Nonlinear influences in the relationship between stock returns and the macroeconomy

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Abstract

The presence of nonlinear influences in the relationship between stock returns and the macroeconomy is examined for eight countries. The markets chosen are Belgium, Canada, France, Germany, Ireland, Japan, U.K. and the U.S. Time variation is accounted for via regime switching using a smooth transition regression (STR) model. There is evidence of nonlinearity in all countries. In the majority of cases the world market return acts as the transition variable, driving the nonlinearity. Given the potentially complex nonlinearities in the determination of stock market prices, the possibility of multiple transition variables (i.e. at least 3 regimes) is also investigated. With the exception of Belgium, all markets exhibit evidence of multiple regimes. Accounting for nonlinearity, interest rate and inflation variables remain strong determinants of stock returns. Dividend yields and oil influence returns in particular regimes only identified by multiple transition models. Industrial production growth is not a significant factor.

Keywords: Smooth transition, Regime switching
JEL Classification: G14, G15
EFM Classification: 350, 630

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1 Introduction

Understanding the relationship between international stock markets and the relationship between stock markets and the macroeconomy is of importance and of relevance to market participants irrespective of their role. Consequently much previous research has been employed trying to analyse these relationships from different perspectives. Research on the the interaction between stock returns and financial and macroeconomic variables is well established. Numerous studies have investigated the relationship between stock returns, interest rates, inflation and real activity (see, *inter alia*, Fama (1981, 1990), James et al. (1985), Mandelker and Tandon (1985), Asprem (1989), Schwert (1990), Lee (1992) and Canova and De Nicoló (2000)) while others consider the relationship between stock returns and a wider spectrum of financial and macroeconomic variables (see, *inter alia*, Chen et al. (1986), Fama and French (1989) Ferson and Harvey (1991) and Cheung and Ng (1998)). However, these studies are all based on linear analysis of the relationships. Importantly they do not account for the time variation in the relationship between these variables. Despite the well documented presence of nonlinearity and/or regime switching, it is rarely, if at all, accounted for explicitly.

This paper investigates the relationship between stock returns and the macroeconomy accounting for nonlinearity for a range of countries. Although it was debated whether economic news had a significant impact on stock prices Pearce and Roley (1985). It is now widely understood that stock prices react in response to and that macroeconomic variables have explanatory power over prices and returns. McQueen and Roley (1993) show that the stock market response to macroeconomic news is dependent upon the state of the economy, while Errunza and Hogan (1998) and Flannery and Protopapakis (2002) highlight that macroeconomic factors influence both stock market volatility and returns. Significantly, it is the time varying nature of these relationships which is important.

Such variation is accounted for by considering regime switching in the form of smooth transition models. This will capture the cyclical behaviour of stock returns and indicate whether the relationship between stock returns and the candidate financial and macroeconomic factors is linear or nonlinear. A conventional set of financial and macroeconomic variables is adopted to investigate the impact of regime change (nonlinearity) on the relationship with stock returns for eight countries. Financial factors are allowed to enter both contemporaneously and with a lag. The key results show that, using contemporaneous financial series, inflation and interest rate variables are most important in describing the behaviour of stock returns, conversely industrial production growth, dividend yields and changes in oil prices are on the whole insignificant. Significantly, the impact of inflation is is only uncovered by the nonlinear model and not the linear specification. When using lagged financial series, the explanatory power of the dividend yield and industrial production becomes more pronounced while inflation is no longer significant. World stock returns acts as the primary transition variable in all countries, while significant secondary nonlinear influences tend to come through changes in short term interest rates.

The remainder of the paper is set out as follows. Section 2 discusses previous research which has investigated the relationship between stock returns and the macroeconomy and documents the importance of possible nonlinearities. Section 3 provides the details of the empirical methodology adopted in the study while section 4 provides a discussion of the data and presents the empirical results. Section 5 concludes.

2 Literature Review

There is a rich history of literature which investigates the relationship between asset returns, real activity, inflation and money. Fama (1981) focusses upon the correlation between stock returns and expected and unexpected inflation in the U.S., showing that the observed negative relation is a 'proxy effect' for more fundamental relationships between stock returns and real activity. Mandelker and Tandon (1985) provides international evidence in support of this proxy effect using data from the U.S., U.K., France, Canada, Japan and Belgium. Geske and Roll (1983) offer a supplementary explanation suggesting that stock prices signal changes in expected inflation because money supply responds to changes in expected real activity. James et al. (1985) uses a VARMA approach to model the relationships, finding strong links between stock returns, real activity and money. Investigating the stock return-inflation relation for the U.S., U.K., Canada and Germany, Kaul (1987) argues that the observed relation is a consequence of money demand and counter-cyclical monetary policy.

Chen et al. (1986) identify the importance of the term spread, oil prices and industrial production growth in explaining stock return behaviour. Evidence of the role of the dividend yield and the term spread in determining stock prices is provided by Fama and French (1989). Clare and Thomas (1994) investigate a wide range of factors in the U.K. reporting broadly consistent findings with those of Chen et al. (1986). Asprem (1989) documents a positive relationship between stock returns and real activity using data from 10 European countries in addition to finding support for money supply, interest rate and exchange rate variables. The strength of the relation between stock returns and real activity or industrial production is further enhanced by the findings of Fama (1990) and Schwert (1990).

Recently, Cheung and Ng (1998) providence evidence of long-run relationships between the stock market and the macroeconomy for five stock markets (the U.S., Canada, Germany, Italy and Japan). The long run relationships provide additional explanatory power for stock returns to that contained in dividend yields, default and term spreads and future GNP growth. Canova and De Nicoló (2000) examine the dynamic interrelationships between stock returns, real activity and inflation for the U.S., U.K., Japan and Germany using both open and closed economy VARs. Results show that innovations in stock returns are not significantly related to inflation or real activity. However, Lamont (2001) provides evidence that portfolios of asset returns can be used to forecast future movements in macroeconomic factors.

It is well established that returns across international stock markets are time varying. In order to take account of the time variation, GARCH type models became very popular, e.g. Flannery and Protopapakis (2002) and Connolly and Wang (2003) utilise such techniques to investigate the influence of domestic and foreign economic news on domestic stock market activity. However, recent empirical evidence has shown that correlations are higher during bear markets than bull markets, see Longin and Solnik (2001). Ang and Bekaert (2002) show that the asymmetric GARCH is unable to take account of this type of correlation pattern. Hence it is the regime or the nonlinearity that is important rather than the changing volatility. Recent evidence has shown that regime switching models that account for different phases in the business cycle are quite successful in this regard, see Schaller and van Norden (1997), Perez-Quiros and Timmermann (2000), Ang and Bekaert (2002), and Guidolin and Timmermann (2003, 2005). These studies adopt the Markov switching approach of Hamilton (1989). However, a special class of regime switching model, where the state variable is observed, and also allows intermediate positions between the regimes (rather than abrupt changes as with Markov switching) is the smooth transition model, see Teräsvirta (1994), van Dijk et al. (2002) and Teräsvirta (2004). This is seen as an appropriate regime switching approach to examine the nature of the underlying regime and has proven to work well with specifications of two or more explanatory variables. A number of studies have applied these type of approaches to modelling stock returns, see Sarantis (2001), McMillan (2001) and Aslanidis et al. (2003).

Sarantis (2001) employs smooth transition autoregressive (STAR) models to investigate cyclical behaviour of stock returns in the G7. The estimated models suggest that stock price behaviour is characterised by asymmetric cycles with relatively slow rates of transition between regimes and out-of-sample forecasts from the models outperform a random walk. McMillan (2001) finds evidence in the U.S. of a nonlinear relationship between stock market returns and macroeconomic and financial variables. Using a two regime STAR model, the results shows that while interest rates are important determinants in both regimes, the macroeconomic series (unemployment) only explains stock returns in one regime. Employing a smooth transition regression (STR) model, Aslanidis et al. (2003) show that U.K. stock returns behave in a non-linear fashion and this non-linearity is being driven firstly by the dividend yield and secondly by U.S. stock returns. Both McMillan (2001) and Aslanidis et al. (2003) report that the in-sample performance and out-of-sample forecasts of the smooth transition regressions are superior to the linear specifications.

In this paper the determinants of stock returns are examined, given the time varying international stock market correlations and domestic conditions. Based on recent empirical evidence which shows that correlations vary with market conditions (Longin and Solnik, 2001), the approach of Aslanidis et al. (2003) is adopted and smooth transition models are used to ascertain the influence of financial and macroeconomic variables on stock returns.

3 Methodology

Initially the relationships between stock returns and the financial and macroeconomic factors are investigated using a simple linear regression. These specifications are then tested for smooth transition type nonlinearity using the approach of Luukkonen *et al.* (1988) and Teräsvirta (1994).

$$y_t = \beta_0 + \beta_1 z_t + \beta_2 z_t s_t + \beta_3 z_t s_t^2 + \beta_4 z_t s_t^3 + \eta_t \qquad (1)$$

where y_t is the dependent variable, country stock returns, z_t represents the financial and macroeconomic factors and s_t includes the candidate transition variables. An LM-type test can be adopted to test the null hypothesis, $H_0 : \beta_2 = \beta_3 = \beta_4 = 0$ against a general alternative:

$$LM = \frac{T(RSS_l - RSS)}{RSS_l}$$

where RSS_l is the sum of squared residuals from the linear equation and RSS is the sum of squared residuals from equation (3). The tests statistic is distributed as χ^2 with $3q$ degrees of freedom.

