338 (.2617)	-1.4684 (.2636)	-1.4949 (.2624)
	Γ_3	4.4009 (1.212)	3.6819 (.8688)	3.5164 (.7952)	3.3211 (.7195)	3.1862 (.6711)
c,S,t	Γ_1	-1.8684 (.2694)	-2.0019 (.2480)	-2.0441 (.2442)	-2.0930 (.2403)	-2.1289 (.2391)
	Γ_2	-1.3206 (.2672)	-1.4164 (.2612)	-1.4416 (.2590)	-1.4747 (.2616)	-1.4989 (.2611)
	Γ_3	4.6981 (1.329)	3.7901 (.8978)	3.5925 (.8136)	3.3641 (.7268)	3.2084 (.6738)

c: Test regression includes an intercept; t: Test regression includes a linear trend; S: Test regression includes three seasonal dummies.

Table 8: Mean and standard deviations for the panel test statistics of panel dimension $N = 20$.

Specification	Statistic	Number of observations				
		$T = 20$	$T = 32$	$T = 40$	$T = 60$	$T = 100$
c	Γ_1	-1.3507 (.1948)	-1.4262 (.1912)	-1.4492 (.1911)	-1.4816 (.1894)	-1.5026 (.1883)
	Γ_2	-0.3079 (.2152)	-0.3528 (.2155)	-0.3676 (.2149)	-0.3887 (.2174)	-0.4038 (.2168)
	Γ_3	0.9910 (.2515)	0.9974 (.2344)	1.0050 (.2324)	1.0167 (.2295)	1.0326 (.2303)
c,t	Γ_1	-1.9263 (.1881)	-2.0318 (.1775)	-2.0664 (.1747)	-2.1087 (.1720)	-2.1406 (.1699)
	Γ_2	-0.3290 (.2067)	-0.3702 (.2103)	-0.3831 (.2109)	-0.4008 (.2149)	-0.4122 (.2154)
	Γ_3	1.3644 (.3496)	1.1820 (.2786)	1.1442 (.2650)	1.1039 (.2494)	1.0830 (.2416)
c,S	Γ_1	-1.3175 (.1908)	-1.4075 (.1854)	-1.4339 (.1861)	-1.4703 (.1856)	-1.4947 (.1857)
	Γ_2	-1.3162 (.1918)	-1.4072 (.1865)	-1.4336 (.1854)	-1.4685 (.1864)	-1.4953 (.1863)
	Γ_3	4.4002 (.8517)	3.6827 (.6157)	3.5163 (.5642)	3.3224 (.5078)	3.1866 (.4738)
c,S,t	Γ_1	-1.8676 (.1912)	-2.0027 (.1758)	-2.0430 (.1726)	-2.0921 (.1702)	-2.1291 (.1683)
	Γ_2	-1.3204 (.1895)	-1.4155 (.1844)	-1.4413 (.1835)	-1.4747 (.1851)	-1.4993 (.1854)
	Γ_3	4.6946 (.9355)	3.7912 (.6355)	3.5918 (.5766)	3.3651 (.5126)	3.2090 (.4758)

c: Test regression includes an intercept; t: Test regression includes a linear trend; S: Test regression includes three seasonal dummies.

Table 9: Mean and standard deviations for the panel test statistics of panel dimension $N = 40$.

Specification	Statistic	Number of observations				
		$T = 20$	$T = 32$	$T = 40$	$T = 60$	$T = 100$
c	Γ_1	-1.3496 (.1377)	-1.4256 (.1352)	-1.4488 (.1345)	-1.4812 (.1336)	-1.5026 (.1329)
	Γ_2	-0.3081 (.1524)	-0.3530 (.1525)	-0.3679 (.1521)	-0.3889 (.1536)	-0.4046 (.1545)
	Γ_3	0.9915 (.1770)	0.9971 (.1658)	1.0047 (.1650)	1.0174 (.1631)	1.0336 (.1630)
c,t	Γ_1	-1.9253 (.1330)	-2.0318 (.1254)	-2.0651 (.1225)	-2.1089 (.1220)	-2.1411 (.1201)
	Γ_2	-0.3294 (.1463)	-0.3705 (.1488)	-0.3835 (.1494)	-0.4010 (.1518)	-0.4130 (.1535)
	Γ_3	1.3646 (.2463)	1.1819 (.1970)	1.1439 (.1882)	1.1046 (.1772)	1.0840 (.1710)
c,S	Γ_1	-1.3166 (.1348)	-1.4069 (.1310)	-1.4335 (.1310)	-1.4698 (.1311)	-1.4947 (.1311)
	Γ_2	-1.3168 (.1358)	-1.4075 (.1312)	-1.4343 (.1311)	-1.4694 (.1314)	-1.4965 (.1316)
	Γ_3	4.4015 (.6005)	3.6832 (.4329)	3.5147 (.4011)	3.3223 (.3595)	3.1893 (.3349)
c,S,t	Γ_1	-1.8668 (.1347)	-2.0024 (.1242)	-2.0418 (.1212)	-2.0923 (.1207)	-2.1296 (.1191)
	Γ_2	-1.3211 (.1341)	-1.4158 (.1298)	-1.4420 (.1299)	-1.4756 (.1304)	-1.5006 (.1310)
	Γ_3	4.6961 (.6593)	3.7909 (.4475)	3.5898 (.4093)	3.3650 (.3627)	3.2117 (.3363)

c: Test regression includes an intercept; t: Test regression includes a linear trend; S: Test regression includes three seasonal dummies.

Table 10: Mean and standard deviations for the panel test statistics of panel dimension $N = 100$.

Specification	Statistic	Number of observations				
		$T = 20$	$T = 32$	$T = 40$	$T = 60$	$T = 100$
c	Γ_1	-1.3503 (.0872)	-1.4261 (.0856)	-1.4493 (.0848)	-1.4810 (.0845)	-1.5039 (.0840)
	Γ_2	-0.3091 (.0960)	-0.3536 (.0964)	-0.3683 (.0965)	-0.3886 (.0971)	-0.4045 (.0978)
	Γ_3	0.9924 (.1127)	0.9976 (.1052)	1.0052 (.1045)	1.0185 (.1032)	1.0342 (.1029)
c,t	Γ_1	-1.9258 (.0844)	-2.0318 (.0794)	-2.0656 (.0782)	-2.1090 (.0772)	-2.1409 (.0760)
	Γ_2	-0.3303 (.0922)	-0.3713 (.0941)	-0.3839 (.0947)	-0.4007 (.0959)	-0.4130 (.0972)
	Γ_3	1.3654 (.1571)	1.1825 (.1250)	1.1447 (.1191)	1.1058 (.1123)	1.0847 (.1080)
c,S	Γ_1	-1.3169 (.0853)	-1.4075 (.0832)	-1.4340 (.0826)	-1.4696 (.0829)	-1.4960 (.0829)
	Γ_2	-1.3167 (.0858)	-1.4073 (.0832)	-1.4342 (.0831)	-1.4693 (.0830)	-1.4960 (.0836)
	Γ_3	4.4014 (.3805)	3.6845 (.2733)	3.5135 (.2525)	3.3207 (.2279)	3.1914 (.2130)
c,S,t	Γ_1	-1.8663 (.0850)	-2.0025 (.0787)	-2.0423 (.0772)	-2.0923 (.0764)	-2.1295 (.0754)
	Γ_2	-1.3210 (.0846)	-1.4156 (.0823)	-1.4420 (.0823)	-1.4755 (.0824)	-1.5001 (.0832)
	Γ_3	4.6934 (.4187)	3.7925 (.2829)	3.5889 (.2574)	3.3633 (.2300)	3.2140 (.2138)

c: Test regression includes an intercept; t: Test regression includes a linear trend; S: Test regression includes three seasonal dummies.

