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Document de travail

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Has the Adoption of Inflation Targeting Represented a Regime Switch? Empirical evidence from Canada, Sweden and the UK♠

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Abstract. Since 1990, a growing number of countries have adopted inflation targeting (IT) around the world. Empirical evidence on its advantages has been mixed so far, and most assessments have been based on a control group methodology. In this paper, using a MSVAR technique, we assess the adoption of IT in three industrialised countries over time; in addition, we compare their outcomes with a non-IT country, the US. Results are manifold. First, an inflation targeting regime exists, although it does not constitute a change in monetary policy reaction. Second, this conclusion is robust on a subsample excluding the periods of high inflation and early sharp disinflation. Third, the sacrifice ratio of higher output volatility generally attributed to inflation stabilisation policies is not sensitive to the adoption of inflation targeting. Fourth, this framework is shown to be conducive to higher monetary policy leeway.

Keywords. Inflation targeting; MSVAR; Counterfactuals

JEL classification. E52, E58.

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1. Introduction

Since 1990, a growing number of countries have adopted explicit inflation targeting (IT) around the world and many assessments have been performed. Although its early advocates (Bernanke et al., 1999) pointed to the many advantages of IT, empirical evidence has been mixed so far. One reason for this relatively poor evidence has been that in a world where inflation has declined substantially since the early 1980s, it is rather difficult to emphasize the country-specific impact of IT on inflation outcomes.

In this paper, we evaluate the existence of a regime switch after IT adoption in three industrialised economies: Canada, Sweden and the UK. Unlike most of the empirical literature so far, we do not perform immediately a comparison with non-IT countries. Our first intention consists in determining clearly the specific outcomes of these IT countries. Therefore, we report individual estimates for each of the three countries. Although they are relatively different one from the other, common results are interpreted as an indication of the existence of a specific behaviour under an IT regime. These common results do not only involve inflation outcomes but also the level of the monetary policy rate, output gap outcomes, and uncertainty. In a second stage, we compare these outcomes with those occurring in a non-IT country, the US. Hence, we are able to assess the robustness of our conclusions on the specificities of IT countries. Moreover, under this methodology, we circumvent the self-selection issue of the control group methodology where estimations are performed simultaneously on countries which are not fully comparable.

A multivariate Markov-Switching VAR model methodology, in the vein of Hamilton (1994) and Sims and Zha (2006), is applied to the three countries. Contrary to the latter, no subjective priors are introduced in the model and the number of endogenous variables is reduced. The framework is close to the New Keynesian type. Two types of model are investigated: model 1 with full changes, i.e. changes in coefficients and in intercept and variance; and model 2 where changes across “regimes” are only due to intercept and variance.

The main common results to the three countries can be summarized as follows. First, according to model 1, IT does not constitute a change in monetary policy reaction. Second, model 2 reveals the existence of a specific IT regime and a better predictability of policy responses under this regime. Third, the IT regime is robust to a change in the sample. Under a sample excluding the 1970s and early 1980s characterised by inflation volatility and the sharpest decline in inflation rates, the behaviour of the IT regime is shown to be quite different from that of other existing regimes. Fourth, the sacrifice ratio of higher output volatility generally attributed to inflation stabilisation policies is not modified under an IT regime. Last, the monetary policy leeway is shown to be higher during IT periods: inflation targeting actually permits to adopt a more flexible monetary policy strategy, *i.e.* low real interest rates.

The remainder of the paper is organised as follows. Section 2 deals with the characteristics of an IT strategy. Empirical evidence on IT countries is reviewed and the choice of the three countries and the underlying model is discussed. In section 3, the empirical methodology is presented and results are commented upon. Robustness checks and counterfactuals are performed. Section 4 summarises our conclusions.

2. A First Look at IT

2.1. Does it Matter?

A great deal of attention has been paid to IT in the recent literature devoted to monetary policy[1]. As such, this strand has advocated a general framing of monetary policymaking, encompassing clear targets, accountable policymakers and a flexible strategy. In the words of its promoters, e.g. Bernanke et al. (1999), inflation targeting should be viewed as a "framework" rather than as a prescription of adopting mechanical rules like the Taylor rule[2].

The essence of IT lies somewhere between rules and discretion, and has been labelled: "constrained discretion". In the words of his promoters: "*Inflation targeting is a framework for monetary policy characterized by the public announcement of official quantitative targets (…) for the inflation rate (…); by explicit acknowledgment that low, stable inflation is monetary policy's primary long-run goal; (…) (by) vigorous efforts to communicate with the public about the plans and objectives of the monetary authorities, and (…) mechanisms that strengthen the central bank's accountability for attaining those objectives*." (Bernanke et al., 1999, p.4). Later on, they add: "*By imposing a conceptual framework and its inherent discipline on the central bank, but without eliminating all flexibility, IT combines some of the advantages traditionally ascribed to rules (**discipline, stability**) with those ascribed to discretion (**flexibility**)*" (Bernanke et al., 1999, p.4, words in bold added).

The IT framework can be related to discipline in that it anchors expectations thanks to the publicly announced inflation target range; but it permits some flexibility: deviations from the target do not incur a loss of credibility and reputation provided the reasons for the deviations are explained to the public. This flexibility gives some leeway to monetary policy and gives IT framework a specific feature that the Taylor rule cannot fully retain.

In the recent past, some OECD countries turned formally to an IT regime (see table 6.1 in Ball and Sheridan, 2003): between New-Zealand, which did it in 1990, and Spain, which did in 1995, five others did like Canada, Sweden and the UK. These institutional regime shifts raised questions on their direct incidence on the optimality of implemented monetary policy, e.g., have (expected) interest and inflation rates been lower than in non IT countries?

