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Growth Cycles in XX[th] Century European Industrial Productivity: Unbiased Variance Estimation in a Time-varying Parameter Model

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Abstract

This note applies the median unbiased estimation of coefficient variance, proposed by Stock and Watson (1998), to the extraction of the time-varying trend growth rate of industrial productivity in fifteen European countries, over most of the XX[th] Century, by means of an unobservable components univariate decomposition. In addition to the description of the procedure, this illustration is particularly useful in explaining why the method is especially appropriate for comparison of trends growth rates extracted from time series with diverse degrees of variability.

Keywords: unobservable components model; industrial productivity; growth cycles; Europe.

JEL codes: C22, N64.

Resumo

Esta nota aplica a estimação mediana não enviesada da variância, sugerida por Stock e Watson (1998), à extracção da taxa de crescimento tendencial, variável ao longo do tempo, da produtividade industrial em 15 países europeus, durante grande parte do século XX, através de uma decomposição univariada de componentes não observáveis. Para além de descrever o procedimento, esta ilustração é particularmente útil para explicar porque é que o método é especialmente apropriado para comparar taxas de crescimento tendenciais extraídas de séries temporais com graus de variabilidade diversos.

Palavras-chave: modelos de componentes não observáveis;produtividade industrial; ciclos de crescimento; Europa.

Classificação JEL: C22, N64.

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1. Introduction

This note describes the econometric procedure suggested by Stock and Watson (1998) for unbiased estimation of coefficient variance in a time-varying parameter model, and illustrates it with the estimation of time-varying trend growth rates of industrial productivity throughout the XXth century, for Portugal and other fourteen European countries.

Identification of the trend path of a time series is often an important empirical issue in macroeconomic analysis. One of the valuable methods currently available for such identification consists of specifying an unobservable components model – typically assuming that trend and cycle follow, respectively, a random walk and a stationary auto-regressive process, with uncorrelated innovations – and carrying out estimation by maximum likelihood using the Kalman filter to compute the likelihood function.

In non-stationary time-series such as, for example, (the log of) real output or productivity, it is useful to allow the trend to include a drift which itself follows a random walk, so that the estimate of this time-varying drift is directly interpretable as a time-varying trend growth rate - see Harvey (1989).

However, if the variation of the trend growth rate is small – which seems plausible for most economic time-series – the maximum likelihood estimator of the variance of its changes is biased towards zero, because a large amount of probability piles-up at zero in the density function.

Stock and Watson (1998) have suggested a solution to this "pile-up problem", designing a procedure for median unbiased estimation of the variance of the changes in the trend growth rate, within an unobservable components model. The intuition behind their method is, in essence, that the magnitude of time-variation in the trend growth rate can be uncovered from the statistics of tests for a break in the regression of the actual growth rate on a constant throughout the sample period. By means of Monte Carlo integration, they have computed a look-up table, where a scale parameter for the variance can be appropriately selected, from the results of various stability test statistics – including the maximum of a sequential GLS Chow test that we use in this illustration.

The unobservable components trend-cycle model, extended with Stock and Watson's (1998) procedure, has been used by Roberts (2001) to study the trends of US hours worked and productivity throughout the last four decades of the XXth century. French (2001) has also used this framework to estimate the trend of US total factor productivity in 1960-1999, comparing its performance to some alternative models.

In this note, we apply the procedure to the estimation of growth cycles in XXth century European industrial productivity, as a background to the comparative analysis of Portuguese industrial productivity growth pursued in Aguiar and Martins (2004). In that paper we use univariate time-varying trend growth rates to analyze the path of Portuguese industrial productivity in international perspective, as well as the diverse intra-industry patterns.

The unobservable components trend-cycle model with a stochastic trend drift turns out to be quite appropriate to analyze long-term industrial productivity, since the XXth Century has been characterized, in the industrialized countries, by secular growth in productivity levels, with phases of considerable and persistent acceleration/deceleration of productivity. By applying Stock and Watson's (1998) procedure, we ensure that the variability of each particular estimated trend series mirrors the variability that can be extracted from the respective underlying time-series of actual productivity growth. In doing so, we include the comparison of variances in the comparisons of trends in productivity growth rates between countries or industries. We believe that, from an economic point of view, this method improves on others that blindly impose a unique smoothing intensity.

This note briefly describes, in section 2, the unobservable components model and the econometric procedure allowing for its estimation according to Stock and Watson (1998). In section 3, the method is illustrated with an account of the estimation of the trend growth rate of Portuguese industrial productivity 1910-2000, and with the report of the main results of similar estimations for fourteen other European countries. Section 4 briefly concludes, and an appendix describes the data and its sources.

2. The unobservable components model and unbiased estimation

In this section we describe the trend-cycle unobservable components model used as a background to Aguiar and Martins (2004), and the procedure suggested by Stock and Watson (1998) for unbiased estimation of the variance of changes in the trend growth rate.

The time-varying parameter model

The model decomposes the level of log industrial productivity (y_t) into the sum of a non-stationary stochastic trend (y_t^{trend}) and a stationary stochastic cycle (y_t^{cycle}),

$$\begin{cases} y_t = y_t^{trend} + y_t^{cycle} & (1) \\ y_t^{trend} = y_{t-1}^{trend} + g_{t-1} + \varepsilon_t^{trend} & (2) \\ g_t - g_{t-1} = \varepsilon_t^g & (3) \\ y_t^{cycle} = \rho y_{t-1}^{cycle} + \varepsilon_t^{cycle} & (4) \end{cases}.$$