Table 11: Rejection frequency under the assumption of a nominal significance level of 5 percent for the panel dimension $N = 5$.

Specifi-			Number of observations				
cation	Lag	Statistic	$T = 20$	$T = 32$	$T = 40$	$T = 60$	$T = 100$
c	0	Γ_1	5.20	5.30	4.90	4.75	4.65
		Γ_2	3.50	4.85	4.25	4.50	4.45
		Γ_3	7.35	5.15	6.60	6.00	7.35
c	1	Γ_1	4.95	4.75	4.55	4.75	4.60
		Γ_2	3.55	3.75	4.10	4.45	4.50
		Γ_3	7.05	5.20	6.90	5.70	7.35
c	2	Γ_1	5.30	5.30	4.75	5.35	4.65
		Γ_2	4.40	5.30	4.75	4.85	4.80
		Γ_3	6.75	5.70	6.60	5.90	7.70
c,t	0	Γ_1	5.30	5.10	5.15	4.60	4.40
		Γ_2	4.05	4.75	4.20	4.85	4.65
		Γ_3	7.40	5.80	6.55	5.90	7.80
c,t	1	Γ_1	4.20	4.50	4.80	4.45	4.50
		Γ_2	2.90	3.30	3.50	3.95	4.15
		Γ_3	1.50	2.35	3.65	3.30	6.05
c,t	2	Γ_1	6.15	5.25	5.25	4.70	4.65
		Γ_2	4.65	5.05	5.15	5.15	4.80
		Γ_3	2.20	3.55	4.25	4.25	6.65
c,S	0	Γ_1	5.55	5.20	4.90	4.50	4.75
		Γ_2	5.25	4.80	5.20	4.70	4.35
		Γ_3	6.00	6.30	6.60	6.80	6.65
c,S	1	Γ_1	3.20	3.60	3.80	3.90	4.40
		Γ_2	3.05	3.10	3.35	3.95	3.75
		Γ_3	6.50	1.35	1.70	2.75	4.25
c,S	2	Γ_1	2.90	4.05	3.60	4.55	4.55
		Γ_2	3.15	3.45	3.35	4.45	3.75
		Γ_3	0.95	1.30	1.25	2.30	3.75
c,S,t	0	Γ_1	5.30	5.00	5.55	4.45	4.50
		Γ_2	5.00	4.50	4.95	4.75	4.25
		Γ_3	6.65	6.40	5.85	7.10	6.70
c,S,t	1	Γ_1	3.00	2.85	3.25	3.45	3.75
		Γ_2	1.55	1.65	2.00	3.50	3.10
		Γ_3	1.35	1.35	1.60	2.60	4.00
c,S,t	2	Γ_1	3.20	3.40	3.00	3.60	3.55
		Γ_2	2.85	3.30	2.90	4.35	3.75
		Γ_3	1.00	0.95	1.05	1.85	3.40

c: Test regression includes an intercept; t: Test regression includes a linear trend; S: Test regression includes three seasonal dummies.

Table 12: Rejection frequency in percent under the assumption of a nominal significance level of 5 percent for the panel dimension $N = 10$.

Specification	Lag	Statistic	Number of observations $T = 20$	$T = 32$	$T = 40$	$T = 60$	$T = 100$
c	0	Γ_1	4.70	4.95	4.50	5.20	4.70
		Γ_2	4.45	4.55	4.50	4.30	4.75
		Γ_3	6.30	5.85	5.95	5.85	7.30
c	1	Γ_1	4.75	5.20	4.20	5.10	5.05
		Γ_2	3.85	3.35	3.90	3.65	4.15
		Γ_3	6.60	6.05	5.90	5.60	6.85
c	2	Γ_1	4.30	5.00	4.25	4.95	4.80
		Γ_2	4.85	4.70	4.65	4.50	4.55
		Γ_3	7.05	5.60	6.75	6.10	7.60
c,t	0	Γ_1	4.95	5.45	4.70	5.30	5.00
		Γ_2	4.25	4.55	4.60	4.40	4.85
		Γ_3	6.80	6.00	6.15	5.90	7.40
c,t	1	Γ_1	4.15	4.90	4.10	5.00	4.70
		Γ_2	2.80	2.75	2.80	2.75	3.60
		Γ_3	0.70	1.45	2.05	3.00	5.15
c,t	2	Γ_1	4.95	5.10	4.20	5.50	5.15
		Γ_2	5.10	4.80	4.65	4.50	4.70
		Γ_3	1.35	2.55	2.85	3.75	5.85
c,S	0	Γ_1	4.70	5.20	4.40	4.70	5.10
		Γ_2	5.10	5.55	4.95	4.05	4.70
		Γ_3	6.45	6.10	5.70	5.80	6.30
c,S	1	Γ_1	2.10	2.90	3.00	3.90	4.55
		Γ_2	2.30	2.80	3.05	2.85	3.95
		Γ_3	0.30	0.80	0.80	2.10	2.65
c,S	2	Γ_1	1.80	3.05	2.75	3.85	4.25
		Γ_2	2.10	3.05	2.80	2.80	4.35
		Γ_3	0.40	0.60	0.70	1.65	2.00
c,S,t	0	Γ_1	5.45	5.40	4.80	5.15	5.25
		Γ_2	5.10	5.70	5.25	3.95	4.45
		Γ_3	6.95	6.10	5.95	5.40	5.80
c,S,t	1	Γ_1	2.05	2.60	2.60	3.75	3.55
		Γ_2	0.85	1.45	1.85	1.90	3.15
		Γ_3	0.60	0.50	0.85	2.05	2.85
c,S,t	2	Γ_1	2.05	2.50	2.25	3.30	4.15
		Γ_2	2.25	2.60	2.90	2.65	4.20
		Γ_3	0.55	0.55	0.50	1.25	1.75

c: Test regression includes an intercept; t: Test regression includes a linear trend; S: Test regression includes three seasonal dummies.

Table 13: Rejection frequency in percent under the assumption of a nominal significance level of 5 percent for the panel dimension $N = 20$.