Given the recent finding that correlations among stock markets are influence by the position on business cycle, to account for the existence of non-linearity the stock return equations are modelled using a regime switching model. Specifically, a smooth transition regression (STR) model is adopted:

$$y_t = \alpha_0' z_t + F(s_t)\alpha_1' z_t + u_t \tag{2}$$

$$F(s_t) = \{1 + exp[-\gamma(s_t - c)]\}^{-1} \qquad \text{where} \quad \gamma > 0 \tag{3}$$

where α_0 and α_1 are the coefficient vectors, z_t is a $(k+1) \times 1$ vector of explanatory variables, u_t is the error term, which is $iid(0, \sigma^2)$ and finally $F(s_t)$ is the transition function defining the regime. The role of the explanatory variables in z_t can differ between the two regimes through the coefficients α_1. Equation (3) shows the transition function, which is defined as a logistic function. Sarantis (2001), McMillan (2001) and Aslanidis et al. (2003) have advocated the use of the logistic as opposed to the exponential function. The S-shaped logistic function is more intuitive to bull and bear stock market regimes or recessions versus expansions, as opposed to the U-shaped exponential function which cannot be used to identify expansion or contraction behaviour.

The transition function determines the regime and is itself governed by the transition variable, s_t, and by the speed of transition, γ. As $\gamma \to \infty$ the transition becomes more and more abrupt, $F(s_t)$ becomes a step function and the model approaches the standard threshold regression model. The transition function is bounded by zero and unity, which is determined by s_t. The parameter c is the threshold variable and the transition function is dependent on the position of the transition variable relative to the threshold variable, with $F(s_t) = 0.5$ when $s_t = c$.

The two regime model assumes that all the nonlinearity in stock returns is captured through a single transition variable. However, this specification may not be sufficiently complex to model the nonlinearity present in stock returns. Thus, the analysis also considers the existence of two transition functions, giving:

$$y_t = \alpha_0' z_t + F_1(s_{1t})\alpha_1' z_t + F_2(s_{2t})\alpha_2' z_t + u_t \tag{4}$$

where each transition function $F_i(s_{it})$, $i = 1, 2$, is a logistic function as defined in equation (3). The two transition variables, s_{1t} and s_{2t}, could be different variables or even the same factor but with two distinct thresholds, i.e. different values for c_1 and c_2. Sensier et al. (2002) use a two transition functions model for modelling macroeconomic variables over the business cycle.

The modelling procedure to determine the appropriate transition variable is as follows:

First, a two dimensional grid search of the residual sum of squares (RSS) over values of γ and c is undertaken in order to identify the appropriate transition variable, i.e. the variable which minimises the RSS.[1] The candidate transition variables s_t are each of the financial and macroeconomic series in z_t and time. Time is considered as a potential transition variable to allow for the possibility of structural change.

Next ordinary least squares estimates of the coefficient values are obtained as initial values of the model conditional on the choice of transition variable and the corresponding values of γ and c from the grid search. A more parsimonious model is obtained via a general to specific modelling procedure.

The final model is estimated by non-linear least squares including estimation of the parameters γ and c. Estimation of the slope parameter, γ, can be problematic. Teräsvirta (1994) and others suggest that the transition function $F(s_t)$ is standardised to make γ scale-free. This implies dividing the exponent in $F(s_t)$ by the standard deviation of s_t. Accurate estimation of the slope parameter relies on a large number of observations in the neighbourhood of c.

For the two transition functions model, a further grid search is undertaken over γ_1, γ_2, c_1, and c_2 based on the parameters estimated from the single transition function model. Model specification and estimation then proceed as above.

The validity of the estimated models is checked by applying a battery of diagnostic tests. Specifically the tests of Eitrheim and Teräsvirta (1996) are employed to check the validity of the STR models with respect to autocorrelation, additional nonlinearity and parameter constancy. Further, the residuals are also checked using the standard test for ARCH effects and the Lomnicki-Jarque-Bera test for normality.

4 Data and Empirical Results

The data employed in the study is monthly observations from 1980:2 to 2001:12 obtained from Datastream. For each of the eight countries the series used are stock returns on the market index, R_t, World market returns, R_t^W, the dividend yield, ΔDY_{t-1}, changes in the short-term interest rate, ΔSR_t, changes in the term structure, $\Delta TERM_t$, i.e. the difference between the short-term (3 month) interest rate and long term (10 year) interest rates,

[1]Each grid search involves $\gamma = 1, 2, \ldots, 250$ and 40 values of c.

inflation, $Infl_{t-1}$, the change in the effective exchange rate, Δs_t, industrial production growth, $\Delta indp_{t-2}$, and changes in oil prices, Δoil_t.[2]

It is anticipated that these variables will capture both the domestic economic and financial conditions in each economy and the stock market. The lag structures for the candidate variables are important in relation to the information set available at any point in time. Financial variables are allowed to enter the model contemporaneously since data and information on such variables are available continuously. Price level (inflation) information releases are made in the subsequent month so the variable enters with a one month lag, however industrial production releases are not and so it enters the model with a two month lag. The analysis is also conducted with financial series restricted to enter with a one month lag.

4.1 Contemporaneous financial data

Table 1 presents the results of the linear model using all the explanatory variables. The most significant variable in describing stock returns in each of the countries is the contemporaneous return on the world market portfolio. This has a significant positive impact on stock returns in all countries. Although, lagged country stock returns do not add any incremental information, the sign of impact varies across countries. Exchange rate changes have significant impacts on most country stock returns while interest rate effects (either through changes in the short term interest rate or changes in the term structure) are also relatively important in describing returns. Inflation, dividend yields (only significant at 10% in the case of Belgium) and industrial production provide little or no explanatory power in explaining stock returns. Despite the linear models explaining between 30% (Belgium) and 68% (U.S.) of the variation in stock returns their performance with respect to the diagnostic tests is weak. Although most of these specifications do not suffer from residual autocorrelation, there is evidence of significant ARCH effects and non normality.

To analyse the models for nonlinearity, the linear model is adopted for testing linearity against smooth transition type nonlinearity as described in section 3. The test results are reported in table 2. All the linear models exhibit significant nonlinearity. Most countries exhibit nonlinearity in relation to returns on the world market portfolio, although the term structure variable is more significant for France and the dividend yield and time are more significant in the case of Japan. The grid search identified world stock returns as the common primary transition variable.

[2] All series are tested for the presence of unit roots and differenced accordingly such that only stationary series are employed in the analysis.

Figure 1 shows the estimated transition functions, $F(R_t^W)$ over time. Although there is a wide variety in the frequency of switching, it can be clearly seen that nearly all markets switch in response to the October 1987 crash, August 1998 (the impact of the Asian crisis) and September 2001 (the impact of the 9/11 terrorist attack) in addition to the periods August and September 1990, September and November 2000 and February and March 2001.

Figure 2 shows the transition function, $F(R_t^W)$, plotted against world stock returns, R_t^W. With the exception of France, all the transition functions seem to have relatively steep slopes, implying high γ values, with few observations positioned on the slope. Thus, in contrast to the findings of Sarantis (2001) the estimated regime changes are abrupt. The threshold at which the switch in regimes takes place is typically for large negative returns. This suggests that market behaviour for large negative returns is distinct to that for smaller falls and positive returns. Hence as shown in figures 1 and 2 the transition functions $F(R_t^W)$ typically take the value 1. For example, this implies the following model for Canada:

$$\widehat{R_t} = 0.0060 + 0.5632R_t^W + 0.1768\Delta SR_t + 0.1167\Delta TERM_t + 0.7590\Delta s_t \quad (5)$$

and for the U.S.:

$$\begin{aligned}\widehat{R_t} = \; & 0.0137 + 0.7829R_t^W - 0.2370\Delta SR_t - 0.2694\Delta TERM_t \\ & +0.2930Infl_{t-1} + 0.5361\Delta s_t - 0.442\Delta oil_t\end{aligned} \quad (6)$$

Table 3 reports the estimated single transition models. On the whole the coefficients are of similar magnitude to those reported for the linear models. World market returns have a significant (with the exception of Canada) positive impact on country returns. Changes in short-term interest rates are important, especially in the U.K. and U.S., for describing stock returns. In contrast to the linear specifications, inflation now has an overall positive impact and is significant in the cases of Japan, the U.K. and the U.S.

The diagnostics suggest that the single transition models represent and improvement on the linear specifications. For all countries the AIC has been reduced and the coefficient of determination, R^2, has increased to between 38% (Germany and Belgium) and 72% (U.S.). Serial correlation and ARCH effects have been removed from all but two models and half the models fail to reject normality. The null hypothesis of parameter constancy also fails to be rejected for the majority of the models. However, in all cases except Belgium there is evidence of remaining nonlinearity (Table 4).

The grid search identifies a number of different factors as the second transition variable, the most prevalent being ΔSR_t, the change in the short-term interest rate. Figures 3a - 3g show the transition functions $F(s_{1t})$ and $F(s_{2t})$ plotted against time and then plotted against the transition variables s_{1t} and s_{2t} respectively. When estimated two transition models typically suggest smoother transitions than observed with the single transition models. Estimation of the two transition functions specifications tends to reconfirm many of the findings obtained with the single transition function models. As shown in figures 3a - 3g the transition functions $F(s_{1t})$ and $F(s_{2t})$ typically take the value 1. For example, this implies the following model for Canada:

$$\begin{aligned}\widehat{R_t} = \; & 0.0019 + 0.5969 R_t^W + 0.1824 \Delta SR_t + 0.1077 \Delta TERM_t \\ & -0.1135 Infl_{t-1} + 0.9098 \Delta s_t + 0.1695 indp_{t-2}\end{aligned} \tag{7}$$

Comparing with this specification with the single transition function model (equation 5) it can be seen that by allowing for additional transitions picks up influences from inflation and industrial production. The findings of the estimated two transitions functions models are reported in table 5. It can be seen in the majority of specifications that returns on the world market portfolio, the two interest rate variables, inflation and changes to exchange rates remain significant factors in determining stock returns. Additionally, allowing for multiple regimes highlights an increased importance for dividend yields and oil prices in explaining the cyclical behaviour of stock returns. The explanatory power of the models has improved significantly, capturing between 48% (France and Germany) and 74% (U.S.) of the variation in stock returns. All seven of the estimated models pass the diagnostic tests for serial correlation and normality. Although, two cases (Ireland and the U.S.) fail the test for the presence of ARCH, these specifications represent a further improvement upon the single transition function models and are clearly superior to the linear specifications.