Specifically, the trend is assumed to follow a random walk process with a stochastic drift (equation 2), which itself follows a random walk process (equation 3), while the transitory component is modelled as a stationary auto-regressive process (equation 4). To allow for estimation, the model is written in state-space format,

$$\begin{cases} y_t = z\alpha_t + d_t + \varepsilon_t^y \\ \alpha_t = Tr\alpha_{t-1} + c_t + \varepsilon_t^\alpha \end{cases},$$

where y_t is the observed time-series, $c_t = d_t = \varepsilon_t^y = 0$, $z = [1 \quad 1 \quad 0]$, and the state vector - comprising the unobservable components - is

$$\alpha_t = \begin{bmatrix} y_t^{trend} \\ y_t^{cycle} \\ g_t \end{bmatrix};$$

and the transition matrix governing the unobservable components dynamics is

$$Tr = \begin{bmatrix} 1 & 0 & 1 \\ 0 & \rho & 0 \\ 0 & 0 & 1 \end{bmatrix}.$$

The vector of stochastic innovations of the system,

$$\varepsilon_t^\alpha = \begin{bmatrix} \varepsilon_t^{trend} \\ \varepsilon_t^{cycle} \\ \varepsilon_t^g \end{bmatrix},$$

is assumed to follow a multivariate normal probability distribution, $\varepsilon_t^\alpha \sim N(0, Q)$, with

$$Q = \begin{bmatrix} \sigma_{\varepsilon\ trend}^2 & 0 & 0 \\ 0 & \sigma_{\varepsilon\ cycle}^2 & 0 \\ 0 & 0 & \sigma_{\varepsilon^g}^2 \end{bmatrix},$$

which incorporates the independence between trend and cycle's innovations - a standard identifying assumption of the unobservable components model.

The model has three time-varying parameters - the unobservable variables in α - and four hyper-parameters - $\rho, \sigma_{\varepsilon_t^{trend}}, \sigma_{\varepsilon_t^{cycle}}$, and $\sigma_{\varepsilon_t^g}$. Once adequate initial conditions are established for both sets of parameters and for the filter variance of the unobservable components, the Kalman filter recursive equations can be iterated, and the parameters of the system can be estimated through maximisation of its likelihood function - Harvey, 1989.

However, as remarked in the introduction, maximum likelihood fails to generate unbiased estimates of $\sigma_{\varepsilon^g}^2$. While the other hyper-parameters are unbiased, the maximum likelihood estimate of $\sigma_{\varepsilon^g}^2$ is typically biased towards zero, and thus towards non-significance. As a result, the unrestricted maximum likelihood estimation of the model produces smooth trends and cycles of the level, that are large in amplitude and very persistent - as is characteristic of unobservable components models with orthogonal trend-cycle –, while the trend growth rate displays no apparent time-variation, irrespective of the actual fluctuations in the rate of change of the time-series. Hence, the usefulness of Stock and Watson's (1998) addition to the method.

The procedure for unbiased estimation of parameter variance

Stock and Watson's (1998) procedure starts off by regressing the first differences of y_t (here, the log of industrial productivity) on a constant. Typically, in empirical macroeconomic analysis, feasible generalised least squares (GLS) is needed, in place of OLS, as the residuals from OLS regressions have a non-white-noise structure that can be well described by a finite order auto-regressive process.

The regression of the growth rate of the observed series on a constant is run over the entire sample (*T observations)* and sequentially over the sub-samples obtained by splitting the full sample at *Ts*, for all $0.15\,T \leq Ts \leq 0.85\,T$ (a standard 15 percent trimming). In the process, the sequential GLS Chow statistics, $F_T(s)$, testing for breaks at dates *Ts*, are extracted. Letting $SSR_{t1,t2}$ denote the sum of squared residuals from the GLS regression over observations $t_1 \leq t \leq t_2$, each Chow statistic is

$$F_T(s) = \frac{SSR_{1,T} - SSR_{1,Ts} - SSR_{Ts+1,T}}{\frac{k}{(T-k)}\left(SSR_{1,Ts} + SSR_{Ts+1,T}\right)}.$$

The higher F_T statistic - which is Quandt's likelihood ratio statistic $QLR_T = \sup F_T(s)$ - is retained, and Stock and Watson's table 3 (1998, page 354) is used to obtain the corresponding median-unbiased estimator of a scale coefficient λ.

Then, the Kalman filter can be run: hyper-parameters ρ and $\sigma_{\varepsilon_t^{cycle}}$ are freely estimated by maximum likelihood; the variance of the innovation to the trend growth rate is restricted as

$$\sigma^2_{\varepsilon^g} = \left(\frac{\lambda}{T}\right)^2 \sigma^2_{\varepsilon^{trend}} ,$$

and the variance of the innovation to the trend level is normalized as a function of the variance of the innovation to the cycle and of its auto-regressive parameter, as

$$\sigma^2_{\varepsilon^{trend}} = \left(\frac{1}{\rho}\right)^2 \sigma^2_{\varepsilon^{cycle}} ;$$

so that compliance with Stock and Watson's (1998) specification - implicit in their Monte Carlo results - is attained.

After convergence, the fixed-interval Kalman smoother is run (Harvey, 1989, page 154), in order to generate estimates of the time-varying parameters – trend level, cycle level, and trend growth rate, - that are, in each period, conditional on the whole sample information. In particular, the smoothed estimates of the time-varying trend growth rate are the crucial ones for the analysis of industrial productivity growth cycles in Aguiar and Martins (2004).

3. Growth Cycles of Industrial Productivity in XXth Century Europe

In this section we apply the model and econometric procedure just described to the estimation of time-varying trend growth rates of industrial productivity in fifteen European countries throughout most of the XXth century, beginning with a more detailed report of the estimation process for the case of Portugal.

The data - described in the appendix - are annual time-series of labor productivity in the industry of Portugal, Belgium, Finland, France, Germany, Italy, Norway, Spain, Sweden, UK, Austria, Denmark, Greece, Ireland and Netherlands. The sample period is 1910-2000, except for the last five countries, for which the sample is 1927-2000.

Productivity has been computed as the ratio of industrial production to industrial labor force. The interpretation of productivity trends during the I and II World War periods is inappropriate, because, with the only exception of Portugal, all productivity series have been interpolated over those periods, as their very sharp and erratic variations precluded a reasonable estimation of the trend.

Figure 1, measuring on the left hand side scale the log level of Portuguese industrial productivity between 1910 and 2000, clearly shows that it has trended upwards during most of the XXth century. The graph also affords some preliminary indication that Portuguese industrial productivity growth has gone through some persistent shifts throughout the century, thus suggesting the relevance of using a time-varying growth rate model. For example, the pace of productivity growth has been larger between the early 1950s and the mid 1970s than during the two previous decades; between the mid-70s and the mid-80s there has been no noticeable rise in productivity; and in the final 15 years of the century Portuguese industrial productivity seems to have augmented at a pace similar to the one observed between the mid-50s and the mid-60s.