Specification	Lag	Statistic	Number of observations $T = 20$	$T = 32$	$T = 40$	$T = 60$	$T = 100$
c	0	Γ_1	5.05	5.35	5.10	4.70	6.05
		Γ_2	4.40	4.70	4.80	4.95	4.95
		Γ_3	5.95	5.65	6.45	5.60	6.95
c	1	Γ_1	4.70	4.90	4.80	4.65	5.40
		Γ_2	3.20	3.40	3.85	4.10	4.20
		Γ_3	5.85	5.70	6.25	5.75	6.45
c	2	Γ_1	5.45	4.90	5.40	4.35	5.80
		Γ_2	5.30	5.60	5.30	5.00	5.20
		Γ_3	6.70	6.50	6.45	6.10	7.00
c,t	0	Γ_1	4.80	5.50	4.35	4.55	5.30
		Γ_2	4.45	4.80	4.80	4.90	4.90
		Γ_3	6.45	5.80	6.35	5.90	7.00
c,t	1	Γ_1	3.60	4.30	4.00	4.85	4.75
		Γ_2	2.05	2.45	2.65	2.80	3.70
		Γ_3	0.05	0.85	1.10	1.90	4.35
c,t	2	Γ_1	3.95	4.80	4.85	5.70	5.35
		Γ_2	5.25	5.70	5.25	4.95	4.95
		Γ_3	0.70	1.35	1.55	2.50	4.70
c,S	0	Γ_1	5.65	5.40	5.55	4.95	5.95
		Γ_2	5.85	5.05	4.50	5.15	4.50
		Γ_3	6.55	6.00	6.50	6.05	5.70
c,S	1	Γ_1	1.50	2.50	3.25	3.80	4.55
		Γ_2	2.00	1.70	2.30	3.20	3.70
		Γ_3	0.15	0.10	0.25	1.15	2.35
c,S	2	Γ_1	1.55	2.75	3.10	3.40	4.75
		Γ_2	1.35	1.60	2.30	3.10	3.70
		Γ_3	0.05	0.25	0.30	0.75	1.70
c,S,t	0	Γ_1	5.10	5.30	4.75	5.05	5.15
		Γ_2	5.30	4.80	4.55	5.00	4.30
		Γ_3	6.60	5.55	6.35	5.60	5.50
c,S,t	1	Γ_1	0.70	1.60	1.95	2.55	3.70
		Γ_2	0.40	0.65	1.30	1.90	2.65
		Γ_3	0.25	0.20	0.45	1.10	2.40
c,S,t	2	Γ_1	0.90	1.75	2.15	3.00	3.45
		Γ_2	1.25	1.40	2.30	2.70	3.60
		Γ_3	0.00	0.20	0.05	0.55	1.35

c: Test regression includes an intercept; t: Test regression includes a linear trend; S: Test regression includes three seasonal dummies.

Table 14: Rejection frequency in percent under the assumption of a nominal significance level of 5 percent for the panel dimension $N = 40$.

Specification	Lag	Statistic	Number of observations $T = 20$	$T = 32$	$T = 40$	$T = 60$	$T = 100$
c	0	Γ_1	4.60	5.20	4.85	4.65	6.15
		Γ_2	4.00	4.45	4.80	4.75	5.00
		Γ_3	5.90	5.80	5.90	5.90	6.15
c	1	Γ_1	4.90	4.30	4.20	4.15	5.60
		Γ_2	2.40	3.50	3.15	3.95	3.80
		Γ_3	5.90	6.15	6.05	5.40	5.95
c	2	Γ_1	4.30	4.25	4.90	4.60	6.15
		Γ_2	4.85	5.40	4.60	4.95	4.70
		Γ_3	7.45	7.05	5.70	5.90	6.30
c,t	0	Γ_1	5.40	4.75	4.95	4.60	4.85
		Γ_2	4.05	4.75	4.90	4.80	5.00
		Γ_3	5.45	5.45	6.05	5.95	6.15
c,t	1	Γ_1	4.35	3.55	4.30	3.50	4.30
		Γ_2	1.30	2.00	1.85	2.70	3.05
		Γ_3	0.00	0.40	0.55	1.30	3.35
c,t	2	Γ_1	3.65	4.05	4.90	4.30	4.30
		Γ_2	5.50	5.50	5.25	5.10	4.75
		Γ_3	0.25	0.80	0.70	1.85	3.50
c,S	0	Γ_1	5.15	5.20	4.85	4.95	5.90
		Γ_2	5.00	4.40	4.20	4.65	5.45
		Γ_3	6.00	5.90	6.30	6.15	5.40
c,S	1	Γ_1	0.55	1.80	2.10	2.65	4.60
		Γ_2	0.95	1.45	1.70	2.85	4.35
		Γ_3	0.00	0.00	0.10	0.65	1.15
c,S	2	Γ_1	0.60	1.50	2.15	2.95	4.10
		Γ_2	0.80	1.10	1.70	2.65	4.10
		Γ_3	0.00	0.00	0.00	0.35	0.55
c,S,t	0	Γ_1	5.15	5.10	5.20	4.10	5.00
		Γ_2	4.90	4.55	4.40	4.75	5.30
		Γ_3	5.55	4.85	6.00	6.35	5.20
c,S,t	1	Γ_1	0.30	0.60	1.50	2.15	2.75
		Γ_2	0.30	0.35	0.30	1.30	2.90
		Γ_3	0.00	0.00	0.05	0.80	1.00
c,S,t	2	Γ_1	0.20	0.65	1.15	2.20	2.80
		Γ_2	0.55	0.90	1.40	2.40	4.00
		Γ_3	0.05	0.00	0.00	0.15	0.50

c: Test regression includes an intercept; t: Test regression includes a linear trend; S: Test regression includes three seasonal dummies.

Table 15: Rejection frequency in percent under the assumption of a nominal significance level of 5 percent for the panel dimension $N = 100$.

Specification	Lag	Statistic	Number of observations $T = 20$	$T = 32$	$T = 40$	$T = 60$	$T = 100$
c	0	Γ_1	4.95	5.10	5.90	4.65	4.90
		Γ_2	4.90	4.55	5.40	5.65	4.80
		Γ_3	6.20	5.95	5.20	5.80	5.75
c	1	Γ_1	4.75	3.95	5.05	3.75	3.95
		Γ_2	1.85	2.55	3.10	3.50	3.30
		Γ_3	6.60	5.60	5.00	5.50	5.35
c	2	Γ_1	3.80	3.40	4.65	3.80	3.75
		Γ_2	7.15	5.45	6.50	6.05	5.45
		Γ_3	8.20	6.80	5.85	5.90	5.80
c,t	0	Γ_1	4.85	4.30	4.90	4.55	4.95
		Γ_2	4.90	4.80	5.20	5.25	4.75
		Γ_3	6.00	5.85	5.20	5.90	5.65
c,t	1	Γ_1	2.95	3.25	3.30	3.65	4.15
		Γ_2	0.50	0.90	0.75	2.00	2.35
		Γ_3	0.00	0.05	0.10	6.50	1.45
c,t	2	Γ_1	2.90	3.20	4.45	4.50	4.75
		Γ_2	7.80	6.00	6.70	6.00	5.35
		Γ_3	0.00	0.20	0.15	1.00	2.35
c,S	0	Γ_1	5.70	4.95	5.95	4.90	4.85
		Γ_2	5.40	4.55	5.40	5.00	3.95
		Γ_3	3.95	5.20	5.00	5.00	5.15
c,S	1	Γ_1	0.15	0.70	1.70	1.80	2.60
		Γ_2	0.40	0.70	1.50	1.55	2.05
		Γ_3	0.00	0.00	0.00	0.05	0.05
c,S	2	Γ_1	0.20	0.35	1.15	1.65	2.45
		Γ_2	0.20	0.40	1.10	1.60	1.90
		Γ_3	0.00	0.00	0.00	0.00	0.25
c,S,t	0	Γ_1	5.25	4.30	4.85	4.55	4.70
		Γ_2	5.05	4.55	5.65	5.20	3.90
		Γ_3	4.40	5.15	5.45	5.30	5.20
c,S,t	1	Γ_1	0.00	0.30	0.50	1.40	2.20
		Γ_2	0.00	0.00	0.15	0.50	0.90
		Γ_3	0.00	0.00	0.00	0.05	0.50
c,S,t	2	Γ_1	0.00	0.30	0.60	1.15	1.80
		Γ_2	0.10	0.45	1.05	1.35	2.00
		Γ_3	0.00	0.00	0.00	0.00	0.20

c: Test regression includes an intercept; t: Test regression includes a linear trend; S: Test regression includes three seasonal dummies.