Johnson (2002) and Ball and Sheridan (2003) made important contributions to the assessment of the effects of IT on the countries which adopted it, developing cross-country studies with a control group. Their conclusion were mixed: whereas Johnson produced evidence of lower expected inflation in IT countries after the announcement of targeting, Ball and Sheridan found no evidence of a beneficial impact of IT on a country's economic performance in comparison with non-IT countries. Economic performance was assessed using a very large scope of indicators: inflation, inflation variability, inflation persistence, output growth, output variability, long-term interest rates, and variability of short-run interest rates.

[1] A critical presentation can be found in Kuttner (2004).

[2] Beyond its potential mechanical feature, the Taylor rule poses two main problems. First, it may produce indeterminacies, either related to the price level (Woodford, 2001), or to the equilibrium trajectories (Benhabib et al., 2001). Second, Qin and Enders (2008) concluded that the out-of-sample forecasting performance of a US Taylor rule were better than a univariate AR model before 1979, but not after although the first assessment by Taylor (1993) pointed to its accuracy between the mid-1980s and early 1990s. The relevance of the Taylor rule for anchoring monetary expectations is at stake.

These latter results raised many doubts on the empirical validity of the methodology of adopting a control group. These doubts can be summarized by the following comments by Gertler (2003): "*(Ball and Sheridan) make two main arguments:*

1. *The existing evidence in favour of inflation targeting is open to identification problems.*
2. *After taking into account this identification problem, the evidence suggests that inflation targeting has been irrelevant.*

(…) The essence of the authors' argument is that the endogeneity of inflation targeting makes the existing evidence difficult to interpret. I will argue that this same endogeneity problem potentially clouds the interpretation of their empirical tests. In particular, to the extent that there is not much exogenous variation in the choice to adopt inflation targeting, it may be very difficult to identify the effects, particularly in a small sample. (…) (M)any of the nontargeters (if not just about all) (…) adopted monetary policies that were very similar in practice to formal inflation targeting. This lack of sharpness in the classification scheme further complicates the task of disentangling the contribution of inflation targeting."

Later on, Gertler (2003) gives an example of how a non-IT country may finally behave like an IT one without officially adopting IT : "*Even though Norway is not officially a targeter, it appears to have tied its monetary policy to a country that does inflation target (i.e., Sweden). It has done so by stabilizing its currency relative to the Swedish currency. In doing so, it may have reaped the benefits from inflation targeting.*"

Despite this criticism, other empirical papers using a cross-country study have recently validated Ball and Sheridan (2003)'s early results. For instance, Angeriz and Arestis (2007) do not find a significant break in the estimated evolution of inflation in the UK after the adoption of inflation targeting. Comparing with a control group made of the US and EMU shows that central banks which do not pursue IT strategy have performed "at least as well" as the UK. According to the authors, this is not surprising since "*in the UK, IT was introduced after inflation had been tamed.*"

On the contrary, Levin et al. (2004) show that in comparison with non-IT countries, inflation targeters have been able to better anchor long-run inflation expectations and have experienced lower inflation persistence.

Using a more sophisticated methodology, Cecchetti et al. (2002) conclude that the extent to which IT exerts a measurable influence on monetary policy is limited. They quantify the monetary transmission mechanism of EU countries using a structural autoregression approach; then, they compute the revealed preferences of each national central bank in terms of the trade off between inflation and output variability to gauge differences among targeters and non-targeters. They conclude that differences are minimal.

These different papers are all confronted with the control group problem first enlightened by Gertler (2003) in this strand of the literature, but they are also with the self-selection problem of policy adoption (Lin and Ye, 2007): what may have led actually to lower inflation in IT countries was their decision to aim specifically at lower inflation than in earlier (pre-IT) periods. As Anna Schwartz has been attributed to put it, IT would be "window-dressing".

Lin and Ye (2007) produce a statistical assessment of the possible effects of inflation targeting strategy on inflation, inflation variability, long-term interest rates and the income velocity of money using propensity score matching methods. They claim to address the self-

selection problem of disentangling between IT and non-IT countries. Their dataset incorporates seven IT countries (Australia, Canada, Finland, New Zealand, Spain, Sweden, and the UK) and fifteen industrial non-IT countries. They conclude that IT has had no significant effects. Whereas propensity score matching is of particular interest in micro empirics, the reliability of this method applied to macroeconomic data remains questionable: matching aggregates is confusing[3], the control group problem remains[4], and the use of annual data seems to stand in opposition with the need for a very large dataset.

A new strand of the literature has developed which permits to date breaks and new regimes while letting data speak. The use of Markov-Switching VAR (MSVAR) can relaunch the interest for empirical studies applying time series technique. It also enables to circumvent the control group problem and to study thoroughly the different regimes which have occurred in these IT countries. Moreover, the choice of regimes rather than pure breaks enables to check the argument that good monetary performances in IT countries had already existed in the past, either shortly before its adoption or hand-in-hand with the "Great Moderation" process, *i.e.* exogenously to IT adoption.

Unlike earlier attempts (see Ammer and Freeman, 1995), sufficiently-long samples since IT adoption will eventually produce the occurrence of a new regime. Ammer and Freeman had estimated a canonical VAR whose sample stopped just before inflation targets were first announced, and then, they compared actual values for GDP, inflation, and the real interest rate with the (out-of-sample) forecasted ones. They interpreted the difference between both variables – actual and forecasted – as evidence of a change of regime. Using MSVAR technique can reveal a new regime rather than assume it.

Moreover, the MSVAR permits to go further than only checking for a change in regime that would only occur at the level of the monetary reaction function[5]. First, tests of these functions generally do not capture multiple shifts in variance because they do not make enough allowance for heteroskedasticity. Second, identification of forward-looking monetary reaction functions is generally fragile.[6] Third, inflation-targeting is not about interest rate rules but it is a conceptual framework which promotes the optimality of constrained discretion for monetary policy.