Figure 1 also shows - measured on the right hand side scale - the annual growth of Portuguese industrial productivity, *ie* the first differences of the series measured on the left hand side axis. The (typical) high volatility of the series of annual growth rates hampers any precise definition of the amplitude and length of the apparent growth cycles. Next, in order to filter the noise, we extract the trend growth rate of Portuguese industrial productivity using the procedure set up by Stock and Watson (1998).

The results of the sequential GLS Chow F_T test for testing the stability of a regression of Portuguese industrial productivity on a constant are depicted in figure 2. Inclusion of one lagged observation proved to be enough to achieve non-correlated residuals, a common feature of annual productivity data. The maximum value of the F_T statistic turns out to be 15.14736 and is located at 1974 - table 1. This value, according to Stock and Watson's (1998) look-up table (Table 3, page 354), yields a coefficient λ = 11.87096, which, divided by the number of observations T, results in 0.1319. Hence, the model described above, in section 2, is applied to the log of Portuguese industrial productivity, imposing the restrictions

$$\sigma^2_{\varepsilon^g} = 0.1319^2 \sigma^2_{\varepsilon^{trend}}$$

$$\sigma^2_{\varepsilon^{trend}} = \left(\frac{1}{\rho}\right)^2 \sigma^2_{\varepsilon^{cycle}},$$

and estimating the hyper-parameters ρ and $\sigma_{\varepsilon_t^{cycle}}$, together with the time-varying parameters (trend level, cycle level, and trend growth rate), by maximum likelihood with the Kalman filter.

As regards the starting values of the state variables, the iterations have been initiated setting to zero the stationary variable (the cycle level) and setting the non-stationary variables (trend level and trend growth rate) equal to their observed counterparts – *ie* actual log productivity and actual growth of productivity at the sample onset, respectively. The filter variances have been initiated at 0.05^2 for all the parameters, corresponding to 95 percent confidence bands as wide as about 10 percentage points.

Focusing on the relevant results for the analysis, figure 3 shows the actual annual growth, the secular average growth and the estimate of the time-varying trend growth rate of Portuguese industrial productivity 1911-2000. The unbiased estimates of the trend growth rate vary from a minimum of 1.6 percent in the late 30s to a maximum of 4.5 percent in the mid-60s, and are about 3.7 percent at the end of the century. The deviations between the trend growth rate and the average secular rate establish the growth cycles that are presented in table 2. Following a first half of the century in which trend growth has been below the average secular growth, from 1951 on Portugal experienced a positive growth cycle of industrial productivity, which has only been discontinued during the erratic years between the 1974 revolution and the advent of political stabilisation, economic reform, and accession to the European Community in the mid-80s.

We now turn to a very brief description of the main results regarding the other fourteen European countries considered in Aguiar and Martins (2004), in a comparative perspective.

Table 1 reports the $\sup F_T(s)$ statistics, their date of occurrence, and the implied values for λ and λ / T. The table shows the wide range of variability in the series of productivity annual growth across these countries and, thus, highlights the relevance of using a specific and unbiased estimate of the variances of each country's changes in trend growth rate.

The fifteen charts in figures 4-7 assemble the annual growth, average secular growth, and estimates of time-varying trend growth rates of industrial productivity of each country, with a uniform scale. Following a standard taxonomy, figure 4 describes the G4 countries (France, Germany, Italy and UK, the European members of the G7), figure 5 comprises the small Northern countries (Austria, Belgium, and Netherlands), figure 6 depicts the Scandinavian countries (Denmark, Finland, Norway and Sweden), and figure 7 the countries that are subject to European Union policies towards economic convergence with the richer members, labelled Cohesion countries (Greece, Ireland, Spain and Portugal).

In line with table 1, figure 4 confirms that the variability of the estimates of trend growth rates of industrial productivity is somewhat modest for all the G4 countries. Figure 5 shows noticeably higher variability of trend growth in the Netherlands and in Belgium. Among the Scandinavian countries in figure 6, Finland has very small variability in industry trend growth –the smallest in our sample –, while Denmark, Sweden and, especially, Norway, show high variability. Figure 7 illustrates, between the Cohesion countries, the relatively low variability of Portuguese and Spanish industrial productivity trend growth rates, the larger variability of Greece's and, especially, Ireland's.

Table 2 presents the industrial growth cycles of each country implied by our estimates of time-varying trend growth rates of productivity. Notably, all the countries went through unfavourable industrial growth cycles during the first decades of the XXth century, and most of them began a positive growth era right after the end of the II World War - the exceptions being Germany and Sweden, which entered such a phase in the early 30s, and Ireland, that only accelerated its trend growth in the early 80s. Most countries in the sample registered a favourable growth cycle throughout all the remaining decades of the century. Here, the exceptions are – besides the already mentioned stagnation in Portugal, 1974-1984 – Greece, the Netherlands and Spain, which went through a cycle of trend growth below the secular average, starting in 1978, 1983, and 1989, respectively.

4. Concluding remarks

This note has briefly described the Stock and Watson (1998) procedure for unbiased estimation of coefficient variance in a time-varying parameter model, illustrating it with the estimation of time-varying trend growth rates of industrial productivity for a sample of fifteen European countries during the XXth century.

There is a noticeable heterogeneity in the variability of industrial productivity growth across the European countries throughout the century, calling for differentiated estimation of the variance of the changes in trend growth rates. The method seems to capture such heterogeneity in its estimates of time-varying trend growth rates.

Comparing the path of each country's trend growth rate with the corresponding secular actual average growth, we have established a dating of growth cycles of industrial productivity in Europe. The estimated growth cycles may be a valuable source for further historical analysis of European industrial growth.

Appendix: Data Sources and Description

<u>Sources</u>:

- **Bairoch** (industrial labor force, irregular census data, 1910-1960)
Bairoch, P. (supervisor) (1968) *The Working Population and its Structure*, Brussels: Institut de Sociologie de l'Université Libre de Bruxelles.

- **Batista** (Portugal, industrial value added 1910-1952)
Batista, Dina, Carlos Martins, Maximiano Pinheiro, and Jaime Reis (1997) *New Estimates for Portugal's GDP 1910-1958*, Lisboa: Banco de Portugal.

- **Feinstein** (UK; industrial labor force 1901 and 1911; total labor force 1902-1919; industrial employment 1920-1959; industrial production index 1910-1959)
Feinstein, C. H. (1972) *national Income, Expenditure and Output of the United Kingdom 1855-1965*, Cambridge: Cambridge University Press.