Table 16: Power simulation Rejection frequency in percent under the assumption of a nominal significance level of 5 percent for the panel dimension $N = 5$.

Specifi- cation	Lag	Statistic	Number of observations $T = 20$	$T = 32$	$T = 40$	$T = 60$	$T = 100$
c	0	Γ_1	8.85	11.35	13.75	22.60	54.65
		Γ_2	36.90	57.40	70.35	90.60	99.75
		Γ_3	22.40	44.25	60.70	89.50	99.90
c	1	Γ_1	7.75	10.15	11.25	20.65	49.65
		Γ_2	28.45	46.90	60.15	85.80	99.35
		Γ_3	19.35	38.80	55.35	87.35	99.90
c	2	Γ_1	8.30	10.30	10.75	20.60	48.55
		Γ_2	32.45	50.45	62.85	86.30	99.25
		Γ_3	17.25	33.25	47.05	78.55	99.35
c,t	0	Γ_1	7.50	8.15	8.80	9.60	23.05
		Γ_2	37.70	57.20	69.75	90.55	99.75
		Γ_3	22.90	47.00	62.10	90.50	99.90
c,t	1	Γ_1	5.45	6.30	6.95	8.90	20.50
		Γ_2	23.65	41.60	56.45	86.25	99.25
		Γ_3	5.70	24.70	41.35	70.50	99.90
c,t	2	Γ_1	6.60	6.90	6.90	7.20	20.95
		Γ_2	32.80	50.25	63.35	78.75	99.15
		Γ_3	5.30	18.65	31.25	66.45	99.00
c,S	0	Γ_1	9.45	12.40	15.60	24.00	56.60
		Γ_2	9.70	12.35	15.95	24.95	55.00
		Γ_3	10.55	16.85	22.90	38.60	77.65
c,S	1	Γ_1	5.20	7.65	9.20	18.95	48.35
		Γ_2	4.20	7.35	9.50	17.70	45.80
		Γ_3	2.00	4.10	8.55	22.05	65.60
c,S	2	Γ_1	3.95	7.05	8.00	16.75	45.40
		Γ_2	3.45	6.50	8.40	16.80	42.00
		Γ_3	1.15	1.80	4.55	12.75	49.20
c,S,t	0	Γ_1	7.65	9.20	9.45	10.30	24.90
		Γ_2	9.45	12.30	15.50	24.85	54.80
		Γ_3	35.85	17.05	22.45	39.80	78.10
c,S,t	1	Γ_1	3.25	4.15	5.35	7.20	18.80
		Γ_2	2.45	4.90	7.05	15.20	42.80
		Γ_3	9.65	4.45	8.60	22.80	66.00
c,S,t	2	Γ_1	3.30	3.20	4.20	6.10	17.80
		Γ_2	3.20	6.05	8.70	16.65	41.25
		Γ_3	5.85	1.65	3.65	11.55	46.95

c: Test regression includes an intercept; t: Test regression includes a linear trend; S: Test regression includes three seasonal dummies.

Table 17: Power simulation Rejection frequency in percent under the assumption of a nominal significance level of 5 percent for the panel dimension $N = 10$.

Specifi- cation	Lag	Statistic	Number of observations $T = 20$	$T = 32$	$T = 40$	$T = 60$	$T = 100$
c	0	Γ_1	12.65	18.15	23.75	44.15	85.30
		Γ_2	67.55	88.69	96.40	99.80	100.00
		Γ_3	34.35	68.15	85.20	99.30	100.00
c	1	Γ_1	9.15	14.95	19.20	38.30	81.35
		Γ_2	54.15	80.65	91.25	99.30	100.00
		Γ_3	26.80	62.20	80.65	98.80	100.00
c	2	Γ_1	8.95	14.75	19.20	36.20	79.35
		Γ_2	58.50	83.10	92.25	99.20	100.00
		Γ_3	22.85	52.55	69.65	97.40	100.00
c,t	0	Γ_1	8.70	9.40	10.25	16.00	41.10
		Γ_2	67.65	88.75	96.15	99.80	100.00
		Γ_3	34.10	70.60	86.70	99.50	100.00
c,t	1	Γ_1	5.15	7.35	8.05	11.95	35.05
		Γ_2	45.30	74.80	87.75	99.30	100.00
		Γ_3	6.05	39.90	65.50	97.85	100.00
c,t	2	Γ_1	5.75	6.80	7.55	11.90	33.35
		Γ_2	57.65	82.50	92.30	99.25	100.00
		Γ_3	4.95	27.60	51.10	92.45	100.00
c,S	0	Γ_1	12.70	19.50	26.25	46.75	87.05
		Γ_2	12.40	19.45	26.35	45.80	85.85
		Γ_3	13.40	25.55	34.95	61.80	95.70
c,S	1	Γ_1	4.40	10.25	14.35	34.55	79.85
		Γ_2	4.20	9.45	14.40	33.30	76.55
		Γ_3	0.75	4.20	10.55	35.95	90.70
c,S	2	Γ_1	3.40	8.70	13.35	28.45	75.35
		Γ_2	3.05	6.35	12.75	28.80	71.90
		Γ_3	0.35	1.15	3.85	19.10	76.45
c,S,t	0	Γ_1	8.55	11.20	11.65	17.20	43.70
		Γ_2	12.70	19.65	25.65	45.00	85.85
		Γ_3	13.25	25.80	34.90	62.90	96.00
c,S,t	1	Γ_1	2.40	3.90	4.65	9.85	32.75
		Γ_2	1.50	5.05	9.60	26.55	72.65
		Γ_3	1.40	4.45	10.55	36.15	91.40
c,S,t	2	Γ_1	2.45	3.15	3.65	7.80	27.70
		Γ_2	2.90	6.25	11.35	28.25	72.00
		Γ_3	0.60	1.25	2.70	16.35	73.60

c: Test regression includes an intercept; t: Test regression includes a linear trend; S: Test regression includes three seasonal dummies.

Table 18: Power simulation Rejection frequency in percent under the assumption of a nominal significance level of 5 percent for the panel dimension $N = 20$.