2.2. Selected countries

In the following, we concentrate on three industrialized IT countries, the biggest ones among the best performers[7]: Canada, Sweden and the UK. The reasons for the choice of these three countries have been twofold. First, the choice has been driven by the need of some similarities

[3] Heckman et al. (1997) and Heckman et al. (1998) showed that data quality and information content are a crucial ingredient to any reliable estimation strategy. Such aggregates like inflation, broad money growth and government fiscal balance, may hide high differences, *e.g.* seemingly comparable fiscal balance may stem from different variations in cyclically-adjusted and automatic components, therefore indicating different fiscal stances.
[4] All countries have experienced common macroeconomic evolution (for instance strong disinflation) and the authors themselves note that "*one can reasonably suspect that the low inflation (variability) might be caused by some common uncontrolled factors that affect both targeting and non-targeting countries*".
[5] Muscatelli et al. (2002) conclude on the instability of univariate estimations of forward-looking interest rate functions in the case of inflation targeting countries. Kuttner (2004) estimates forward-looking rules to assess the flexibility of central banks' strategies distinguishing IT and non-IT countries.
[6] These first two remarks are developed in section 2 of Sims and Zha (2006).
[7] Gosselin (2007) ranks UK, Canada and Sweden respectively 2nd, 4th and 5th in terms of mean absolute deviation of actual inflation from target. Switzerland and New Zealand are ranked respectively 1st and 3rd.

among them; a minimum set of similarities is required to perform a sensible international comparison. But, second, a minimum set of differences is also required in that it enables to assess the robustness of IT country-performances: despite differences, the fact that IT performances may be comparable would be an answer to the papers which state that monetary institutional design cannot explain a change in policy outcomes and that these changes come fully from external factors, like the exchange rate or the world disinflation era of the early 1980s to 1990s, *i.e.* the so-called "Great Moderation".

Among the similarities between these three countries, one finds that they are in a flexible *de jure* exchange rate regime and are part of trade agreements which make competitiveness a crucial growth factor: Sweden and the UK are European Union members, hence part of the EU Single Market; unlike Spain, which was an inflation targeter between 1995 and 1998, they have not adopted the Euro. As for Canada, it is part of the North American Free Trade Area. The three countries can also be considered to follow a *de facto* peg regime: Sweden and the UK are mimicking the ERM II, except during financial turmoil; and Canada looks like having a peg with fluctuation bands *vis-à-vis* the US dollar.

Among the differences, one finds economic structures and the respective degrees of openness. Canada benefits from abundant natural resources, whereas the UK has a prominent part of its economy that is driven by the tertiary sector. Sweden stands halfway between those two, with industrial activities and services taking a prominent share of overall activity. Moreover, the size of the UK economy is paramount in comparison with Canada and even more so in comparison with Sweden. In 2007, Canada's GDP, expressed in volume and in PPP figure, represented 58% of UK's; and Sweden's only 16%, based upon OECD data. As for the degree of openness, which may have an impact on imported inflation, it was similar for Canada and the UK in 2007 (total imports were worth 34% of GDP), but Sweden was much higher (67%).

IT has been adopted in Canada in February 1991 and has been in its completion form at the end of 1995 when the decelerating path of inflation[8] was transformed in a fixed target range. The same process has taken place in the UK: an adoption in October 1992 and a completion in May 1997 that corresponds to the statute change of the Bank of England and its independence declaration. In Sweden, IT has been adopted in January 1993 with the objective to be fully applied in January 1995. Contrary to the other countries, the inflation target has remained the same since the beginning of the IT regime and no decelerating path of inflation occurred.

2.3. Data and the underlying model

We use monthly data, from 1971:1 to 2006:12 for the UK and Canada and from 1987:1 to 2007:12 for Sweden[9]. The interest rate is the central bank reference rate as advertised by central banks themselves. The inflation rate expressed in month-over-month growth rate is the measure of inflation targeted by central banks. For the UK, the series is extrapolated from RPIX, RPI and CPI-H, the harmonised index of consumer prices. In Canada, the series is the CPI excluding eight of the most volatile components; and for Sweden, UND1X is used. In the latter two countries, the targeted measure corresponds to core inflation. The output gap

[8] On most figures, the transition period between the adoption of IT and its completion in final form has been represented by a grey area.

[9] We extend the Sweden sample until 2007 although data will certainly be adjusted, because the MSVAR methodology needs long time series and this particular sample starts only in 1987.

measure is the interpolated monthly measure of the OECD[10]. The inflation variables are expressed in first difference of the price index and all variables in the VAR and MSVAR are expressed in percent.

Models with three to six variables have been tested; they have always included the central bank interest rate, the inflation rate (either CPI, GDP deflator or core CPI), and the output gap, and they have been extended to real GDP, M2, energy prices and/or exchange rate.

Contrary to Sims and Zha (SZ, 2006) who always include a monetary aggregate, commodity prices and the unemployment rate, we have finally focused on a smaller structural model comprising only three endogenous variables: the output gap, the nominal short-run interest rate and the officially-targeted CPI index. The focus on core inflation in Canada and Sweden, in line with their central banks' objectives and in countries which are highly opened to international trade, challenges the possible drawback of an analysis undertaken in a closed economy framework because imported inflation plays a relative minor role in core inflation.

Residuals of the canonical VAR model extended to include M2 are reported in Appendix A. They help to legitimate the three-variable-only VAR. Three results emerge. First, adding M2 has no noteworthy effects on the residuals of the interest rate, the output gap and the inflation rate. Exception is the UK as far as the inflation rate is concerned: the fit with M2 is worse than without this variable. Second, the overall fit of the canonical VARs is poor. Third, multiple shifts in variance have occurred in the three countries and point to the adoption of a more sophisticated methodology like MSVAR.

Disregarding M2, as it does not seem to improve the fit, has two additional advantages. First, it saves some degrees of freedom, and this is important specifically for countries like Sweden for which data are available on a very short time period, but also on general grounds because MSVARs are pretty much "data-consuming": the number of parameters to estimate depends on the number of variables, lags and states and can quickly be explosive[11]. Second, no *ad hoc* restrictions are needed to separate money demand and supply, or to make sure that money demand (supply) reacts negatively (positively) to the interest rate.