The estimated models highlight the importance of modelling the cyclical behaviour of stock returns to identify the real significance of the influence of financial and macroeconomic variables on returns. Stock returns, interest rates and exchange rates are significant determinants in all models. Inflation is found to be a significant factor with both the single and two transition functions regressions. Dividend yields and oil prices exert greater influence over returns when the two transition functions model is adopted, suggesting that their influence is restricted to particular periods of the cycle. Industrial production growth is only ever significant in the two transitions model for Canada.

4.2 Lagged financial data

The results when using lagged financial series are broadly similar to those reported above.[3] In terms of the linear regressions the lagged return on the world market portfolio is less prominent and there is greater explanatory power derived from lagged country stock returns than under the contemporaneous analysis. Again all linear models exhibit nonlinearity.

The two regime smooth transition models reveal that world returns and the interest rate variables (ΔSR_{t-1} and $\Delta TERM_{t-1}$) are important determinants of the behaviour of country stock returns. While inflation is found to be an important variable in the contemporaneous analysis, it is not when only lagged financial series are examined. Conversely, the dividend yield and industrial production variables have more explanatory power then in the contemporaneous analysis. Using lagged returns on the world market portfolio as the transition variable, the speed of transition is typically smoother than with contemporaneous returns. The two regime specification also captures all the nonlinearity present in the majority of cases. Naturally, the omission of contemporaneous information reduces the estimated R^2 for all models. However, again the performance of the nonlinear models is superior to that of the linear specifications, passing all the diagnostic tests.

5 Conclusion

This paper contributes to the rich literature on relationships between the stock market and the macroeconomy providing international evidence from 8 countries on the influence of macroeconomic and financial variables on stock returns. Previous research has provided evidence of a role for such information in determining movements in the stock market. The novel aspect of this study is that regime switching is used to account for time variation in the relationships. The approach used is the smooth transition regression (STR) model.

Similar to previous studies, the analysis highlights a range of important financial and macroeconomic factors for determining the behaviour of stock returns. Key is that the results provide evidence that the real significance of the influence of factors such as dividend yields and inflation is only revealed once regimes are explicitly modelled. Interestingly, industrial production growth is not a significant factor.

Stock returns respond in a nonlinear fashion to financial and macroeconomic factors. The nonlinearity or cyclical behaviour is captured by world

[3] Results not reported. Available from the authors on request.

market stock returns with large negative falls leading to a different regime to that of smaller negative or positive returns. The single transition models all isolate extreme falls in returns or 'crisis' periods including key dates such as the market crash in October 1987, the consequence of the Asian financial crisis and the impact of the 9/11 terrorist attacks in September 2001.

Additional nonlinearity is captured using a smooth transition regression with two transition functions. The second transition variable is most commonly identified as changes in short-term interest rates although industrial production, dividend yields, exchange rates and oil prices are also found to provide a secondary nonlinear influence. Importantly, allowing for multiple regimes signals significant influences from dividend yields and oil prices on stock returns. This suggests these variables only impact stock returns in particular periods of the cycle.

In the majority of the STR models having accounted for the nonlinearity, the ARCH effects present in the linear model are removed. This suggests, in support of Longin and Solnik (2001) that it is the nonlinearities or regimes which are important rather than volatility. The in-sample performance of the smooth transition regressions is superior to the simple linear specifications.

The findings highlight the importance of accounting for nonlinearity and the cyclical behaviour of stock returns. The analysis reveals that the significance of the influence of inflation and dividend yields on stock returns is not captured by the linear models, only once nonlinearity is accounted for.

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	Germany		Belgium		Canada		France	
Variable	Coeff.	t-stat.	Coeff.	t-stat.	Coeff.	t-stat.	Coeff.	t-stat.
$const$	0.0007	0.2091	0.0017	0.4614	0.0065	2.1725	0.0026	0.5759
R_{t-1}	0.1979	1.4405	-0.0572	-0.5264	-0.0844	-0.6452	0.1471	1.2666
R_t^W	0.6689	10.2870	0.5661	8.9292	0.7177	14.8050	0.8030	11.1560
ΔDY_{t-1}	0.0985	0.7933	-0.1519	-1.6715	-0.0943	-0.7405	0.0848	0.8146
ΔSR_t	0.1098	0.6900	-0.0014	-0.0093	0.2080	3.5357	-0.2752	-1.9949
$\Delta TERM_t$	0.1403	0.7228	0.0321	0.2421	0.1582	2.5046	-0.2170	-1.3795
$Infl_{t-1}$	-0.0054	-0.0113	1.0399	1.3000	-0.8215	-1.5578	-0.3230	-0.3751
Δs_t	-0.5713	-1.6375	-0.9414	-2.5743	0.8635	4.1460	-1.1729	-2.9859
$\Delta indp_{t-2}$	0.0126	0.0803	-0.0225	-0.5788	0.0058	0.1004	0.0097	0.4523
Δoil_t	-0.0091	-0.2673	-0.0542	-1.6057	-0.0353	-1.4052	0.0188	0.4918
$S.E.$	0.0440		0.0428		0.0326		0.4850	
AIC	-6.2059		-6.2598		-6.8074		-6.0114	
R^2	0.34		0.30		0.53		0.39	
Diagnostics								
$AUTO$	0.0857		0.8949		0.0162		0.4899	
$ARCH$	0.5385		0.2681		0.0789		<0.0001	
$NORM$	<0.0001		<0.0001		<0.0001		<0.0001	
Parameter constancy								
All coeffs.	0.1713		0.3047		0.0157		0.4347	
Intercept	0.9479		0.5002		0.3830		0.2445	

Table 1: Linear regressions

Notes: Diagnostic test results are p-values. Tests for autocorrelation (AUTO) and ARCH are LM tests up to lag 6. NORM is the Lomnicki-Jarque-Bera test.

Variable	Ireland Coeff.	Ireland t-stat.	Japan Coeff.	Japan t-stat.	U.K. Coeff.	U.K. t-stat.	U.S. Coeff.	U.S. t-stat.
$const$	0.0040	1.0646	-0.0035	1.2697	0.0043	1.2918	0.0014	0.5010
R_{t-1}	0.1693	1.3186	0.0094	0.0489	-0.0325	-0.1841	0.1380	0.8052
R_t^W	0.8068	10.9790	0.9765	16.2310	0.7719	14.4900	0.8362	22.2710
ΔDY_{t-1}	0.0789	0.6732	-0.0435	-0.2321	-0.0244	-0.1437	0.1899	1.1085
ΔSR_t	0.1781	1.9904	0.1248	1.0233	-0.1178	-1.2593	-0.1835	-3.3028
$\Delta TERM_t$	0.1993	2.1718	0.1327	1.2893	0.0006	0.0051	-0.2316	-3.3790
$Infl_{t-1}$	-0.1398	-0.3393	-0.1689	-0.3252	0.0265	0.0575	0.4686	0.8051
Δs_t	-1.3565	-4.5828	-0.1573	-1.5248	-0.1794	-1.3298	0.5582	6.2112
$\Delta indp_{t-2}$	-0.0100	-0.2868	0.0404	1.1897	-0.0510	-1.5738	-0.0414	-0.5181
Δoil_t	-0.1177	-3.0418	0.0118	0.3777	-0.0167	-0.5982	-0.0246	-1.2538
$S.E.$	0.0496		0.0396		0.0361		0.0250	
AIC	-5.9646		-6.4151		-6.6013		-7.3386	
R^2	0.42		0.54		0.47		0.68	
Diagnostics								
$AUTO$	0.8054		0.6482		0.1626		0.1318	
$ARCH$	0.0008		0.0442		0.1910		<0.0001	
$NORM$	<0.0001		0.3130		<0.0001		<0.0001	
Parameter constancy								
All coeffs.	0.9821		0.0004		0.7634		0.0008	
Intercept	0.5736		0.1543		0.9045		0.0754	

Table 1 (cont.): Linear regressions
Notes: Diagnostic test results are p-values. Tests for autocorrelation (AUTO) and ARCH are LM tests up to lag 6. NORM is the Lomnicki-Jarque-Bera test.

Transition Variable	Germany	Belgium	Canada	France	Ireland	Japan	U.K.	U.S.
R_{t-1}	0.0672	0.9872	0.8156	0.1757	0.9163	0.0036	0.9007	0.2163
R_t^W	<0.0001	0.0188	0.0043	0.0261	0.0001	0.0588	<0.0001	0.0004
ΔDY_{t-1}	0.1786	0.9274	0.3621	0.6547	0.7876	0.0012	0.7305	0.2387
ΔSR_t	0.9460	0.7801	0.2277	0.0123	0.8932	0.4139	0.0009	0.2417
$\Delta TERM_t$	0.8606	0.2835	0.1429	0.0011	0.1597	0.0729	0.0105	0.8152
$Infl_{t-1}$	0.9729	0.7933	0.8573	0.6463	0.6631	0.9666	0.2301	0.0531
Δs_t	0.7887	0.6585	0.9232	0.5356	0.0854	0.2629	0.4191	0.3069
$\Delta indp_{t-2}$	0.2772	0.1120	0.1111	0.0685	0.4795	0.0873	0.0651	0.7617
Δoil_t	0.2875	0.6420	0.5889	0.8097	0.4795	0.0873	0.8815	0.1127
$Time$	0.0979	0.5979	0.0154	0.5930	0.9855	0.0041	0.8607	0.0013

Table 2: Tests for STR nonlinearity
Notes: Nonlinearity test of Luukkonen *et al.* (1988). The p-value is presented for a test for nonlinearity for each possible transition variable.