- **ILO disk** (industrial labor force 1950-1990 at the end of each decade)
International Labour Office (1997) *Economically Active Population 1950-2010*, Fourth Edition, on diskette, Geneva: International Labour Office.

- **ILO yearbook** (industrial labor force 1950-1994, very irregular yearly data)
International Labour Office (1970-1994) *Yearbook of Labour Statistics*, Fourth Edition, on diskette, Geneva: International Labour Office.

- **INE** (Portugal, industrial employment and industrial production index 1996-2000)
Instituto Nacional de Estatística *INFOLINE* http://www.ine.pt

- **Maddison** (total population 1910-1955)
Maddison, Angus (2001) *The World Economy: A Millennial Perspective*, Paris, Development Centre of the OECD.

- **Mitchell** (total population 1946-1955 and industrial production index 1910-1974)
Mitchell, B. R. (1998) *International Historical Statistics, Europe 1750-1993*, Fourth Edition, Londres: Macmillan.

- **NSO** (industrial employment UK 1978-2000)
UK National Statistics Online http://www.statistics.gov.uk

- **Nunes** (Portugal, industrial labor force 1910-1981)
Nunes, Ana Bela (1989) *População activa e actividade económica em Portugal dos finais do século XIX à actualidade - Uma contribuição para o estudo do crescimento económico português*, Doctoral Dissertation at the Instituto Superior de Economia, Universidade Técnica de Lisboa; Data also available as Nunes, Ana Bela (2001) "Economic Activity of the Population" (pp.149-196) *in* Nuno Valério (coord.) *Portuguese Historical Statistics*, Lisboa: INE.

- **OECD labor** (industrial employment 1956-2000)
OECD (1956-2000) *Labour Force Statistics*, Paris: OECD.

- **OECD industrial production** (Main Economic Indicators, industrial production index 1960-2000)

OECD (2002) *OECD Statistical Compendium* (CD-ROM ed. 02#2002).

- **Pinheiro** (Portugal, industrial employment 1982-1995, and industrial value added 1953-1995)

Pinheiro, Maximiano (coord.) (1997) *Séries Longas para a Economia Portuguesa pós II Guerra Mundial, Volume I - Séries Estatísticas*, Lisboa: Banco de Portugal; Data updates available at http://www.bportugal.pt/publish/serlong/serlong_p.htm.

Description:

The industrial sector comprises, in general, Mining and Quarrying, Manufacturing, Electricity, Gas and Water, and Construction.

Labor Force = active population

Variable Country	Industrial Labor Force
Austria 1927-2000 Belgium 1910-2000 Denmark 1927-2000 Finland 1910-2000 France 1910-2000 Greece 1927-2000 Ireland 1927-2000 Italy 1910-2000 Netherlands 1927-2000 Norway 1910-2000 Spain 1910-2000 Sweden 1910-2000	- Basis: ILO disk 1950-1990. - Other years and interpolations, based on the path of: - 1910-1949 Bairoch when available, Maddison otherwise; - 1951-1955 ILO yearbook when available, Maddison otherwise - 1956-1994 ILO yearbook when available, OECD labor otherwise; - 1995-2000 OECD labor
Germany 1910-2000 (Total 1910-1939, West only 1946-2000)	- Basis: Bairoch 1907-1964, ILO yearbook 1965-1993. - Other years and interpolations, based on the path of: - 1910-1939 Maddison; - 1946-1955 Mitchell population; - 1956-1964 ILO yearbook; - 1966-2000 OECD labor
Portugal 1910-2000	- Basis: Nunes 1910-1981. - Other years based on the path of: - 1982-1995 Pinheiro industrial employment; - 1996-2000 INE industrial employment.
UK 1910-2000	- Basis: Feinstein 1901 and 1911, Bairoch 1921 and 1931, ILO disk 1950-1990. - Other years and interpolations, based on the path of: - 1910-1919 Feinstein total labor force; - 1920-1959 Feinstein industrial employment; - 1961-1977 ILO yearbook when available, OECD labor otherwise; - 1978-1993 ILO yearbook when available, NSO otherwise; - 1994-2000 NSO otherwise.

Variable / Country	Industrial Production
Austria 1927-2000 Belgium 1910-2000 Finland 1910-2000 France 1910-2000 Germany 1910-2000 (Total 1910-1939, West only 1946-2000) Italy 1910-2000 Netherlands 1927-2000 Norway 1910-2000 Sweden 1910-2000	- Basis: OECD industrial production 1960-2000. - Other years based on the path of Mitchell industrial production.
Denmark 1927-2000	- Basis: OECD industrial production 1970-2000. - Other years based on the path of Mitchell industrial production.
Greece 1927-2000	- Basis: OECD industrial production 1962-2000. - Other years based on the path of Mitchell industrial production.
Ireland 1927-2000	- Basis: OECD industrial production 1975-2000. - Other years based on the path of Mitchell industrial production.
Portugal 1910-2000	- Basis: Pinheiro industrial value added 1953-1995. - Other years based on the path of: - 1910-1952 Batista industrial value added; - 1996-2000 INE industrial production.
Spain 1910-2000	- Basis: OECD industrial production 1961-2000. - Other years based on the path of Mitchell industrial production.
UK 1910-2000	- Basis: OECD industrial production 1960-2000. - Other years based on the path of Feinstein industrial production.

Variable / Country	Industrial Productivity = $\frac{\text{Industrial Production}}{\text{Industrial Labor Force}}$ (1910=100 or 1927=100)
Austria 1927-2000 Netherlands 1927-2000	Geometric interpolations: 1939-1949
Belgium 1910-2000	Geometric interpolations: 1914-1919 and 1939-1946
Denmark 1927-2000 Greece 1927-2000	Geometric interpolations: 1939-1946
Finland 1910-2000 France 1910-2000 Italy 1910-2000 Norway 1910-2000 Sweden 1910-2000 UK 1910-2000	Geometric interpolations: 1914-1918 and 1939-1946
Germany 1910-2000	Geometric interpolations: 1914-1918 and 1939-1949
Ireland 1927-2000	Geometric interpolations: 1930, 1932-1935 and 1939-1946
Spain 1910-2000	Geometric interpolations: 1914-1918 and 1936-1946

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French, Mark W. (2001), "Estimating changes in trend growth of total factor productivity: Kalman and H-P filters versus a Markov-switching framework", Board of Governors of the Federal Reserve System Finance and Economics Discussion Series Nº 44, October.