The three endogenous variables fit also relatively well in the new Keynesian framework which has developed at the same time as the IT literature. However, the underlying model cannot retain all the specificities of the new framework (see Walsh, 2003, for a presentation), which can be described by:

$$x_t = E_t x_{t+1} - \frac{1}{\sigma}(i_t - E_t \pi_{t+1}) + u_t$$
$$\pi_t = \beta E_t \pi_{t+1} + \kappa x_t + e_t$$
$$i_t = E_t \pi_{t+1} + \alpha(E_t \pi_{t+1} - \pi^T) + \gamma x_t$$

where x is the output gap, i the nominal short-run interest rate, π is the inflation rate, E is the expectation operator, σ is the marginal utility of consumption, π^T is the inflation target, and u and e are disturbances. The first equation is the demand side of the economy, representing a linear approximation to the representative household's Euler condition for optimal

[10] Despite an empirical agnostic approach (see *infra*), the use of a computed measure like the output gap will permit to interpret the results in terms of the new Keynesian framework (see also *infra*).
[11] With n variables, p lags and m states, there are $m \times (n \times (n \times p + 1) + (n \times (n - 1)/2)$ parameters for the VAR plus $m \times (m - 1)$ elements in the transition probabilities matrix.

consumption (hence, the expectational IS curve); the second equation gives inflation whose adjustment is derived under the assumption of monopolistic competition, with individual firms adjusting prices in a staggered, overlapping fashion; the third equation involves monetary policy represented by a rule for setting the nominal interest rate.

Within a VAR representation, the above 3-equation model would be based on a reduced-form which would make impossible to distinguish regimes shifts from one structural equation to the other[12]. Thus, we adopt the nonlinear stochastic dynamic simultaneous equations model of SZ (2006). Moreover, lags are included and the empirical model will depart from a *pure* new Keynesian model which predicts nearly no persistence, except that coming from shocks u_t, e_t or the inflation target π^T [13]. The fact that the general framework is close to the new Keynesian *fully coherent* framework will permit to interpret on economic grounds the different results deriving from the estimated model.

3. A MSVAR Analysis

3.1. Methodology

3.1.1. The Multivariate Markov-Switching Model[14]

The Markov-Switching VAR, as proposed by Hamilton (1994), allows the structural coefficients and the covariance matrix to be dependent on an unobserved state variable S_t which is assumed to follow a 1st order Markov chain. The joint distribution of the shocks can be non-constant across our sample periods.

The general framework is described by the following equation:

$$\begin{cases} y_t = x_t \cdot \beta_{S_t} + u_t & t = 1,...,T \\ u_t \left| S_t \sim N(0, \Sigma_{S_t}) \right. & S_t = \{1,...,M\} \end{cases} \tag{1}$$

where $y_t = (y_{1,t},...,y_{p,t})$ is an $1 \times n$ vector of endogenous variables, with n the number of variables of interest, x_t is an $1 \times np$ vector of p lagged endogenous variables, S_t is an unobserved state, β is an $np \times 1$ vector of parameters, T is the sample size and M the number of states (or regimes). This baseline equation of the model is free of restrictions[15].
The covariance matrix Σ_{S_t} takes the form:

$$\Sigma_{S_t} = \sigma_S^2(S_t) \cdot I_p$$

[12] The 1st and 3rd equations of the system under a reduced-form involve the disturbance on inflation.
[13] See Gali et al. (2001) for an empirical characterisation of "hybrid Phillips curve", where inertial processes are introduced in the new Keynesian setting.
[14] See Hamilton (1994, chapter 22) for more in-depth details.
[15] Since we do not know *ex ante* the possible changes of monetary policy effects implied by IT and because the empirical approach is data driven (*i.e.* we are looking for what data tell us about this framework setting aside any preconceived conclusions), we do not impose restrictions on parameters. The *ad hoc* nature of restrictions is opposed to the seminal motivation of our methodology. The use of Bayesian techniques, though it represents a great advancement in structural estimation, run up against the same motivation. Indeed, the link between estimation and calibration is strong and depends on subjective priors, which we chose not to use. In the end, the nearest method to Bayesian one is the Maximum Likelihood's, which is free of calibration as our approach needs.

The transition probabilities matrix, noted *P*, is defined following Hamilton (1994):

$$P = \begin{pmatrix} p_{11} & \cdots & p_{M1} \\ p_{12} & \cdots & p_{M2} \\ \vdots & \cdots & \vdots \\ p_{1M} & \cdots & p_{MM} \end{pmatrix},$$

with $\sum_{j=1}^{M} p_{kj} = 1$ and $p_{kj} \geq 0, \quad \forall k, j \in \{1...M\}$.

Two models are tested:

$$y_t = (1_n, y_{t-1}, ..., y_{t-p}) \cdot \beta_{S_t} + u_t$$

$$y_t = 1_n \cdot \beta_{S_t} + (y_{t-1}, ..., y_{t-p}) \cdot \delta + u_t$$

and can be written as:

$$y_t = x_t \cdot \beta_{S_t} + z \cdot \delta + u_t \qquad (2)$$

M different models are then simultaneously estimated such as:

$$(1_p \otimes y_t) = x_t \cdot (\beta_1 | \cdots | \beta_M) + (1_p \otimes z_t) \cdot \delta + (u_t^1 | \cdots | u_t^M)$$

and leads for a given regime $S_t = j$ to:

$$\begin{cases} y_t = x_t \cdot \beta_j + z_t \cdot \delta + u_t \\ u_t | S_t = j \sim N(0, \Sigma_j) \end{cases}$$

Initial values of the vector of parameters are calculated. A conditional probability density function is defined according to the information set in t-1. The model is recursively estimated through the Maximum likelihood "EM" algorithm, starting from the unconditional density of y_t which is calculated by summing conditional densities over possible values for S_t. The maximum likelihood estimates are finally obtained by maximizing the log-likelihood function and allows to attain the final matrix of parameters.