	Germany		Belgium		Canada		France	
Variable	Coeff.	t-stat.	Coeff.	t-stat.	Coeff.	t-stat.	Coeff.	t-stat.
$const$	0.0137	3.326	0.6041	4.231	-0.0756	-1.438	0.0072	1.766
R_{t-1}	0.2147	2.448						
R_t^W	1.034	8.798	6.288	5.033	-0.2435	-0.3954	1.076	3.506
ΔDY_{t-1}			-0.1094	-2.497				
ΔSR_t					0.4796	1.594		
$\Delta TERM_t$			-0.3037	-0.6343	0.1666	0.9700		
$Infl_{t-1}$	0.0441	0.1001	-4.010	-0.8447				
Δs_t	-1.370	-1.752			0.7590	4.454		
$\Delta indp_{t-2}$								
Δoil_t								
F			-0.5993	4.194	0.0816	1.545		
FR_{t-1}	-0.2291	-2.180						
FR_t^W	-0.6920	-3.879	-5.809	-4.641	0.8067	1.315	-0.4713	-1.386
$F\Delta DY_{t-1}$								
$F\Delta SR_t$					-0.3028	-0.9830		
$F\Delta TERM_t$			0.2879	0.5963	-0.0499	-0.2715		
$FInfl_{t-1}$			4.787	0.9909				
$F\Delta s_t$	0.8987	1.045	-0.8028	-2.491			-2.075	-1.050
$F\Delta indp_{t-2}$								
$F\Delta oil_t$								
γ	32.72	0.6729	41.09	0.3280	986.4	0.0060	1.001	1.136
c	-0.0209	-4.787	-0.0861	-20.73	-0.0656	-10.402	-0.0178	-0.1458
$S.E.$	0.0423		0.0406		0.0286		0.0481	
AIC	-6.2889		-6.3578		-7.0670		-6.0452	
R^2	0.38		0.38		0.48		0.39	
Diagnostics								
$AUTO$	0.0902		0.5535		0.0097		0.3891	
$ARCH$	0.4127		0.9655		0.1319		<0.0001	
$NORM$	<0.0001		<0.0001		0.3700		<0.0001	
Parameter constancy								
All coeffs.	0.3024				0.2944		0.6527	
Intercept	0.7925		0.3437		0.1345		0.3620	

Table 3: Single transition regressions
Notes: Diagnostic test results are p-values. Tests for autocorrelation (AUTO) and ARCH are LM tests up to lag 6. NORM is the Lomnicki-Jarque-Bera test.

	Ireland		Japan		U.K.		U.S.	
Variable	Coeff.	t-stat.	Coeff.	t-stat.	Coeff.	t-stat.	Coeff.	t-stat.
$const$	0.01375	3.468	-0.0527	-3.371	0.7796	44.94	0.0032	1.431
R_{t-1}	1.120	3.729	0.3967	1.760				
R_t^W	1.392	10.70			7.340	174.6	1.116	11.22
ΔDY_{t-1}	0.9594	3.344						
ΔSR_t					-0.2305	-4.590	1.115	5.187
$\Delta TERM_t$							0.5690	2.300
$Infl_{t-1}$			-12.21	-3.694	-9.060	-166.62	9.748	6.354
Δs_t	-1.341	-4.941	-0.1927	-2.113	-1.8256	-25.7852		
$\Delta indp_{t-2}$								
Δoil_t							-0.0442	-2.477
F			0.0466	2.882	-0.7732	43.999		
FR_{t-1}	-1.162	-3.518	-0.3537	-1.527				
FR_t^W	-0.8667	-4.955	1.016	14.99	-6.6880	-157.550	-0.3331	-3.035
$F\Delta DY_{t-1}$	-1.029	-3.298						
$F\Delta SR_t$							-1.352	-6.152
$F\Delta TERM_t$					-0.0956	-1.864	-0.8384	-3.284
$FInfl_{t-1}$			12.65	3.802	9.0673	167.308	-9.455	-5.962
$F\Delta s_t$					1.6468	24.120	0.5361	6.794
$F\Delta indp_{t-2}$								
$F\Delta oil_t$	-0.1066	-2.683						
γ	212.1	0.1752	10.32	0.6428	150.0	3195.0	150.0	4549.0
c	-0.0387	-50.50	-0.0701	-13.03	-0.09982	-91.393	-0.06839	-7.594
$S.E.$	0.0475		0.0382		0.0332		0.0233	
AIC	-6.0507		-6.4906		-6.7657		-7.4697	
R^2	0.47		0.57		0.55		0.72	
Diagnostics								
$AUTO$	0.7523		0.5357		0.0135		0.1005	
$ARCH$	0.0024		0.5357		0.0550		0.0829	
$NORM$	0.0846		0.4110		0.1297		<0.0001	
Parameter constancy								
All coeffs.	0.5953		<0.0001				0.0006	
Intercept	0.3689		0.0831		0.9403		0.1764	

Table 3 (cont.): Single transition regressions
Notes: Diagnostic test results are p-values. Tests for autocorrelation (AUTO) and ARCH are LM tests up to lag 6. NORM is the Lomnicki-Jarque-Bera test.

Transition Variable	Germany	Belgium	Canada	France	Ireland	Japan	U.K.	U.S.
R_{t-1}	0.7890	0.9785	0.4074	0.1877	0.8099	0.0077	0.7656	0.5041
R_t^W	<0.0001	0.5006	0.9020	0.1677	0.0391	0.1442	0.0333	0.0503
ΔDY_{t-1}	0.7189	0.6517	0.2683	0.7767	0.7847	0.0015	0.3753	0.4371
ΔSR_t	0.8235	0.6339	0.6992	0.0066	0.7704	0.0256	0.0098	0.2829
$\Delta TERM_t$	0.7770	0.6538	0.8429	0.0014	0.3881	0.1323	0.0003	0.4176
$Infl_{t-1}$	0.9296	0.8933	0.5905	0.2110	0.3541	0.4406	0.0459	0.0054
Δs_t	0.6880	0.5504	0.4977	0.1723	0.0190	0.2044	0.4680	0.3578
$\Delta indp_{t-2}$	0.2696	0.7256	0.3476	0.0651	0.4828	0.4006	0.8229	0.2535
Δoil_t	0.1354	0.4052	0.4265	0.4266	0.0862	0.0739	0.7467	0.0201
$Time$	0.3274	0.5118	0.0053	0.7424	0.8448	<0.0001	0.8487	0.0214

Table 4: Tests for remaining STR nonlinearity.
Notes: Additional nonlinearity test of Eitrheim and Teräsvirta (1996). The p-value is presented for a test for additional nonlinearity for each possible transition variable.

	Germany		Canada		France	
Variable	Coeff.	t-stat.	Coeff.	t-stat.	Coeff.	t-stat.
$const$	0.002443	0.9198	0.1566	4.697	0.0021	0.4175
R_{t-1}						
R_t^W	4.277	1.790	2.533	7.768	0.9417	7.769
ΔDY_{t-1}						
ΔSR_t	-1.816	-1.334			-0.1876	-0.8388
$\Delta TERM_t$			0.1077	2.020	-0.6793	-2.7478
$Infl_{t-1}$	3.730	2.287	-9.572	-3.347	4.5537	3.1200
Δs_t	-0.5744	-2.065	0.9098	5.166		
$\Delta indp_{t-2}$			0.1695	2.355		
Δoil_t						
F_1			-0.02652	-2.620	-17.9882	-0.9702
$F_1 R_{t-1}$						
$F_1 R_t^W$	-7.411	-1.360	-0.6481	-4.434	357.7678	1.0015
$F_1 \Delta DY_{t-1}$						
$F_1 \Delta SR_t$			0.1824	3.609		
$F_1 \Delta TERM_t$					-84.3900	-0.9637
$F_1 Infl_{t-1}$					666.0625	0.9585
$F_1 \Delta s_t$						
$F_1 \Delta indp_{t-2}$						
$F_1 \Delta oil_t$						
F_2			-0.1282	-3.819		
$F_2 R_{t-1}$						
$F_2 R_t^W$			-1.288	-4.456		
$F_2 \Delta DY_{t-1}$						
$F_2 \Delta SR_t$	18.24	1.415			0.4489	1.4589
$F_2 \Delta TERM_t$					0.8150	2.5437
$F_2 Infl_{t-1}$	-26.15	-2.144	9.4585	3.243	-6.2727	-2.1722
$F_2 \Delta s_t$					-1.9280	-3.8462
$F_2 \Delta indp_{t-2}$						
$F_2 \Delta oil_t$						
γ_1	0.5589	1.907	28.41	1.439	2.8248	2.8394
c_1	0.004867	0.2944	-0.02751	-19.440	0.1462	5.2817
γ_2	1.021	2.220	7.629	1.161	7.1217	0.6389
c_2	0.1042	2.629	-0.04889	-7.029	0.0142	2.1796
$S.E.$	0.03899		0.0294		0.0452	
AIC	-6.444		-6.993		-6.1321	
R^2	0.48		0.63		0.48	
Diagnostics						
$AUTO$	0.0698		0.052		0.1174	
$ARCH$	0.3008		0.207		0.0925	
$NORM$	0.8648		0.447		0.3431	
Parameter constancy						
All coeffs.	0.4558		0.2413		0.0867	
Intercept	0.6280		0.4571		0.7047	

Table 5: Two transition variable regressions
Notes: Diagnostic test results are p-values. Tests for autocorrelation (AUTO) and ARCH are LM tests up to lag 6. NORM is the Lomnicki-Jarque-Bera test.