Harvey, Andrew (1989), *Forecasting, structural time series models and the Kalman filter*, Cambridge University Press.

Roberts, John M. (2001), "Estimates of the Productivity Trend Using Time-Varying Parameter Techniques", *Contributions to Macroeconomics:* Vol. 1: Nº 1, Article 3. http://www.bepress.com/bejm/contributions/vol1/iss1/art3

Stock, James, and Mark Watson (1998), "Median Unbiased Estimation of a Coefficient Variance in a time-varying Parameter Model," *Journal of the American Statistical Association*, Vo. 93, Nº 441, March, p. 349-358.

Figure 1. Level and First Differences of log of Portuguese Industrial Productivity

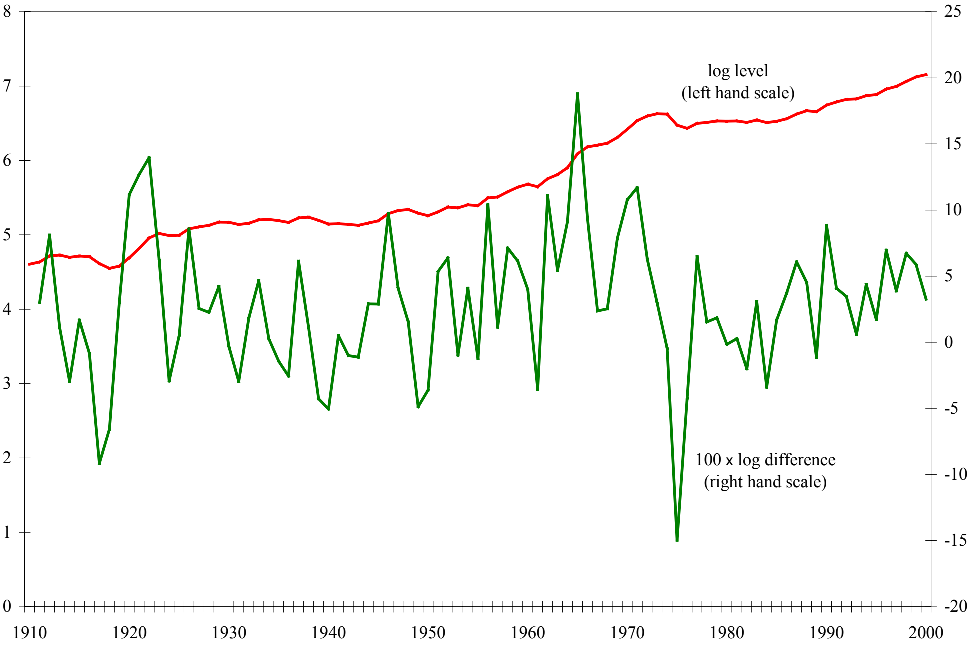

Figure 2. F_T, Sequential Chow Test Statistic - Portugal

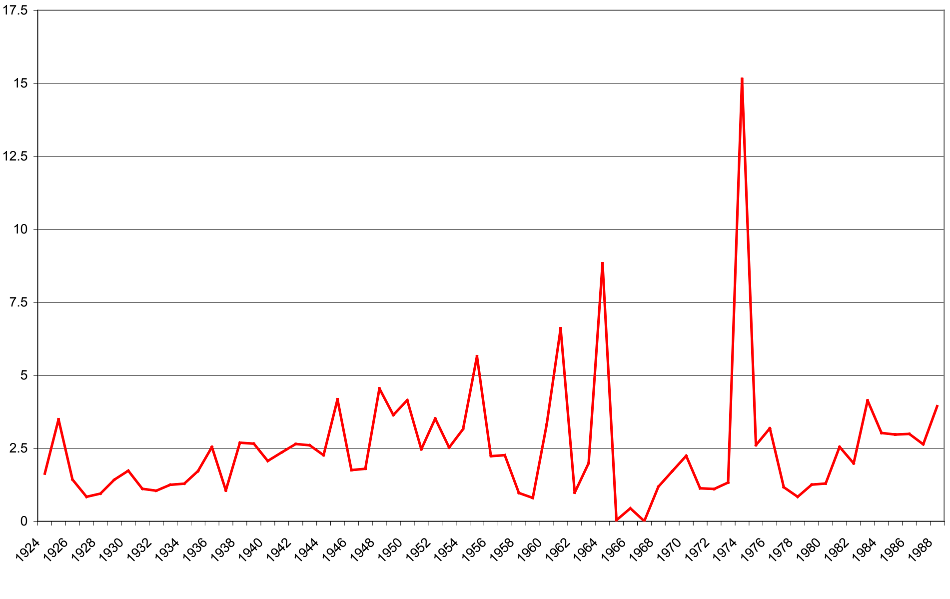

Figure 3. Growth, Average Growth, and Trend Growth of Portuguese Industrial Productivity

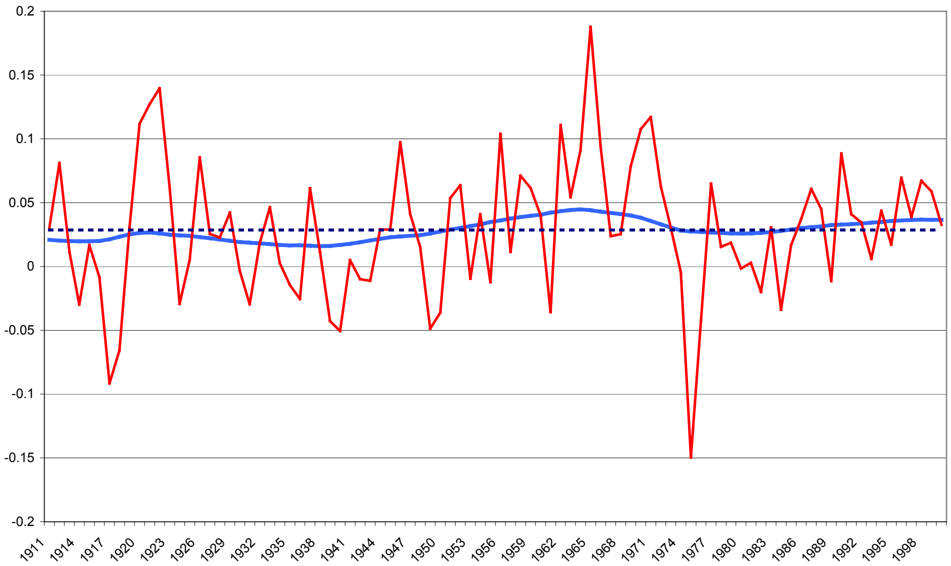

Figure 4. Growth, Average Growth, and Trend Growth of Industrial Productivity - G4 European Countries