Specification			Number of observations				
cation	Lag	Statistic	$T = 20$	$T = 32$	$T = 40$	$T = 60$	$T = 100$
c	0	Γ_1	18.35	29.75	39.80	70.90	98.90
		Γ_2	93.70	99.70	99.95	100.00	100.00
		Γ_3	50.45	91.30	98.40	100.00	100.00
c	1	Γ_1	13.70	23.20	34.50	63.50	97.65
		Γ_2	83.55	98.60	99.80	100.00	100.00
		Γ_3	41.75	86.00	97.15	100.00	100.00
c	2	Γ_1	12.95	22.50	31.60	60.80	97.05
		Γ_2	87.55	99.00	99.80	100.00	100.00
		Γ_3	35.35	76.25	92.25	100.00	100.00
c,t	0	Γ_1	11.65	12.55	14.65	24.55	65.05
		Γ_2	94.05	99.75	99.95	100.00	100.00
		Γ_3	50.40	92.65	99.75	100.00	100.00
c,t	1	Γ_1	6.05	8.95	10.00	18.05	57.10
		Γ_2	73.70	97.35	99.55	100.00	100.00
		Γ_3	6.70	61.70	89.50	100.00	100.00
c,t	2	Γ_1	5.60	9.40	9.20	17.15	53.35
		Γ_2	87.10	99.00	99.70	100.00	100.00
		Γ_3	5.50	43.45	75.85	99.75	100.00
c,S	0	Γ_1	19.65	33.65	43.90	74.55	99.15
		Γ_2	20.15	33.65	45.75	74.15	99.00
		Γ_3	20.75	40.75	54.30	86.15	100.00
c,S	1	Γ_1	4.90	14.85	24.75	57.80	97.60
		Γ_2	4.40	12.95	24.60	56.40	97.90
		Γ_3	0.60	3.95	13.65	57.80	99.40
c,S	2	Γ_1	3.40	11.00	19.10	49.85	95.35
		Γ_2	3.10	10.15	19.40	47.95	95.95
		Γ_3	0.05	0.35	2.85	28.25	96.80
c,S,t	0	Γ_1	11.00	15.10	17.30	27.70	67.65
		Γ_2	19.05	32.70	45.05	74.25	99.05
		Γ_3	19.35	41.05	54.70	87.10	100.00
c,S,t	1	Γ_1	1.55	3.55	5.10	12.85	53.10
		Γ_2	0.85	5.95	14.80	46.75	96.75
		Γ_3	0.85	4.40	14.25	58.65	99.50
c,S,t	2	Γ_1	1.05	3.50	3.70	9.45	44.20
		Γ_2	2.80	8.50	18.35	47.00	95.60
		Γ_3	0.25	0.35	2.15	22.60	96.05

c: Test regression includes an intercept; t: Test regression includes a linear trend; S: Test regression includes three seasonal dummies.

Table 19: Power simulation Rejection frequency in percent under the assumption of a nominal significance level of 5 percent for the panel dimension $N = 40$.

Specifi- cation	Lag	Statistic	$T = 20$	$T = 32$	$T = 40$	$T = 60$	$T = 100$
c	0	Γ_1	29.90	53.30	68.80	95.00	100.00
		Γ_2	99.85	100.00	100.00	100.00	100.00
		Γ_3	76.25	99.60	100.00	100.00	100.00
c	1	Γ_1	19.25	40.95	55.90	90.25	100.00
		Γ_2	98.80	100.00	100.00	100.00	100.00
		Γ_3	63.95	98.60	100.00	100.00	100.00
c	2	Γ_1	17.75	36.90	52.90	87.90	100.00
		Γ_2	99.10	100.00	100.00	100.00	100.00
		Γ_3	53.40	96.30	99.75	100.00	91.15
c,t	0	Γ_1	14.10	17.80	21.85	41.20	100.00
		Γ_2	99.80	100.00	100.00	100.00	100.00
		Γ_3	77.05	99.60	100.00	100.00	83.60
c,t	1	Γ_1	6.45	9.50	12.50	27.95	100.00
		Γ_2	95.90	100.00	100.00	100.00	100.00
		Γ_3	7.10	88.65	99.35	100.00	80.20
c,t	2	Γ_1	5.15	9.50	12.30	26.45	100.00
		Γ_2	99.15	100.00	100.00	100.00	100.00
		Γ_3	5.00	68.00	95.70	100.00	100.00
c,S	0	Γ_1	29.40	57.15	73.35	96.20	100.00
		Γ_2	32.30	56.80	74.60	95.75	100.00
		Γ_3	29.80	64.10	81.55	98.95	99.95
c,S	1	Γ_1	5.65	23.00	42.00	86.15	100.00
		Γ_2	4.95	22.95	41.90	85.85	100.00
		Γ_3	0.30	3.95	19.10	83.90	99.95
c,S	2	Γ_1	2.80	15.40	32.55	78.75	99.95
		Γ_2	2.60	15.15	31.65	77.40	99.95
		Γ_3	0.00	0.15	2.65	48.10	92.85
c,S,t	0	Γ_1	13.90	21.00	24.95	46.30	100.00
		Γ_2	30.35	56.00	73.35	95.60	100.00
		Γ_3	26.70	63.25	81.50	99.05	79.90
c,S,t	1	Γ_1	0.85	2.30	5.20	19.55	99.95
		Γ_2	0.80	7.40	23.90	75.55	99.95
		Γ_3	0.55	3.85	20.75	84.15	100.00
c,S,t	2	Γ_1	0.35	1.00	3.00	12.45	70.65
		Γ_2	2.20	12.40	29.00	75.80	99.95
		Γ_3	0.20	0.10	1.30	38.05	99.95

c: Test regression includes an intercept; t: Test regression includes a linear trend; S: Test regression includes three seasonal dummies.

Table 20: Power simulation Rejection frequency in percent under the assumption of a nominal significance level of 5 percent for the panel dimension $N = 100$.

Specification	Lag	Statistic	Number of observations $T = 20$	$T = 32$	$T = 40$	$T = 60$	$T = 100$
c	0	Γ_1	56.70	87.95	96.85	100.00	100.00
		Γ_2	100.00	100.00	100.00	100.00	100.00
		Γ_3	97.65	100.00	100.00	100.00	100.00
c	1	Γ_1	35.95	73.30	90.90	100.00	100.00
		Γ_2	100.00	100.00	100.00	100.00	100.00
		Γ_3	92.20	100.00	100.00	100.00	100.00
c	2	Γ_1	30.95	68.95	87.90	99.85	100.00
		Γ_2	100.00	100.00	100.00	100.00	100.00
		Γ_3	83.55	100.00	100.00	100.00	100.00
c,t	0	Γ_1	22.70	32.15	41.55	76.20	99.90
		Γ_2	100.00	100.00	100.00	100.00	100.00
		Γ_3	98.00	100.00	100.00	100.00	100.00
c,t	1	Γ_1	6.45	13.45	21.75	56.05	99.45
		Γ_2	100.00	100.00	100.00	100.00	100.00
		Γ_3	8.70	99.70	100.00	100.00	100.00
c,t	2	Γ_1	5.05	10.95	20.00	52.20	99.35
		Γ_2	100.00	100.00	100.00	100.00	100.00
		Γ_3	4.25	94.50	100.00	100.00	100.00
c,S	0	Γ_1	59.35	91.05	98.10	100.00	100.00
		Γ_2	62.30	90.85	98.05	100.00	100.00
		Γ_3	55.95	93.35	99.50	100.00	100.00
c,S	1	Γ_1	6.00	44.85	77.10	99.95	100.00
		Γ_2	5.50	47.45	79.35	99.85	100.00
		Γ_3	0.00	4.90	37.75	99.80	100.00
c,S	2	Γ_1	2.10	27.50	62.60	99.10	100.00
		Γ_2	2.10	28.85	63.65	99.10	100.00
		Γ_3	0.00	0.05	2.10	82.95	100.00
c,S,t	0	Γ_1	22.60	37.40	48.25	81.35	100.00
		Γ_2	59.45	90.35	97.60	100.00	100.00
		Γ_3	52.20	92.60	99.45	100.00	100.00
c,S,t	1	Γ_1	0.10	1.95	5.45	37.90	98.90
		Γ_2	0.45	14.25	49.95	98.95	100.00
		Γ_3	0.10	5.30	40.95	99.80	100.00
c,S,t	2	Γ_1	0.10	0.40	2.70	24.40	96.50
		Γ_2	1.10	22.75	58.10	98.95	100.00
		Γ_3	0.00	0.05	0.70	71.00	100.00

c: Test regression includes an intercept; t: Test regression includes a linear trend; S: Test regression includes three seasonal dummies.