	Ireland		Japan		U.K.		U.S.	
Variable	Coeff.	t-stat.	Coeff.	t-stat.	Coeff.	t-stat.	Coeff.	t-stat.
$const$	0.0147	3.7947	-0.006762	-2.435	0.01146	3.769	0.2518	1.415
R_{t-1}	2.1742	2.4964	0.4037	1.954	-2.692	-4.601	2.174	2.796
R_t^W	1.8975	3.3460	0.5045	3.741	1.979	11.50	3.555	2.881
ΔDY_{t-1}	1.9227	2.2599			-2.977	-4.879	2.038	2.498
ΔSR_t					-0.7302	-5.235		
$\Delta TERM_t$							0.3854	2.788
$Infl_{t-1}$			-10.87	-3.896	8.335	4.016	11.24	3.503
Δs_t	-1.2504	-4.8893			-0.8303	-3.385		
$\Delta indp_{t-2}$								
Δoil_t					0.2042	2.654		
F_1			-0.1017	-4.526			0.0518	3.385
$F_1 R_{t-1}$					3.059	5.003	-2.052	-2.561
$F_1 R_t^W$	0.4120	1.1606			-0.6305	-4.903	0.2990	2.310
$F_1 \Delta DY_{t-1}$			1.058	5.074	3.141	5.00	-1.853	2.310
$F_1 \Delta SR_t$	1.1479	2.8538	1.095	2.945	0.6344	3.77	-0.2565	-5.126
$F_1 \Delta TERM_t$	1.4056	3.0256			0.6293	3.532	-0.7192	-4.645
$F_1 Infl_{t-1}$			-6.608	-3.966	-4.3753	-3.368	-5.604	-3.143
$F_1 \Delta s_t$					0.9109	3.179	-0.8946	-2.473
$F_1 \Delta indp_{t-2}$								
$F_1 \Delta oil_t$	-0.3453	-2.3170			-0.2420	-2.989	0.2598	3.318
F_2							-0.3694	-1.525
$F_2 R_{t-1}$	-2.7371	-2.3850	-0.3414	-1.694	-0.2376	-0.9028		
$F_2 R_t^W$	-1.4608	-2.4673	0.5136	3.389	-0.9028	-5.047	-2.346	-2.211
$F_2 \Delta DY_{t-1}$	-2.5835	-2.5997						
$F_2 \Delta SR_t$								
$F_2 \Delta TERM_t$					-0.7160	-4.405		
$F_2 Infl_{t-1}$			11.41	4.065	-4.172	-2.322	-6.669	-2.254
$F_2 \Delta s_t$							1.627	4.268
$F_2 \Delta indp_{t-2}$								
$F_2 \Delta oil_t$	-0.1158	-1.9575	0.06190	2.157			-0.3518	-3.567
γ_1	6.5694	1.6226	126.5	0.3277	27.49	0.8575	11.01	2.384
c_1	0.0081	4.4128	-0.07145	11.64	-0.03797	-11.96	-0.07346	-7.986
γ_2	0.7475	1.6704	29.27	0.6689	165.70	0.5520	0.9088	2.940
c_2	-0.0821	-1.6614	-0.06761	-30.51	-0.0380	-12.21	-0.06926	-2.559
$S.E.$	0.0451		0.0406		0.03146		0.02297	
AIC	-6.1357		-6.5912		-6.83067		-7.4594	
R^2	0.53		0.63		0.62		0.74	
Diagnostics								
$AUTO$	0.9501		0.6791		0.4050		0.3106	
$ARCH$	0.0025		0.5787		0.1755		0.0211	
$NORM$	0.9609		0.1858		0.2275		0.3042	
Parameter constancy								
All coeffs.	0.4298		0.0082		0.0681		0.0037	
Intercept	0.2641		0.1749		0.6256		0.5694	

Table 5 (cont.): Two transition variable regressions

Notes: Diagnostic test results are p-values. Tests for autocorrelation (AUTO) and ARCH are LM tests up to lag 6. NORM is the Lomnicki-Jarque-Bera test.

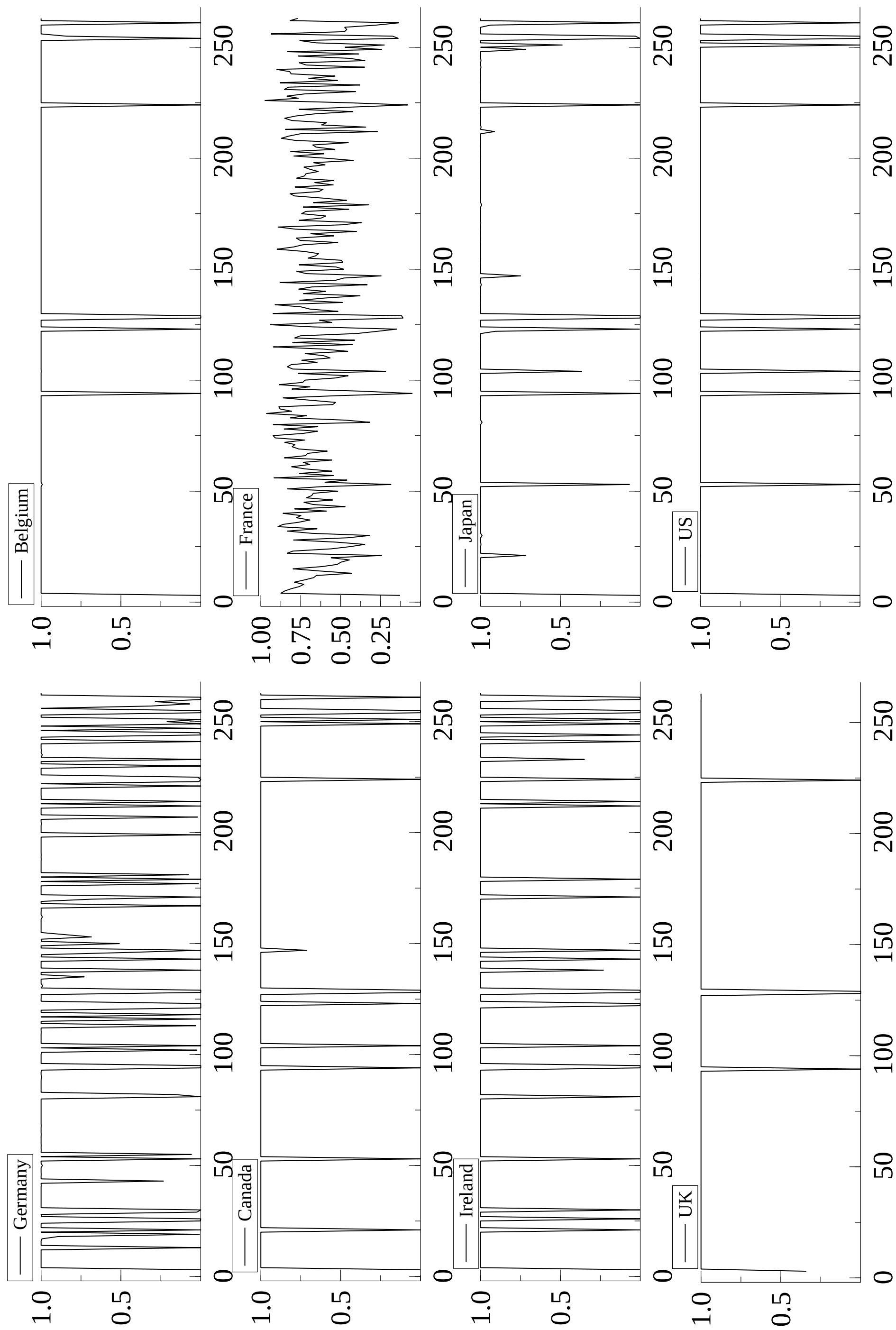

Figure 1 : Transition Functions over time.