3.1.2. Specification

Based on Hamilton (1989, 2004)'s method and SZ (2006)'s work, various specifications were considered in which the numbers of regimes and lags were allowed to vary. We considered specifications in which coefficients and residual variance switch and specifications in which only intercept and variance switch. In light of some SZ's findings, we have not tried "particularly ill-fitting models" like those with a single regime or those in which regime changes are constrained to never occur again.

With the 3-variable VAR (see *supra*), we allowed for 2 or 3 regimes to occur on the whole sample. Because of our interest in inflation, at least two regimes were possible: one with relatively high inflation, around the successive oil shocks of the 1970s, and one with relatively low inflation thereafter. A third regime may have therefore occurred since IT regime was adopted, separating the second period into two distinct ones.

Therefore we favour the 3-state specification. SZ (2006) have analysed a 4-state specification, but the 4th regime is rare and it always occurred during geopolitical crises: Tehran's hostages in 1980, the beginning of the 1st Irak war in 1991, and 9/11. The three countries under study were not engaged in comparable events and with comparable intensity so that a 4th regime does not seem necessary.

The Schwarz criterion for the 3-variable VAR specification gave the following numbers of lags: $p = 3$ for Canada, 4 for Sweden and 5 for the UK.

3.2. Regime Switches

3.2.1. Full Changes

In this section, we present the key results of the 3-equation specification with changes in coefficients and variances. This pattern is of interest because it follows the widespread idea that monetary policy and the structure of the economy have changed significantly since the late 1970s[16]. It may first capture the main characteristics of this conventional wisdom and may also describe the policy change ensuing from IT adoption.

Figure 1 depicts the implied state-probabilities[17] over time produced by this model for Canada. Regime 1 did not prevail before the beginning of the 1980s, dominated the end of this decade and has been the main regime since roughly the middle of the 1990s. Regime 2 dominated the 1970s and has appeared sporadically since then, whereas Regime 3 occurred almost exclusively between 1979 and 1982. Regime 1 seems to fit best during IT period, but occurred before that period, while Regime 2 also occurred under IT. Regime 3 almost disappeared with completion of IT. The steady-state probabilities range from 0.51 for Regime 1, 0.36 for Regime 2, to 0.13 for the last one.

Figure 2 describes the state probabilities for the UK. Regime 1 prevailed since the beginning of the sample, with a probability of occurrence rising over time. Regime 2 occurred during almost the whole sample but did not ever significantly; whereas Regime 3 took place in the 1970s, and progressively lost influence during the 1980s to finally disappear at the beginning of the 1990s. The adoption of IT does not seem to have corresponded to a regime switch, but more to the continuation of the main 'old regime'. The disappearance of Regime 3, the second most prominent over the full sample, corresponds to the date of adoption of IT. More than half of the steady-state probability (0.64) is associated with Regime 1, whereas Regime 2 has a probability of 0.16 and Regime 3 of 0.20.

Figure 3 focuses on state probabilities for Sweden. Regime 1 prevails mainly after IT adoption, but irregularly so. Indeed, Regime 2 has also occurred after (and only after) 1993, always in place of Regime 1. Regime 3 took place only before IT and never after. Finally, the probability of standing in Regime 1 is 0.41, to be compared with 0.42 for Regime 2 and 0.17 for Regime 3.

In the three cases, a regime appears to end with IT, but IT periods are shared between 2 regimes (Canada and Sweden) and/or characterized by a regime that already occurred significantly before (Canada, UK and Sweden).

[16] See, e.g. Clarida et al. (2000).
[17] Figures depict at each date the average probability to stand in the corresponding regime over the last 6 months.

These findings tend to prove that IT adoption has not constituted a monetary policy change *per se*, contrary to the above-mentioned conventional wisdom. However, the methodology reveals that adopting IT in the 3 countries clearly meant that a pre-existing regime was taken to an end.

These results lead to focus on the intercept and variance only specification where coefficients are kept fixed on the whole period. Thus, it allows to shed light more precisely on the variation of the non-coefficients changes. This specification has been shown to correspond to the best-fit model of SZ (2006) with US data.

3.2.2. Intercept and Variance only

Contrary to the previous section, coefficients are assumed to be the same across regimes, and we focus on whether the change of monetary policy framework has induced changes in disturbances terms.

Figure 4 shows the probabilities across time for Canada. Regime 1 seems to emerge significantly with the completion of IT, while Regime 2 and even more notably Regime 3 appear to vanish during the same period. The state probabilities are respectively 0.33, 0.54 and 0.13 on the whole sample. A transition period during the IT period has occurred in Canada, where Regimes 2 and 1 are complementary.

Figure 5 presents the probabilities of regimes occurrence for UK. Here again, two regimes (the 1st and 3rd) disappear with the development of IT but, contrary to Canada, the regime that characterizes IT has occurred from the beginning of the sample. However, uncertainty around this regime is null after the adoption of IT while much higher before (because Regime 1 and 3 occurred several times during the pre-period), meaning it better fits IT-period than pre-IT-period. The state probabilities are 0.05, 0.75 and 0.20.

Figure 6 displays the probabilities for Sweden. The results are quite straightforward: Regime 1 occurred quite consistently after the adoption of IT, Regime 2 before and Regime 3 during the transition period. The state probabilities are 0.69, 0.25 and 0.06 respectively.

At this point, we can find a regime in each country which fits the IT period. In the case of the UK however, the regime has almost always existed, though uncertainty surrounding it is the lowest during the IT period.

Matching regimes with IT period requires more than chronological coincidence. Attributing the regime switch to IT adoption can be handled along the following procedure. One can check that the regime which matches IT chronologically does it also in terms of the properties which are attributed to it. The IT framework assumes that the monetary policy regime can mix discipline and flexibility and can reduce overall variability (see *supra* and Kuttner, 2004). Discipline, in the vein of Barro and Gordon (1983), should refrain central banks (or government in their seminal framework) from using their instruments, hence taming their ‘inflation bias’. Consequently, deviations of variables from their steady-state values would be minimal. Policy flexibility after a shock, insofar as it cushions the shock and helps variables to converge towards the steady-state, produces the same effect. All in all, IT should produce lower uncertainty regarding inflation and output.