Table 21: Power simulation approach 2 Rejection frequency in percent under the assumption of a nominal significance level of 5 percent for the panel dimension $N = 5$.

Specification	Lag	Statistic	$T = 20$	$T = 32$	$T = 40$	$T = 60$	$T = 100$
c	0	Γ_1	2.65	1.85	2.15	2.40	6.20
		Γ_2	61.75	84.90	93.55	99.60	100.00
		Γ_3	33.70	66.60	82.25	97.65	100.00
c	1	Γ_1	9.65	11.35	11.20	19.05	48.60
		Γ_2	29.10	46.90	60.90	86.20	99.45
		Γ_3	18.65	38.80	53.80	86.65	99.90
c	2	Γ_1	9.60	10.50	11.60	20.05	46.20
		Γ_2	33.25	50.05	63.35	86.40	99.50
		Γ_3	16.55	31.45	44.80	80.45	99.50
c,t	0	Γ_1	1.30	0.55	0.45	0.30	0.60
		Γ_2	58.70	82.90	92.65	99.25	100.00
		Γ_3	33.30	66.85	81.85	97.80	100.00
c,t	1	Γ_1	7.85	7.70	7.10	9.20	20.55
		Γ_2	24.20	41.70	56.85	84.05	99.45
		Γ_3	5.65	23.50	39.00	80.85	99.85
c,t	2	Γ_1	7.40	7.50	7.55	9.00	19.85
		Γ_2	33.45	49.45	62.90	86.55	99.50
		Γ_3	4.90	17.15	30.25	70.10	99.25
c,S	0	Γ_1	4.45	3.10	2.75	3.15	7.95
		Γ_2	22.60	39.30	53.75	77.25	96.55
		Γ_3	19.80	40.40	51.80	78.25	97.90
c,S	1	Γ_1	4.80	7.35	8.15	16.25	45.15
		Γ_2	5.00	7.25	10.90	19.15	48.80
		Γ_3	1.40	4.20	8.40	21.25	64.40
c,S	2	Γ_1	4.80	6.80	8.25	14.95	41.45
		Γ_2	4.20	5.85	9.40	17.95	44.80
		Γ_3	0.85	1.70	4.40	13.40	51.45
c,S,t	0	Γ_1	3.05	1.10	1.00	0.45	1.10
		Γ_2	19.70	36.65	50.85	75.20	96.35
		Γ_3	18.55	37.50	50.35	76.95	97.95
c,S,t	1	Γ_1	3.10	3.30	4.30	6.75	17.15
		Γ_2	2.35	4.50	7.90	16.60	44.35
		Γ_3	1.90	4.45	7.95	20.60	63.60
c,S,t	2	Γ_1	3.30	3.75	3.70	6.15	15.85
		Γ_2	3.95	5.45	8.60	17.80	44.25
		Γ_3	1.45	1.25	3.45	10.95	47.90

c: Test regression includes an intercept; t: Test regression includes a linear trend; S: Test regression includes three seasonal dummies.

Table 22: Power simulation Rejection frequency in percent under the assumption of a nominal significance level of 5 percent for the panel dimension $N = 10$.

Specifi- cation	Lag	Statistic	Number of observations $T = 20$	$T = 32$	$T = 40$	$T = 60$	$T = 100$
c	0	Γ_1	2.25	1.50	1.25	1.95	8.85
		Γ_2	91.05	99.50	99.95	100.00	100.00
		Γ_3	53.15	91.30	97.15	99.95	100.00
c	1	Γ_1	12.15	17.05	20.05	36.00	79.25
		Γ_2	53.55	81.60	93.05	99.20	100.00
		Γ_3	26.25	61.60	79.80	98.75	100.00
c	2	Γ_1	11.65	16.70	19.70	32.90	75.95
		Γ_2	58.30	83.10	93.05	99.30	100.00
		Γ_3	21.90	51.30	69.50	96.20	100.00
c,t	0	Γ_1	0.60	0.10	0.15	0.00	0.15
		Γ_2	89.25	99.30	99.95	100.00	100.00
		Γ_3	50.80	90.75	97.25	99.95	100.00
c,t	1	Γ_1	8.55	8.10	7.75	13.40	32.85
		Γ_2	44.95	75.15	89.30	98.90	100.00
		Γ_3	5.90	37.75	63.40	96.70	100.00
c,t	2	Γ_1	7.10	8.55	8.40	12.25	31.95
		Γ_2	57.90	83.00	92.85	99.20	100.00
		Γ_3	4.55	24.90	48.75	92.55	100.00
c,S	0	Γ_1	4.30	2.80	2.35	3.65	12.40
		Γ_2	36.80	65.90	81.45	96.25	100.00
		Γ_3	29.55	61.40	76.00	96.60	100.00
c,S	1	Γ_1	4.40	9.55	12.10	28.75	75.05
		Γ_2	6.05	10.80	16.30	34.05	80.35
		Γ_3	0.90	3.50	10.25	35.40	90.80
c,S	2	Γ_1	3.50	9.20	11.25	25.05	71.35
		Γ_2	4.35	9.05	13.95	30.30	76.40
		Γ_3	0.65	1.10	3.90	18.75	78.90
c,S,t	0	Γ_1	2.35	0.55	0.45	0.10	0.20
		Γ_2	30.85	60.90	78.45	95.05	100.00
		Γ_3	27.10	58.10	74.30	95.95	100.00
c,S,t	1	Γ_1	1.95	3.10	3.75	8.50	28.05
		Γ_2	2.25	6.05	10.90	27.85	76.15
		Γ_3	1.30	3.50	9.75	33.60	90.50
c,S,t	2	Γ_1	1.90	2.50	3.20	7.40	24.50
		Γ_2	3.90	7.70	13.10	28.75	76.35
		Γ_3	0.55	0.55	2.65	14.40	75.35

c: Test regression includes an intercept; t: Test regression includes a linear trend; S: Test regression includes three seasonal dummies.

Table 23: Power simulation Rejection frequency in percent under the assumption of a nominal significance level of 5 percent for the panel dimension $N = 20$.