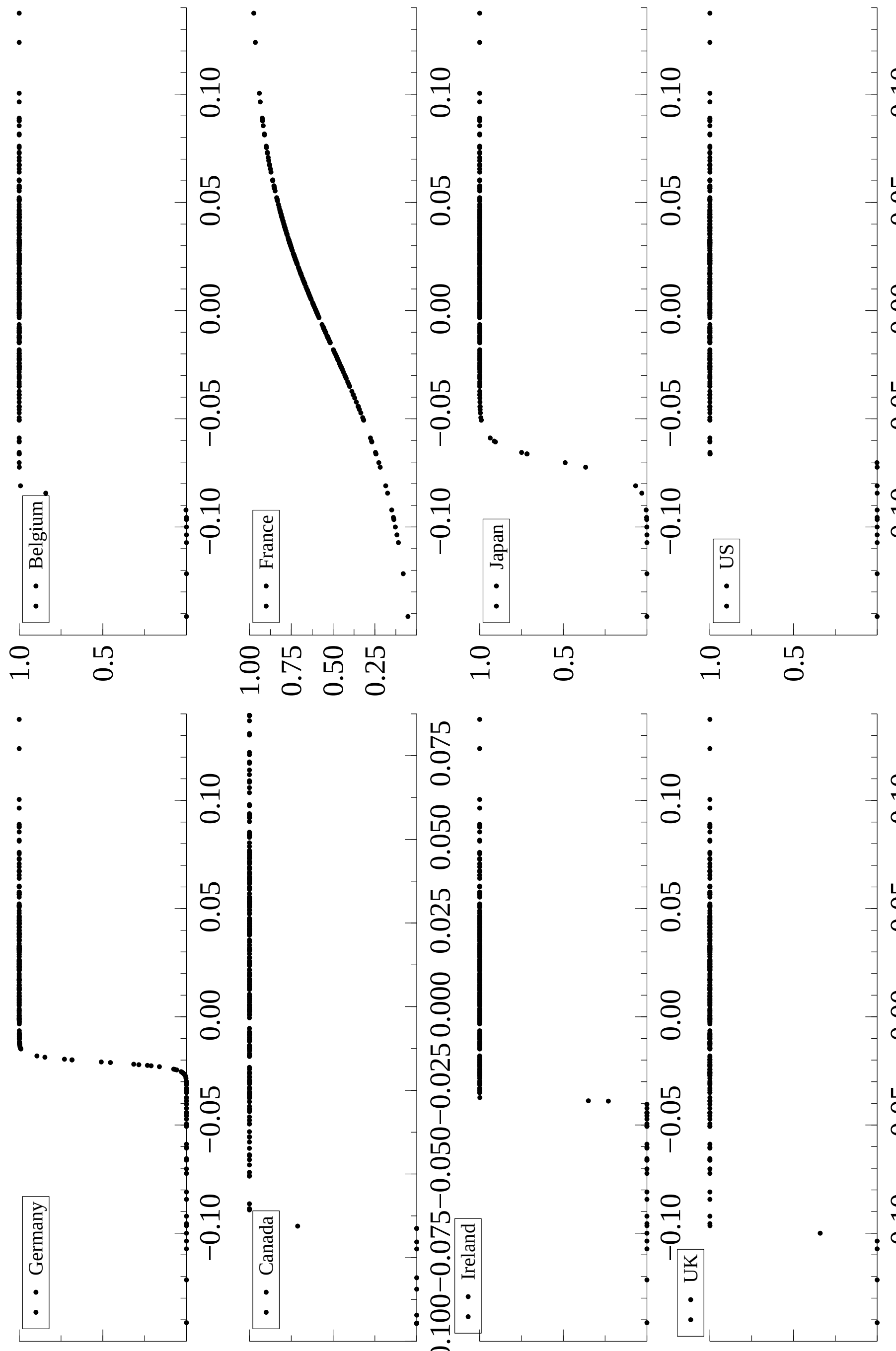

Figure 2: Transition Functions

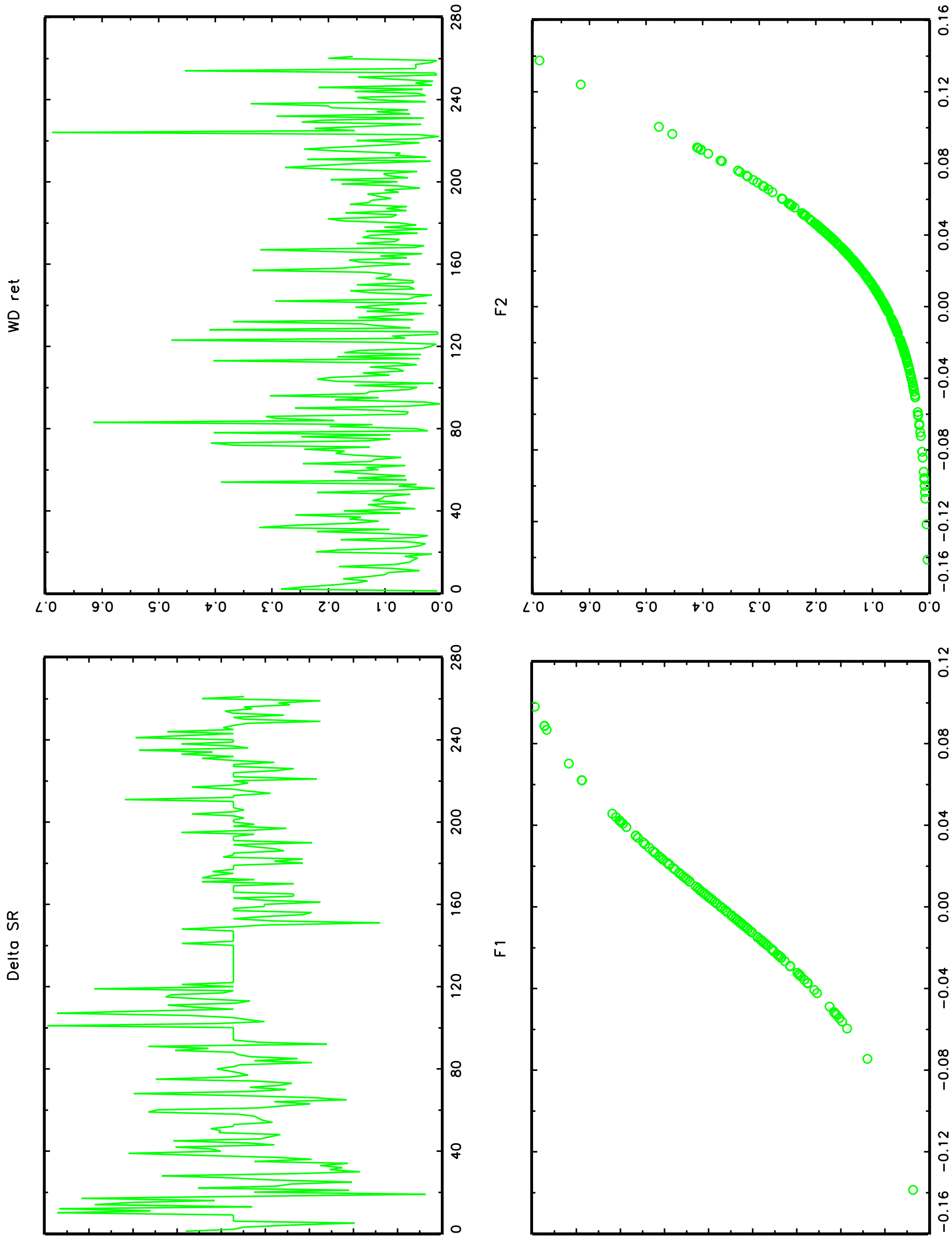

Figure 3a: Germany - Transition Functions

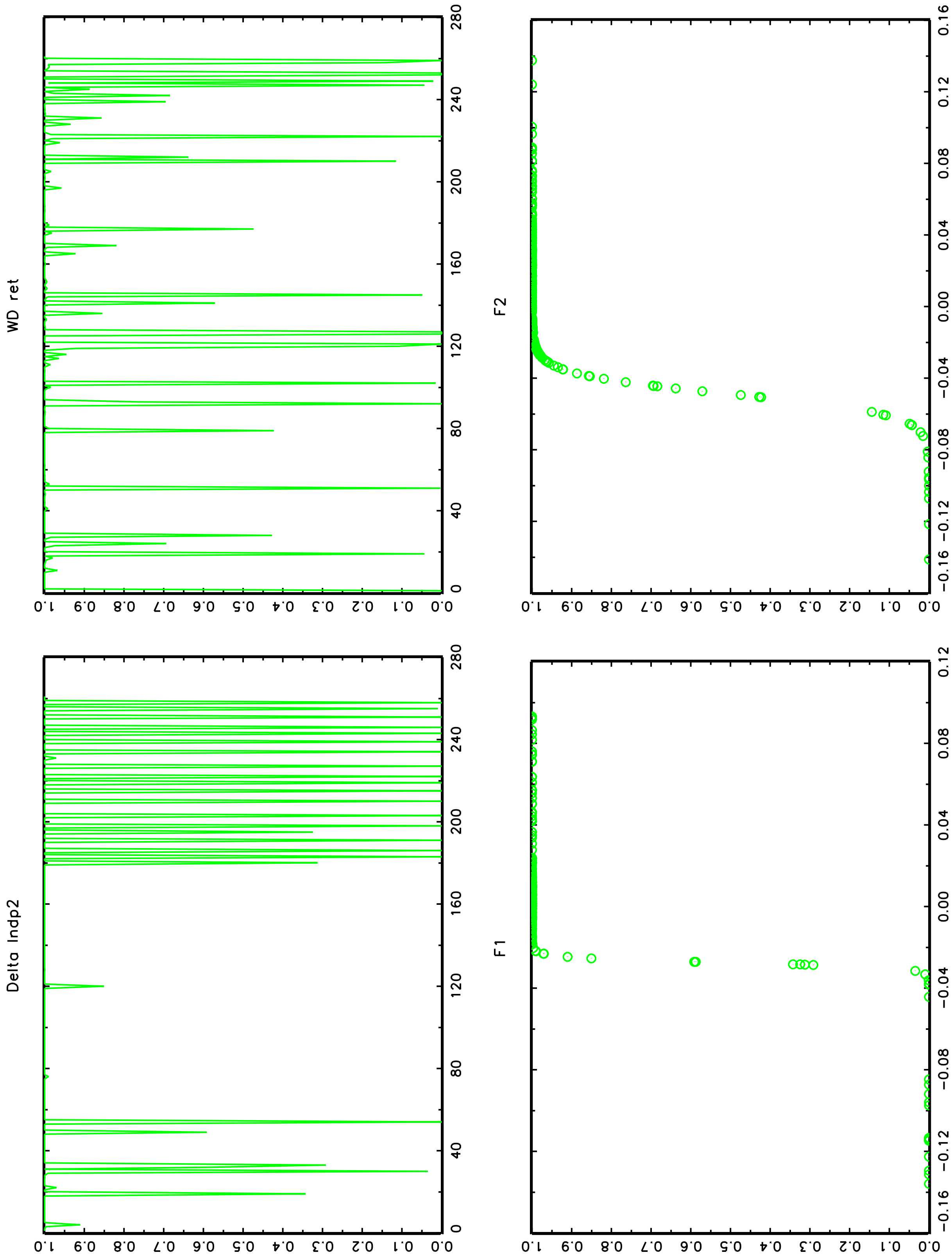