Within a setting where coefficients remain constant, the reducing-uncertainty property of IT can be captured by the values of the constant terms and the variance in the inflation and output gap equations. Restraining to variance only may hide sharp moves in inflation or output gap that would appear in the constant term.

In dealing with the specific patterns of the regime we wish to attribute to IT, it is worth noting that group transition matrices for all countries and specifications[18] show that the three states behave quite differently. It means that the regime we wish to attribute to IT behaves differently from the other two regimes. Moreover, a glance at the values of the constant terms and the variance which are reported for the three countries in table 1 gives straightforward results. Indeed, it is very clear that regimes which have been considered so far to correspond to IT are effectively those for which uncertainty has been the smallest: Regime 1 for Canada and Sweden, and Regime 2 for the UK[19].

The IT period has thus corresponded to a specific regime for each country along which uncertainty has been minimised. Finally, results suggest the following conclusions: IT has produced a regime switch and IT has worked in these three countries in the sense that policy outcomes have been improved.

3.3 Robustness analysis

In this section, we provide some evidence on the robustness of our results. First, we focus on the relevance of model and specification 2. Second, we study a subsample starting once the sharpest disinflation period has ended. Over this subsample, we assess whether changes in variance are still concomitant with the adoption of IT. Third, we perform tests with US data and compare US outcomes with those of IT countries: differences between the US and the other countries are interpreted as evidence of the specificities of IT countries.

3.3.1 Model and specification

Table 2 reports "artificial long run responses" of the policy rate to both objectives of monetary policy, as presented by SZ[20]. We annualise inflation variable to match the annual rate of interest and the output gap. Estimates of responses of the interest rate to macro variables are in line with monetary practice and with the usual weights attributed to or estimated for central banks' objectives in the literature. The tough reaction of the Sveriges Riksbank to inflation and the revealed relative high preference for inflation *vis-à-vis* the output gap is comparable to results reported by Kuttner (2004). The under reaction of the policy rate to inflation and the relative lower inflation preference by the Bank of England in comparison with the Sveriges Riksbank is similar to Muscatelli et al. (2002)'s estimates (over their subsample 1980-1999), or to Clarida et al. (1998). Results for Canada are also comparable to Muscatelli et al. (2002) over the subsample 1980-1999. Thus, figures obtained for the long run policy responses suggest that the underlying model is relevant.

[18] See appendices B and C.
[19] Intercepts of the output gap are never statistically different from zero whichever the regime.
[20] According to SZ, "(artificial long run responses) are neither an equilibrium outcome nor multivariate impulse responses, but are calculated from the policy reaction function *alone*, asking what would be the permanent response in (the policy rate) to a permanent increase in the level or rate of change of the variable in question, if all other variables remained constant".

Investigation of consistency of intercept-and-variance-only specification is pursued with estimates of the model's impulse dynamic responses as shown in Figures 7, 8 and 9. Shocks are identified through a Cholesky decomposition of innovations where variables have been ordered as: policy rate, price index and output gap. We assume that monetary policy does not react immediately to monthly released data on inflation and output gap. The shapes of responses are very similar to those usually obtained in canonical or structural VAR: without any forward variable, like commodity prices, a monetary policy shock produces a "price puzzle" and a lower output gap, except in Sweden where the immediate, though temporary, price decline is concomitant with a significant positive, though temporary, response of the output gap. Consistency of all these responses with usual IRFs confirms that the model and specification are appropriate.

3.3.2 Stable sample with 3 states

Robust estimations over a sample characterised by a stable economic environment will rule out the usual criticism that IT was performed after inflation had been tamed. In the case of Sweden, the fact that the sample starts in 1987 constitutes a robustness check in itself. The short sample begins after the high inflation then disinflation periods; it also begins after the literature usually dates the most significant change in monetary policy in OECD countries[21]. Detection of a regime switch over this "stable sample" is a robust characterisation of an IT regime beyond inflation outcomes: IT regime is also characterised by output outcomes and the policy rate. Estimations for Canada and the UK on the "stable sample" 1987-2006 were performed and results underline changes in intercept and variance. Figure 10 for Canada confirms the conclusion of Figure 4 that a regime (Regime 2) dominates most of the IT period and may be associated with it. Contrary to Figure 4, Regime 2 is prominent earlier, *i.e.* also during the transition period to full IT completion. Figure 11 for the UK shows a break occurring simultaneously with the adoption of IT; this break was already distinguishable on Figure 5.

Table 3 reports the intercepts and variance of the three regimes for Canada and the UK on the short sample. In Canada, variance and the intercept in the CPI equation are minimised under the IT regime. In the UK, the constant term in the CPI equation captures the most substantial part of reduced uncertainty under the IT regime; variance is above that occurring under regime 2 by .0005; this is dramatically insufficient to reverse the optimal feature of the IT regime: minimising uncertainty.

3.3.3 Stable sample with 2 states

On figures 12 to 14 and in table 4, we also report results from specification intercept and variance only with 2 rather than 3 regimes on the short sample. Figures 10 and 11 displayed a somewhat artificial distinction between regimes 1 and 2. The clearest outcome was the very low probability of occurrence of regime 3 after IT had been adopted. With only two regimes, we can also check the robustness of our conclusions on Sweden.

In Sweden, but also in the UK, a regime is distinctly attributable to the IT framework: shortly before the end of 1992, a regime appeared and it has been exclusive ever since. The lower uncertainty property of IT regime is confirmed by intercepts and variance outcomes (table 4).

[21] For instance, Clarida and al. (2000) use 1979 (the beginning of the Volcker mandate) or 1982 (after "Volcker disinflation") as thresholds for subsamples.