Specifi- cation	Lag	Statistic	Number of observations $T = 20$	$T = 32$	$T = 40$	$T = 60$	$T = 100$
c	0	Γ_1	1.95	1.05	1.35	3.05	20.00
		Γ_2	99.85	100.00	100.00	100.00	100.00
		Γ_3	73.25	99.10	99.95	100.00	100.00
c	1	Γ_1	17.10	25.30	33.55	61.05	97.85
		Γ_2	86.25	99.05	99.90	100.00	100.00
		Γ_3	38.45	86.45	97.00	100.00	100.00
c	2	Γ_1	15.00	23.40	32.10	58.20	96.95
		Γ_2	89.15	99.00	99.95	100.00	100.00
		Γ_3	32.25	76.00	92.80	99.90	100.00
c,t	0	Γ_1	0.15	0.05	0.00	0.00	0.35
		Γ_2	99.30	100.00	100.00	100.00	100.00
		Γ_3	71.25	99.15	99.95	100.00	100.00
c,t	1	Γ_1	8.50	9.60	11.60	18.90	55.35
		Γ_2	76.70	97.60	99.85	100.00	100.00
		Γ_3	5.75	59.20	89.00	99.90	100.00
c,t	2	Γ_1	7.15	9.65	10.35	18.55	52.25
		Γ_2	88.55	99.00	99.90	100.00	100.00
		Γ_3	4.00	40.70	73.60	99.65	100.00
c,S	0	Γ_1	4.85	2.90	3.15	5.95	28.95
		Γ_2	56.95	88.20	96.85	100.00	100.00
		Γ_3	40.00	80.40	93.95	99.80	100.00
c,S	1	Γ_1	5.00	12.05	21.30	50.15	96.70
		Γ_2	5.90	15.95	26.15	61.45	97.55
		Γ_3	0.40	4.25	13.55	56.60	99.65
c,S	2	Γ_1	3.80	10.15	18.15	43.85	95.15
		Γ_2	3.50	11.85	21.45	54.75	96.55
		Γ_3	0.10	0.65	3.85	30.25	97.20
c,S,t	0	Γ_1	1.85	0.40	0.05	0.05	0.40
		Γ_2	48.85	85.05	95.85	100.00	100.00
		Γ_3	38.15	77.60	92.45	99.80	100.00
c,S,t	1	Γ_1	1.40	2.75	3.80	10.75	46.85
		Γ_2	1.25	7.95	16.40	51.30	96.70
		Γ_3	0.60	3.90	12.90	54.80	99.70
c,S,t	2	Γ_1	1.05	1.80	2.80	8.90	40.45
		Γ_2	2.50	10.80	19.70	53.45	96.55
		Γ_3	0.30	0.40	2.10	23.20	95.80

c: Test regression includes an intercept; t: Test regression includes a linear trend; S: Test regression includes three seasonal dummies.

Table 24: Power simulation Rejection frequency in percent under the assumption of a nominal significance level of 5 percent for the panel dimension $N = 40$.

Specification	Lag	Statistic	Number of observations				
			$T = 20$	$T = 32$	$T = 40$	$T = 60$	$T = 100$
c	0	Γ_1	1.10	0.40	0.90	2.35	33.95
		Γ_2	100.00	100.00	100.00	100.00	100.00
		Γ_3	94.40	100.00	100.00	100.00	100.00
c	1	Γ_1	23.75	39.15	57.05	88.75	99.95
		Γ_2	98.70	100.00	100.00	100.00	100.00
		Γ_3	61.30	98.70	100.00	100.00	100.00
c	2	Γ_1	20.10	35.95	53.10	86.45	99.95
		Γ_2	99.15	100.00	100.00	100.00	100.00
		Γ_3	51.95	95.70	99.70	100.00	100.00
c,t	0	Γ_1	0.00	0.00	0.00	0.00	0.00
		Γ_2	100.00	100.00	100.00	100.00	100.00
		Γ_3	93.95	100.00	100.00	100.00	100.00
c,t	1	Γ_1	9.45	11.65	15.50	28.25	82.20
		Γ_2	96.50	100.00	100.00	100.00	100.00
		Γ_3	7.25	84.55	99.15	100.00	100.00
c,t	2	Γ_1	8.30	10.65	13.80	27.80	79.00
		Γ_2	99.05	100.00	100.00	100.00	100.00
		Γ_3	4.95	65.25	94.35	100.00	100.00
c,S	0	Γ_1	4.15	2.30	3.35	6.45	47.75
		Γ_2	83.10	99.15	99.95	100.00	100.00
		Γ_3	67.00	97.95	99.85	100.00	100.00
c,S	1	Γ_1	4.25	16.45	34.80	79.25	99.95
		Γ_2	6.15	27.05	46.40	89.25	100.00
		Γ_3	0.05	4.10	16.60	82.65	99.95
c,S	2	Γ_1	3.10	13.85	28.80	74.55	99.95
		Γ_2	3.30	20.30	37.65	84.20	100.00
		Γ_3	0.05	0.30	2.15	50.30	99.95
c,S,t	0	Γ_1	0.35	0.05	0.05	0.00	0.05
		Γ_2	74.70	98.25	99.95	100.00	100.00
		Γ_3	61.70	97.05	99.85	100.00	100.00
c,S,t	1	Γ_1	0.65	1.95	4.05	15.45	73.25
		Γ_2	0.75	12.45	28.60	80.35	100.00
		Γ_3	0.35	3.25	15.45	81.50	99.95
c,S,t	2	Γ_1	0.40	1.40	3.05	12.35	66.45
		Γ_2	2.25	16.95	34.20	82.55	100.00
		Γ_3	0.05	0.10	0.90	38.50	99.90

c: Test regression includes an intercept; t: Test regression includes a linear trend; S: Test regression includes three seasonal dummies.

Table 25: Power simulation Rejection frequency in percent under the assumption of a nominal significance level of 5 percent for the panel dimension $N = 100$.