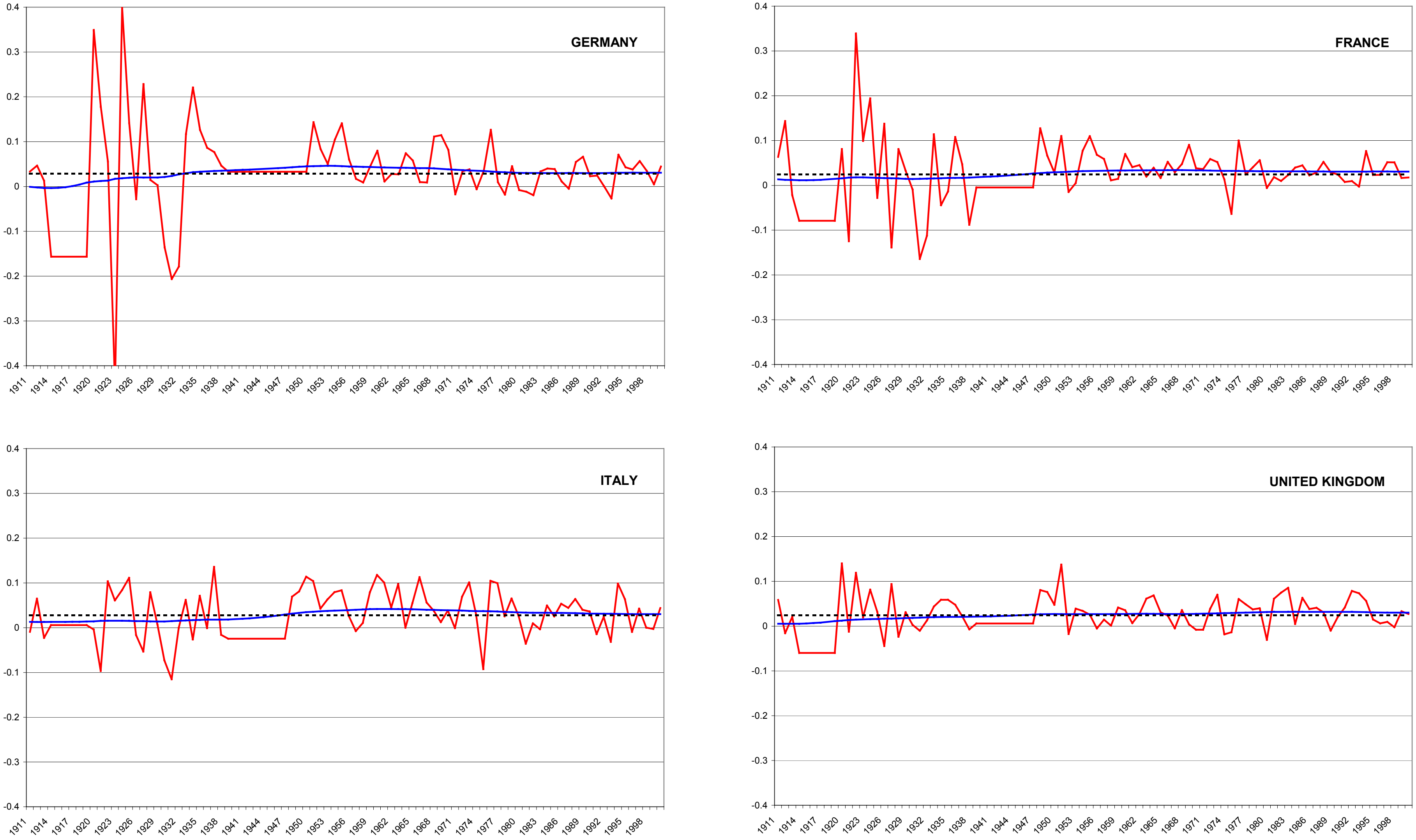

Figure 5. Growth, Average Growth, and Trend Growth of Industrial Productivity - Small Northern European Countries