Figure 3b: Canada - Transition Functions

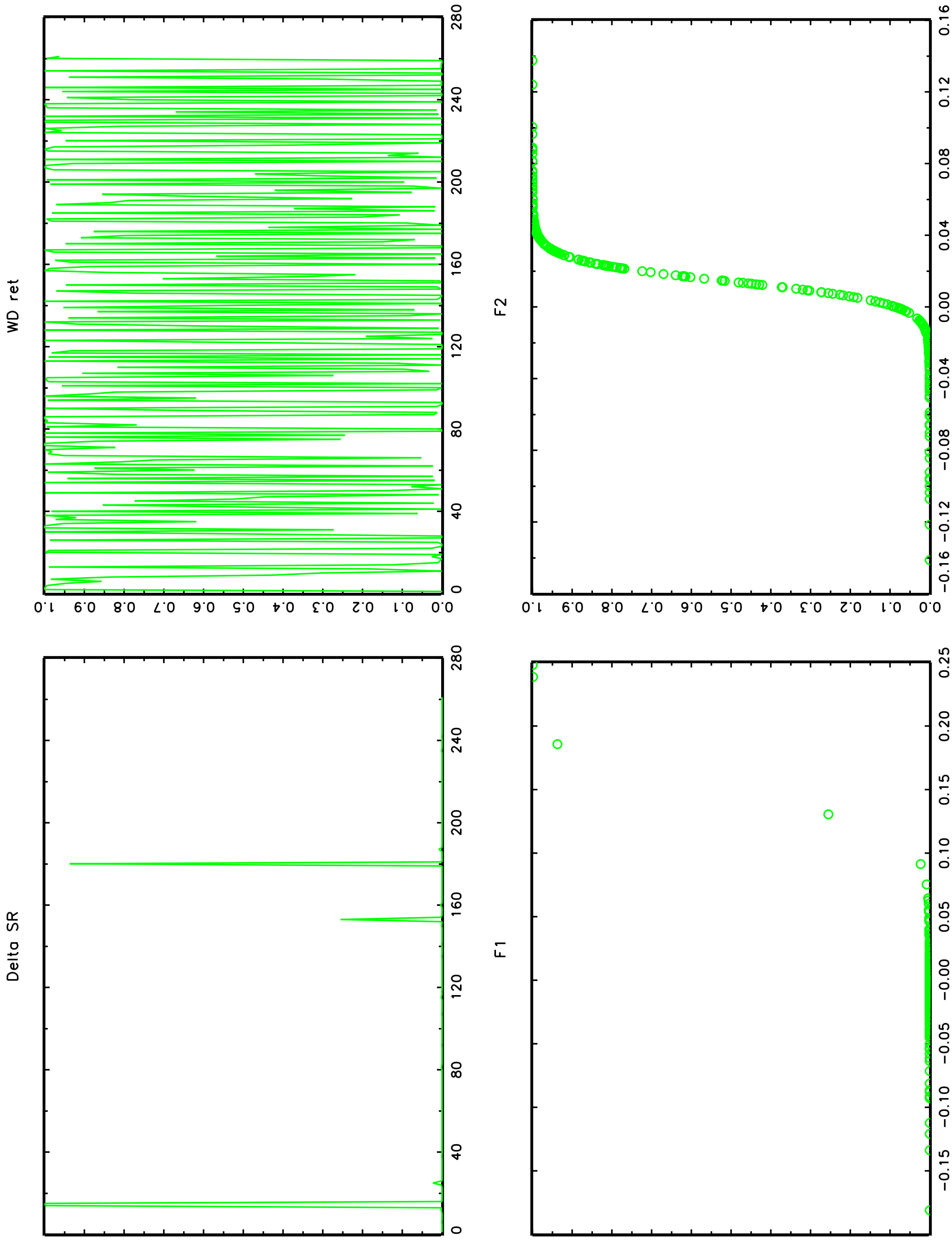

Figure 3c: France - Transition Functions

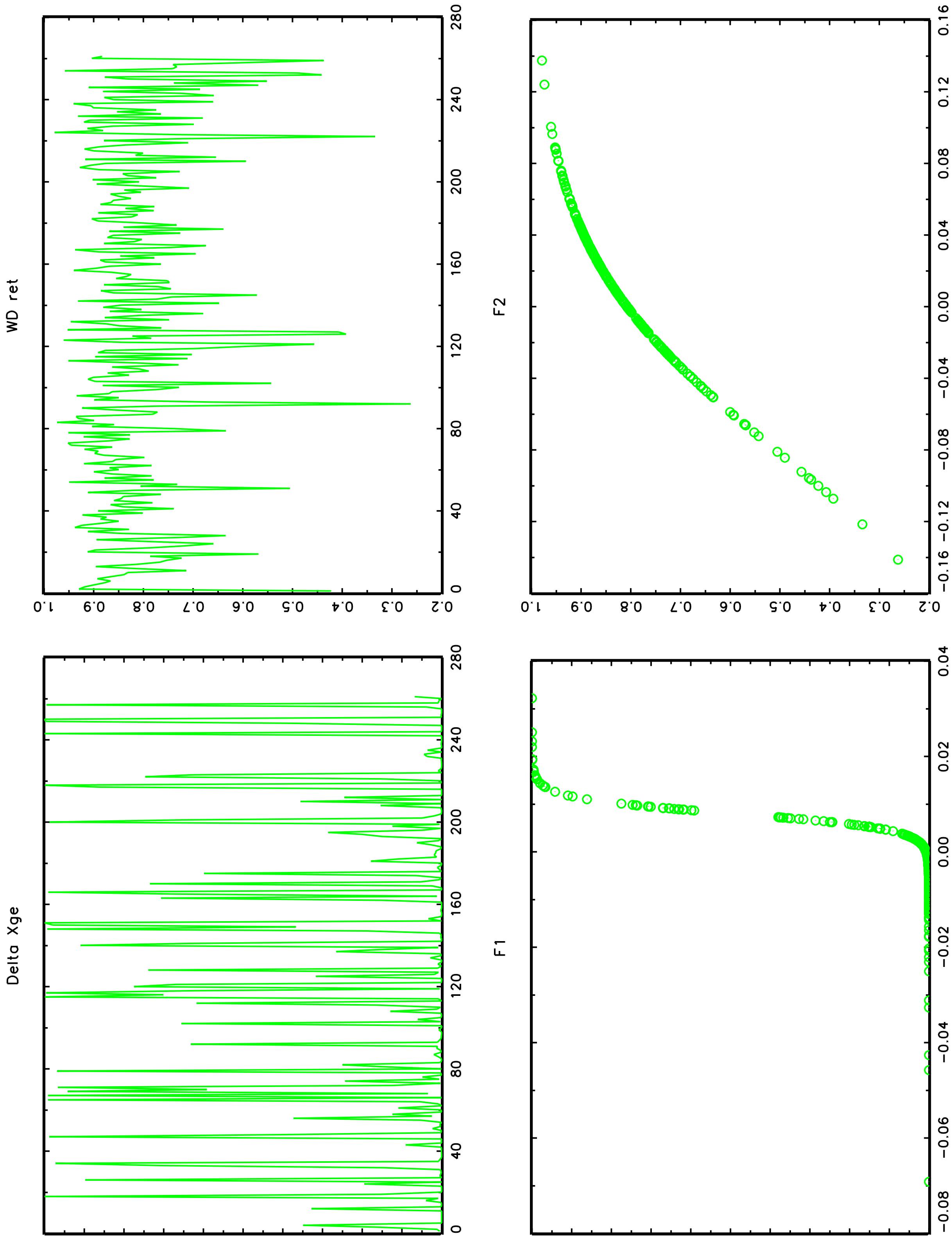

Figure 3d: Ireland - Transition Functions

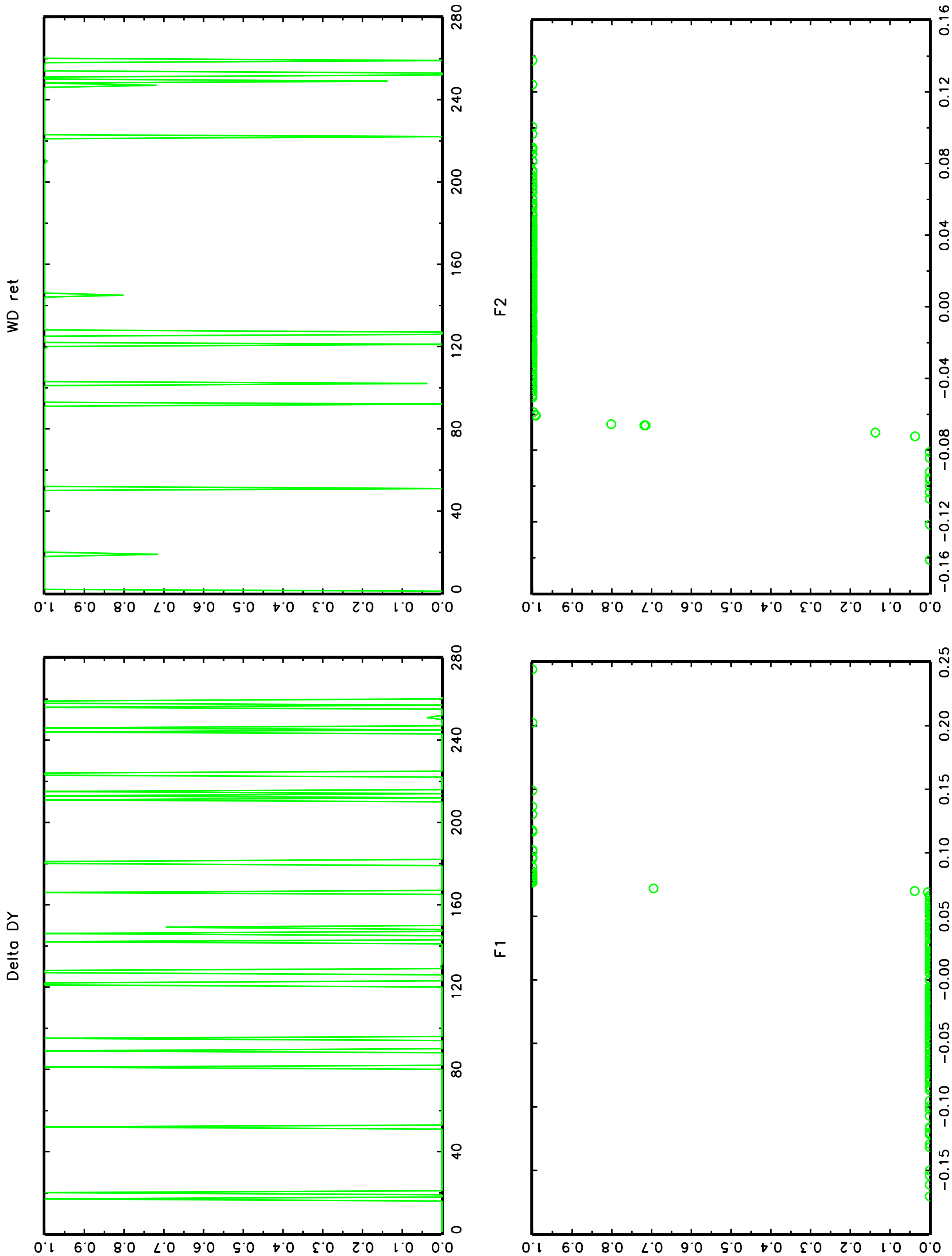