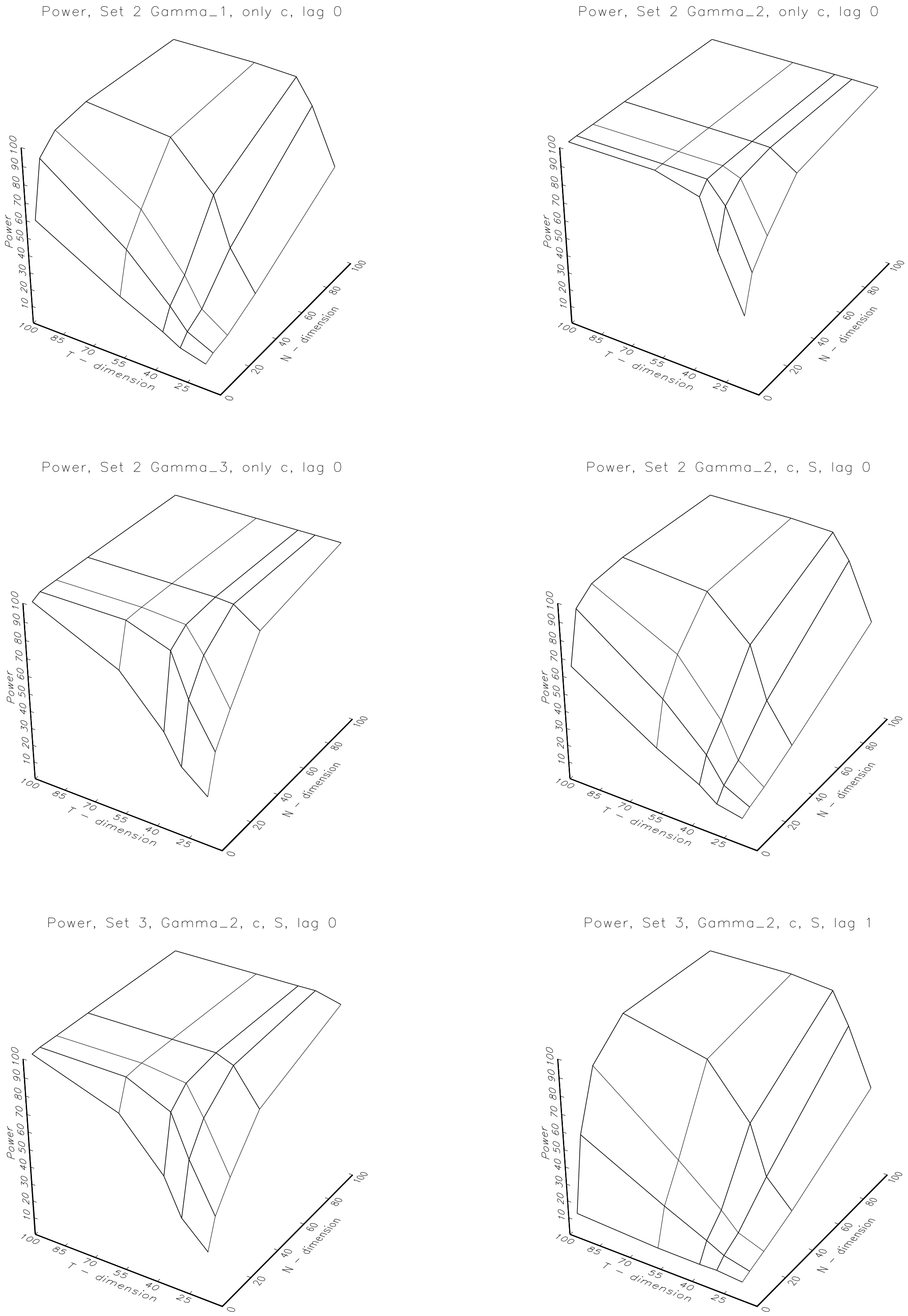
Specification	Lag	Statistic	Number of observations $T = 20$	$T = 32$	$T = 40$	$T = 60$	$T = 100$
c	0	Γ_1	0.10	0.10	0.10	2.10	71.75
		Γ_2	100.00	100.00	100.00	100.00	100.00
		Γ_3	100.00	100.00	100.00	100.00	100.00
c	1	Γ_1	41.40	74.15	90.95	99.85	100.00
		Γ_2	100.00	100.00	100.00	100.00	100.00
		Γ_3	92.30	100.00	100.00	100.00	100.00
c	2	Γ_1	33.70	67.20	87.60	99.90	100.00
		Γ_2	100.00	100.00	100.00	100.00	100.00
		Γ_3	82.95	100.00	100.00	100.00	100.00
c,t	0	Γ_1	0.00	0.00	0.00	0.00	0.00
		Γ_2	100.00	100.00	100.00	100.00	100.00
		Γ_3	99.95	100.00	100.00	100.00	100.00
c,t	1	Γ_1	11.30	16.80	24.50	57.35	99.30
		Γ_2	100.00	100.00	100.00	100.00	100.00
		Γ_3	8.40	99.70	100.00	100.00	100.00
c,t	2	Γ_1	7.65	15.20	22.40	52.20	98.85
		Γ_2	100.00	100.00	100.00	100.00	100.00
		Γ_3	4.00	93.90	100.00	100.00	100.00
c,S	0	Γ_1	3.25	1.00	2.45	11.70	88.00
		Γ_2	99.45	100.00	100.00	100.00	100.00
		Γ_3	94.50	100.00	100.00	100.00	100.00
c,S	1	Γ_1	3.05	29.80	67.15	99.15	100.00
		Γ_2	8.70	51.45	83.70	99.95	100.00
		Γ_3	0.00	3.35	35.35	99.75	100.00
c,S	2	Γ_1	2.20	21.20	56.80	98.10	100.00
		Γ_2	3.35	38.35	73.45	99.70	100.00
		Γ_3	0.00	0.05	2.65	87.00	100.00
c,S,t	0	Γ_1	0.10	0.00	0.00	0.00	0.00
		Γ_2	98.55	100.00	100.00	100.00	100.00
		Γ_3	91.40	100.00	100.00	100.00	100.00
c,S,t	1	Γ_1	0.00	1.35	2.65	27.00	97.70
		Γ_2	0.20	18.70	59.15	99.30	100.00
		Γ_3	0.00	3.15	32.10	99.60	100.00
c,S,t	2	Γ_1	0.00	0.50	1.60	18.90	95.45
		Γ_2	0.15	30.20	67.60	99.60	100.00
		Γ_3	0.00	0.00	0.40	72.20	100.00

c: Test regression includes an intercept; t: Test regression includes a linear trend; S: Test regression includes three seasonal dummies.

Table 26: Results of the individual HEGY-tests and panel seasonal unit root tests.

Country	Specification	Γ_1^i	Γ_2^i	Γ_3^i	DW
Austria	c, D_1, D_2, 1, 2, 4	0.326	-2.949*	0.750	1.418
Belgium	c, 1, 2, 4	-2.796	-0.279	1.587	2.122
Denmark	c, 1, 2, 4	-2.637	0.624	1.072	2.011
Finland	c, 1, 3	-1.959	-0.850	0.136	2.154
France	c, 1, 2	-1.703	-0.941	0.941	2.043
Germany	c, 1, 2	-1.846	-0.239	0.551	2.046
Ireland	c, 1, 2	-0.221	-0.622	7.946*	1.794
Italy	c, 1	-2.141	-3.685*	2.598	1.854
Japan	c, 1, 4	0.517	-2.042*	0.733	1.933
Luxembourg	c, 1, 3, 4	-1.717	-5.137*	1.623	2.207
Netherlands	c, 1, 3,4	-1.048	-1.323	3.565*	1.666
Portugal	c, 1	-3.775*	-2.948*	3.918*	1.939
Spain	c, 1, 3	-1.562	-3.321*	3.008	1.859
Sweden	c, 1, 2	-1.660	-0.833	2.397	1.999
United Kingdom	c, 1,2	-1.045	-0.219	3.671*	1.866
United States	c, 1,2	-1.713	-0.528	1.622	1.963
Averages		-1.561	-1.581	2.257	
Panel test	c	-0.296	-3.893*	3.633*	

Specification describes the choice of the deterministic terms and the lag numbers for the year-on-year-changes; c: Test regression includes an intercept; D_1 Dummy-variable with unity at and zeros elsewhere, D_2 Dummy-variable with unity at and zeros elsewhere. Critical values for the individual tests of HEGY. * significant at the 5 percent level.



Power, Set 2 Gamma_1, only c, lag 0

Power, Set 2 Gamma_2, only c, lag 0

Power, Set 2 Gamma_3, only c, lag 0

Power, Set 2 Gamma_2, c, S, lag 0

Power, Set 3, Gamma_2, c, S, lag 0

Power, Set 3, Gamma_2, c, S, lag 1

Figure 1: Power of set 2 and set 3 approaches for different cases.