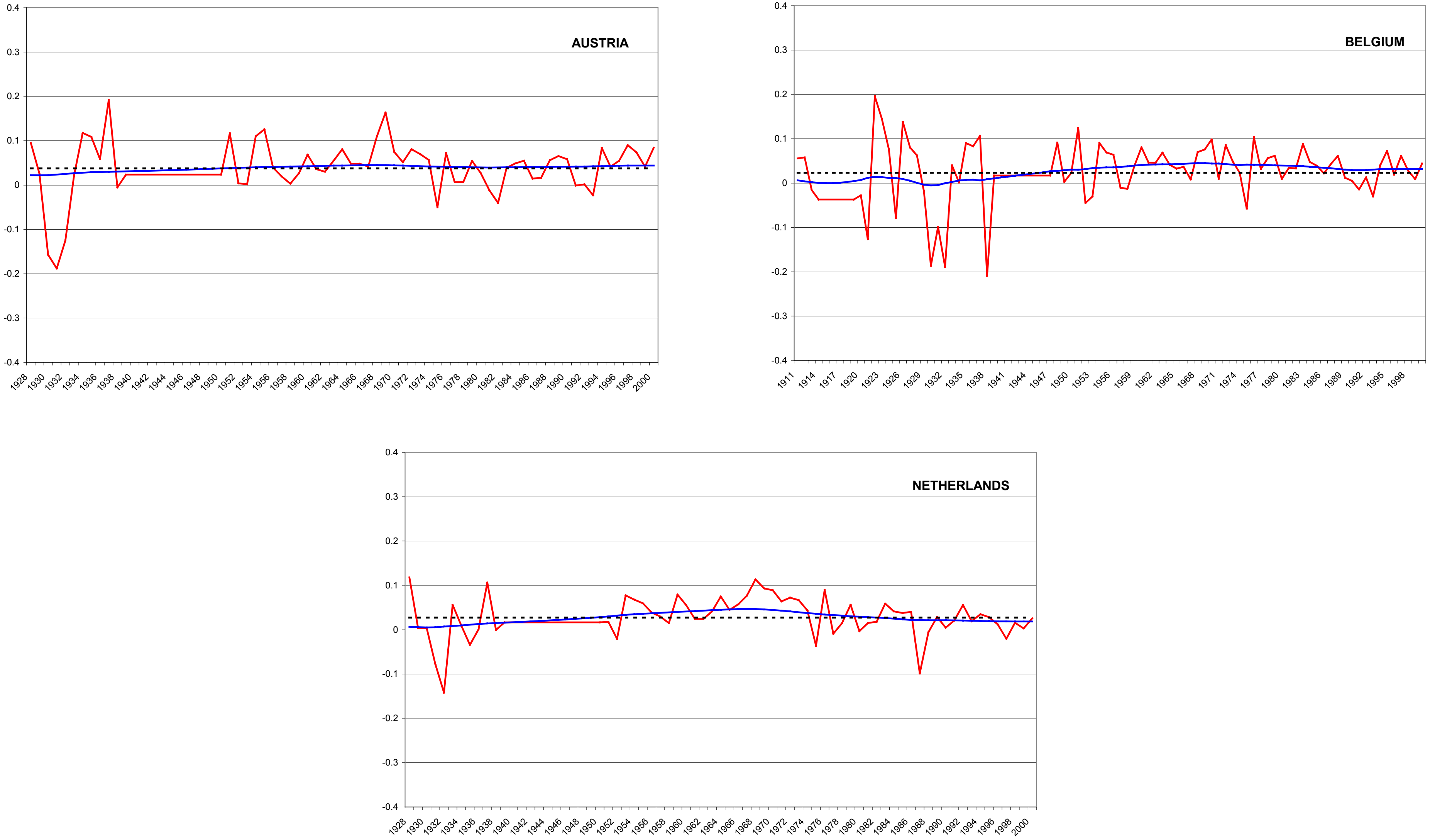

Figure 6. Growth, Average Growth, and Trend Growth of Industrial Productivity - Scandinavian European Countries

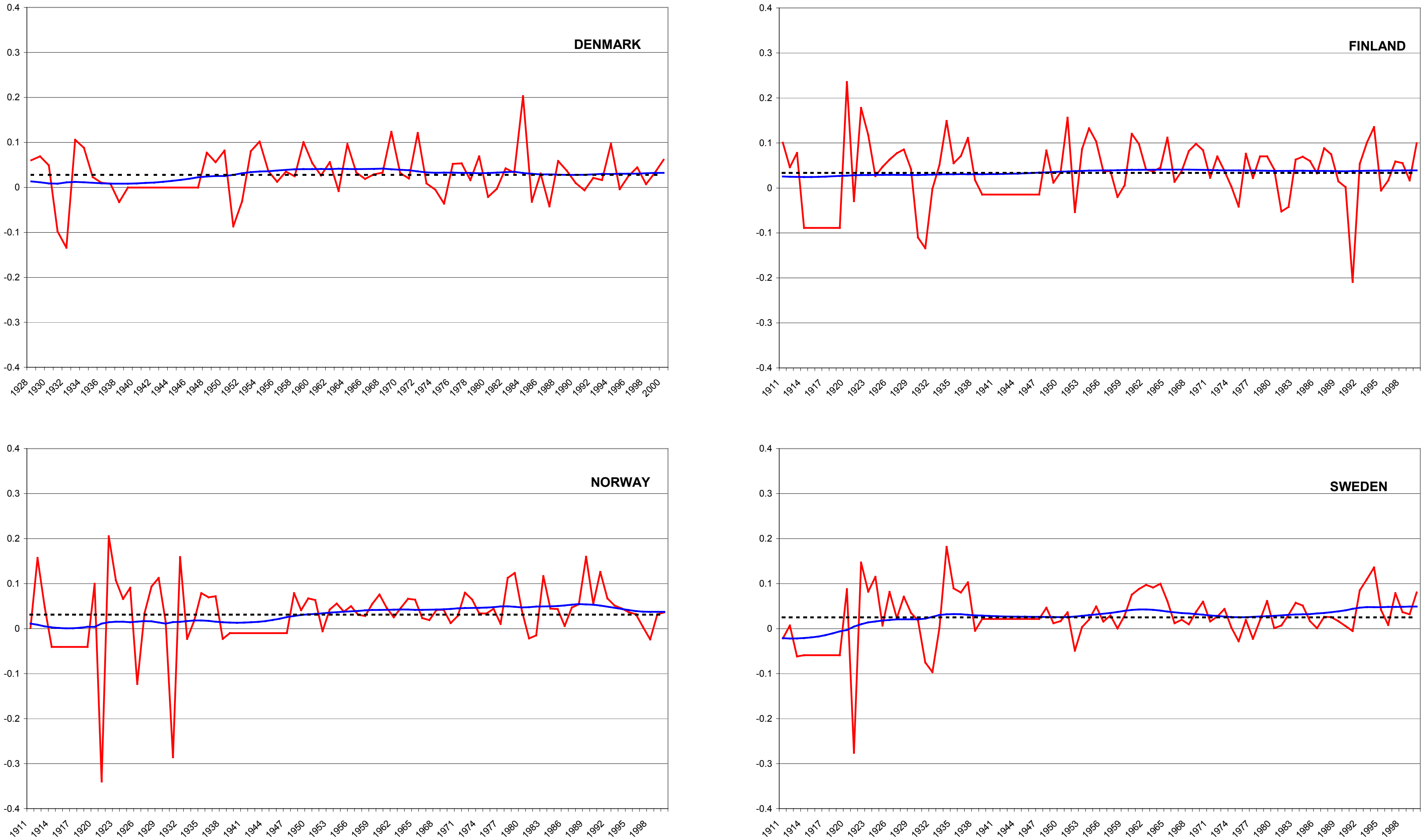

Figure 7. Growth, Average Growth, and Trend Growth of Industrial Productivity - Choesion European Countries