Figure 3e: Japan - Transition Functions

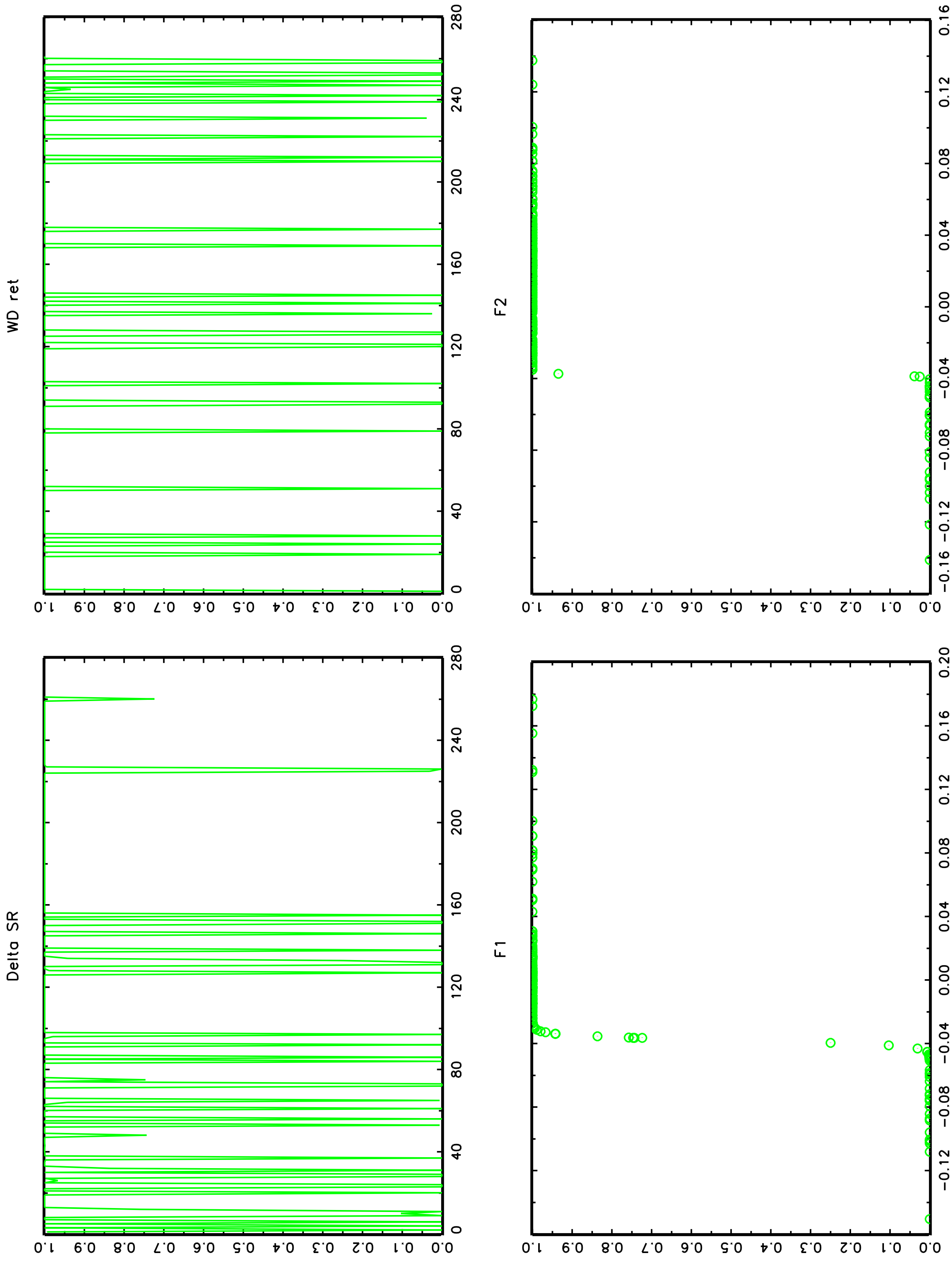

Figure 3f: U.K. - Transition Functions

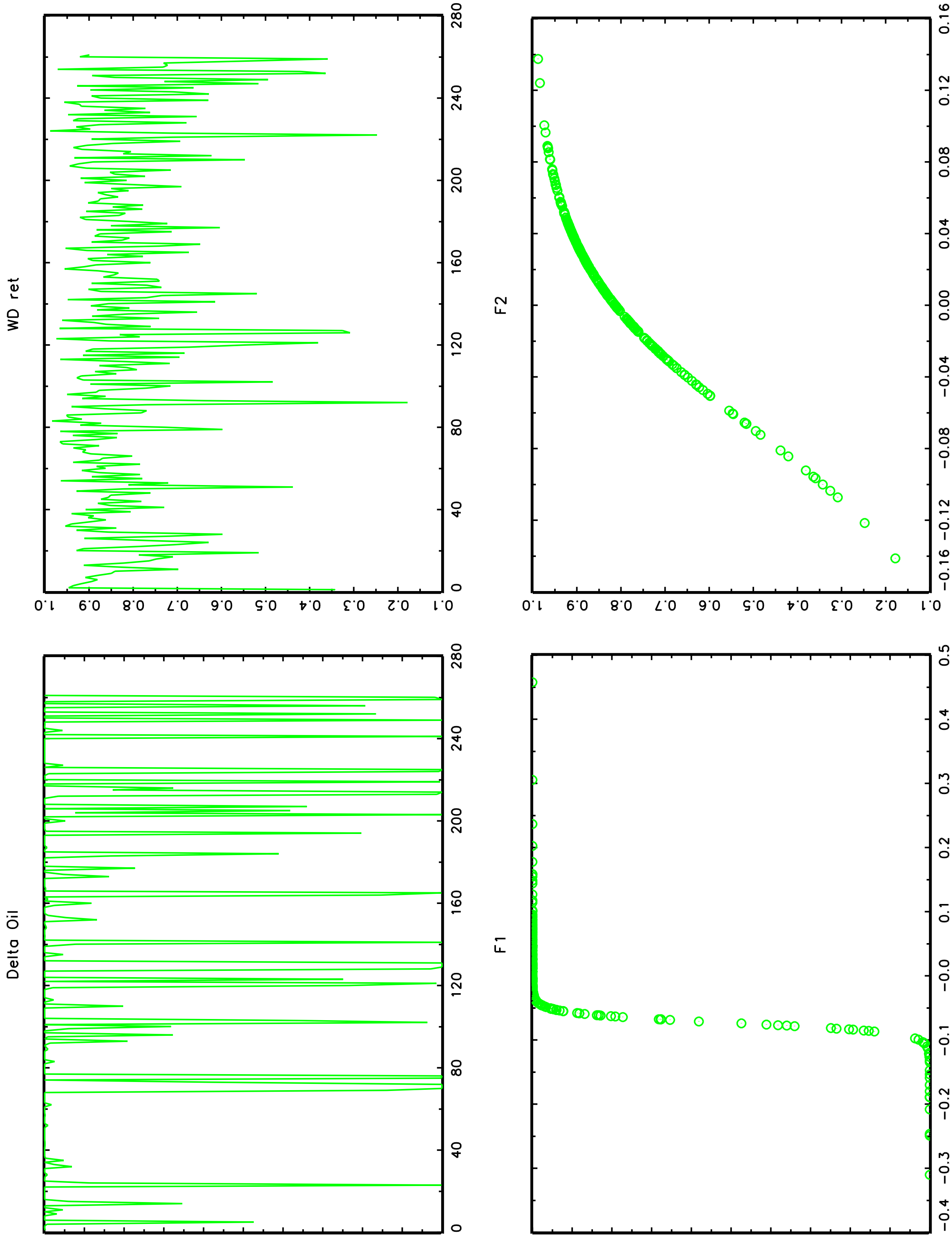

Figure 3g: U.S. - Transition Functions