The case of Canada is less clear-cut: it shows a lower variance and intercept for a regime which encompassed the whole time period. The second regime occurred only during the transition period to IT adoption. Therefore, none of the two regimes can be attributed to IT. It is noteworthy that this second regime is similar to regime 3 within the 3-state specification (see *supra*). Comparing the 3-state specification with the 2-state specification, it can be asserted that the regime whose properties are closest to an IT regime is merged with the regime which occurred before IT was adopted. Tables 3 and 4 confirm this conclusion.

3.3.4 Comparison with the US

One may ask whether the changes underlined previously have been common to a non-IT country. In this respect, we have chosen the US as a benchmark because of its clear difference in terms of monetary policy framework *vis-à-vis* IT countries. Indeed, the Federal Reserve publishes its forecasts with a 5-year lag compared to IT central banks for which transparency and communication issues are essential. Moreover, the objective of economic growth is more pronounced in the Fed statutes, whereas IT central banks focus primarily on inflation. Table 5 reports intercepts and variance of specification 2 with 2 regimes in the US case[22].

Over a long horizon (1971-2006) and with 3 regimes, figure 15 shows that a regime (the second one) has become prominent, although not exclusive, after 1988. Contrary to what happened in IT countries, this prominent regime cannot be chronologically associated with a specific change in the institutional monetary framework. Over the short sample which is generally associated from beginning to end with the "great moderation era", two regimes are intertwined (see figure 16) and one cannot draw conclusions on the superiority of one regime over the other. Regime 1 shows better performance than regime 2 in terms of lower intercept in the CPI equation and variance. However, uncertainty has decreased more substantially in IT countries under the IT regime than in the US under regime 2 (table 6)[23]. One conclusion arises: there are specific benefits to IT adoption which have not been shared by a non-IT country like the US.

At this stage, three results are worth summarizing: first, despite their differences, the three IT countries witnessed a regime switch after IT adoption. Second, this switch is visible too on a sample which is characterised by a relatively stable macroeconomic environment. Third, a comparison with the US has revealed differences which emphasize the specific outcomes of IT countries.

Two comments emerge. First, a conclusive comment: the regime switch is robust to a change in the sample and to an international comparison. Second, a prospective comment: inflation outcomes are not the sole exclusive link with IT; the sacrifice ratio of achieving low inflation has to be investigated. So does the variability of the policy rate. In order to perform such investigation, counterfactuals are set up.

[22] Data were taken from the website of the Federal Reserve Board, except the output gap whose source is the OECD.

[23] The change in uncertainty has corresponded to the change in the variance and the intercepts during IT regime for IT countries or during regime 2 for the US, compared to their corresponding outcomes in the previous regime. We have excluded Canada for which the switch in the small sample is blurred.

3.4. Counterfactuals

Results of the first specification suggest that there is no coefficients switch with the adoption of IT; it is then possible to escape from the Lucas critique and to provide some historical counterfactuals based on the second specification; then we can assess how and the extent to which the optimal path of the policy rate, the inflation rate and the output gap have changed over time.

In this exercise, coefficients are the same across regimes, and the differences among them stem from the intercepts and variances, that we choose to set at values of the IT regime. To obtain the path of the policy instrument as it would have evolved, had IT been adopted at the beginning of the sample, we simulate the policy equation without the disturbance term. With this optimal simulated rule, we compute the corresponding inflation rate and output gap over the full sample. These counterfactuals do not provide assessment of the stance of monetary policy across time *per se*, but they suggest levels of the variables and the macroeconomic effect of the IT framework.

Results are reported on Figures 17 to 19. In the following, we compare the situation where IT regime would have always dominated the other two regimes with the actual evolution of the different endogenous variables. As far as interest rates are concerned, their variations would have been smoother over the whole sample. Moreover, interest rates would have been relatively low earlier, then they would have been higher: since 2001 in Canada, 1996 in Sweden and 2000 in the UK. We interpret this latter result as a higher monetary leeway enabling to face a negative shock with a sharp fall in the interest rate. This interpretation is confirmed by the evolution of the price index: in the three countries, disinflation would have occurred earlier, but inflation rates would have been higher after 1983, though to a lesser extent in Canada. Thus the scope for achieving low real interest rates would have been higher in the recent history. Fluctuations in the inflation rate would have been smoother in Sweden and the UK; but it would have remained broadly similar in Canada. The evolution of the output gap in the three countries would have been broadly similar under IT regime and the results do not point to an increase in the sacrifice ratio under IT regime.

4. Conclusion

The MSVAR methodology has revealed that in different countries like Canada, Sweden and the UK, the adoption of inflation targeting has given rise to a regime switch. The latter has not been characterised by a change in the coefficients of the monetary policy rule *per se*; rather, it has been characterised by lower intercept and variances, hence a better predictability of policy responses. Finally, a counterfactual exercise has shown that IT could give more monetary leeway, *i.e.* central banks under an IT regime could achieve a lower real interest rate, to be compared with situation where the *same* central banks were not actually under IT regime. In the face of a negative shock, this potentially low real interest rate can be viewed as a further gain associated with the adoption of IT.

It is interesting to make a comparison across IT countries: the switch has been extremely pronounced in the UK and Sweden, for which the central bank has adopted all the features advocated for in this framework. On the contrary, Canada does not publish its forecasts. This is a major difference with the two other countries since IT is aimed at better anchoring expectations and requires communication to be at the forefront.

The return of worldwide inflation over the recent years challenges the optimality of monetary policies: central bankers are relatively deprived of means in the face of externally-driven inflation, as it is the case in most OECD countries. If the price shocks are concomitant with a slower growth process, the monetary leeway that IT has been shown to provide may be viewed as an incentive for new countries to adopt IT.