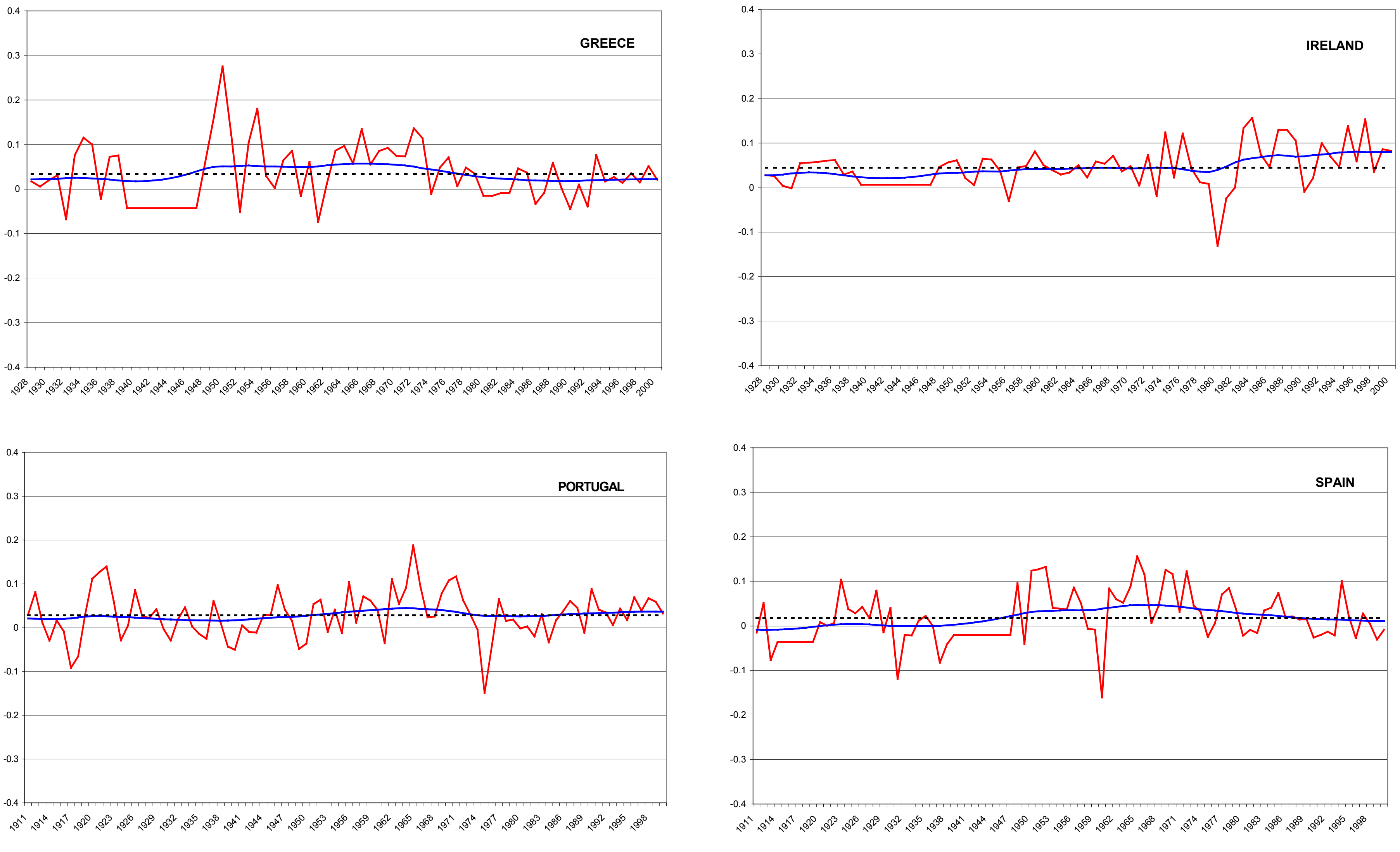

Table 1. Sup F_T Statistic, λ, and λ/T - Fifteen European Countries

Industrial productivity time-series *Country*	 *Sample*	*QLR statistic* Sup F_T	Date of ocurrence of Sup F_T	λ	λ/T
Portugal	1910-2000	15.14736	1974	11.87096	0.13190
Germany	1910-2000	11.54345	1926	9.74805	0.10831
Italy	1910-2000	10.45865	1947	8.86577	0.09851
France	1910-2000	8.84317	1930	7.79346	0.08659
United Kingdom	1910-2000	10.36092	1950	8.80061	0.09778
Netherlands	1927-2000	12.38808	1986	10.43523	0.14295
Belgium	1910-2000	25.17260	1937	17.07763	0.18975
Austria	1927-2000	6.71246	1950	6.03227	0.08263
Denmark	1927-2000	18.70736	1983	13.69272	0.18757
Sweden	1910-2000	24.70231	1933	16.86204	0.18736
Norway	1910-2000	28.88790	1930	18.27865	0.20310
Finland	1910-2000	6.60118	1950	5.91861	0.06576
Spain	1910-2000	16.38453	1959	12.56819	0.13965
Ireland	1927-2000	33.35979	1979	20.01673	0.27420
Greece	1927-2000	16.15063	1949	12.42582	0.17022

Table 2. XXth Century Industrial Growth-Cycles in Fifteen European Countries

	Average Secular Growth	*Trend Growth Rate versus Average Secular Growth*			
Country		Below	Above	Below	Above
Portugal	2.83%	1911-1950	1951-1973	1974-1984	1985-2000
Germany	2.90%	1911-1932	1933-2000		
Italy	2.78%	1911-1946	1947-2000		
France	2.45%	1911-1945	1946-2000		
United Kingdom	2.39%	1911-1944	1945-2000		
Netherlands	2.72%	1928-1949	1950-1982	1983-2000	
Belgium	2.36%	1911-1945	1946-2000		
Austria	3.77%	1928-1950	1951-2000		
Denmark	2.79%	1928-1951	1952-2000		
Sweden	2.53%	1911-1931	1932-2000		
Norway	3.08%	1911-1949	1950-2000		
Finland	3.33%	1911-1946	1947-2000		
Spain	1.80%	1911-1945	1946-1988	1989-2000	
Ireland	4.45%	1928-1980	1981-2000		
Greece	3.42%	1928-1946	1947-1977	1978-2000	

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