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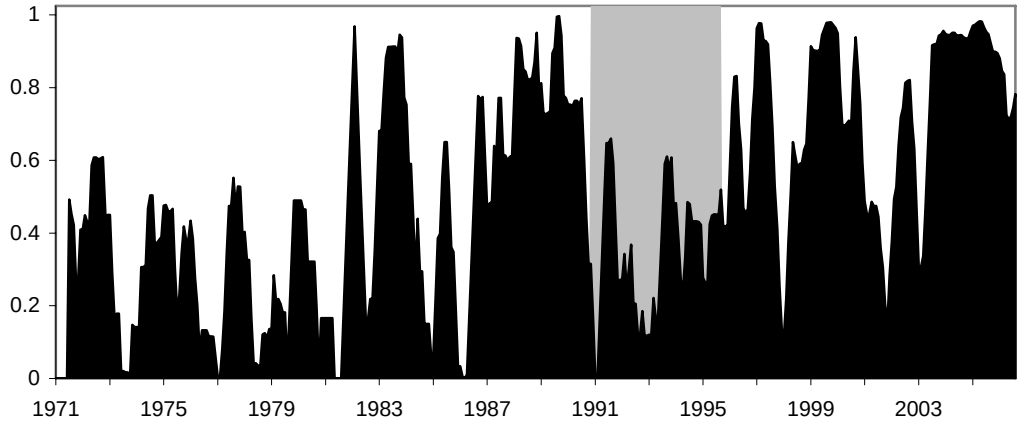
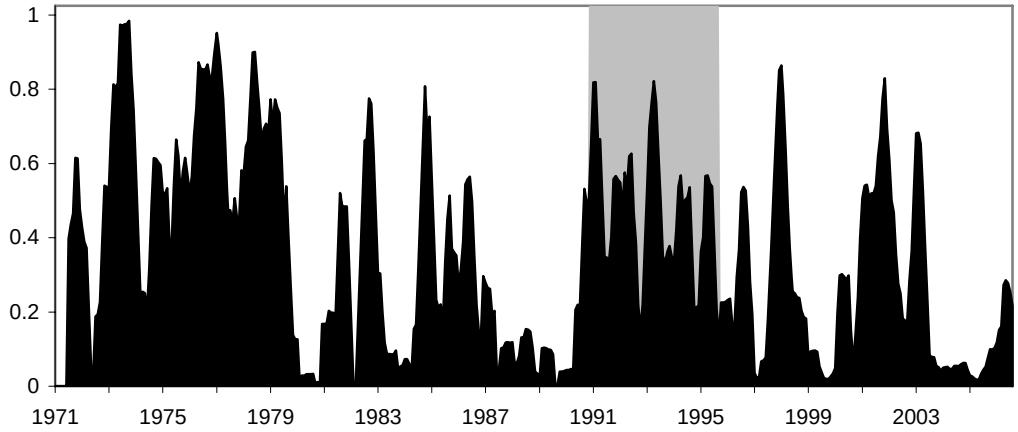
Figure 1
Full changes specification probabilities – Canada

Regime 1



Regime 2



Regime 3

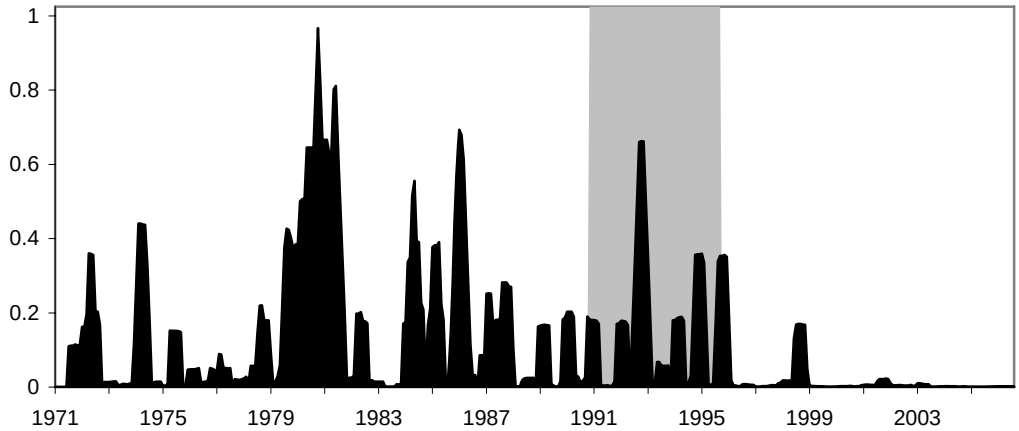
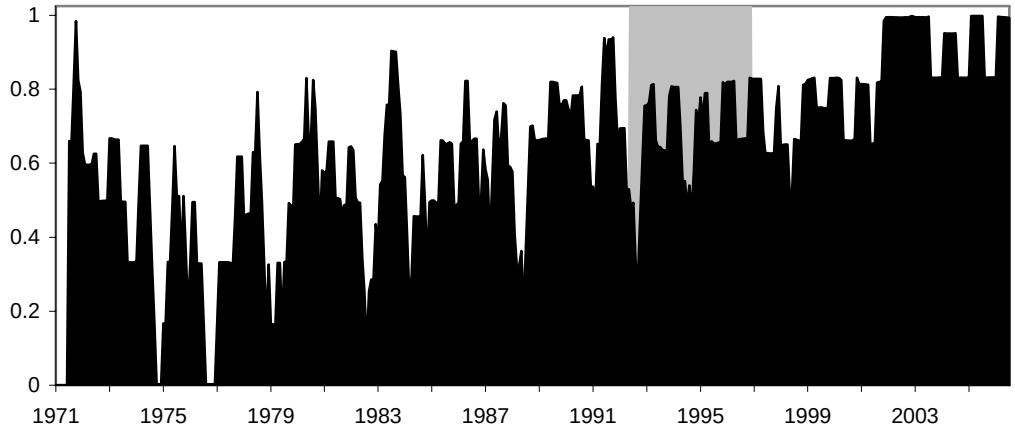
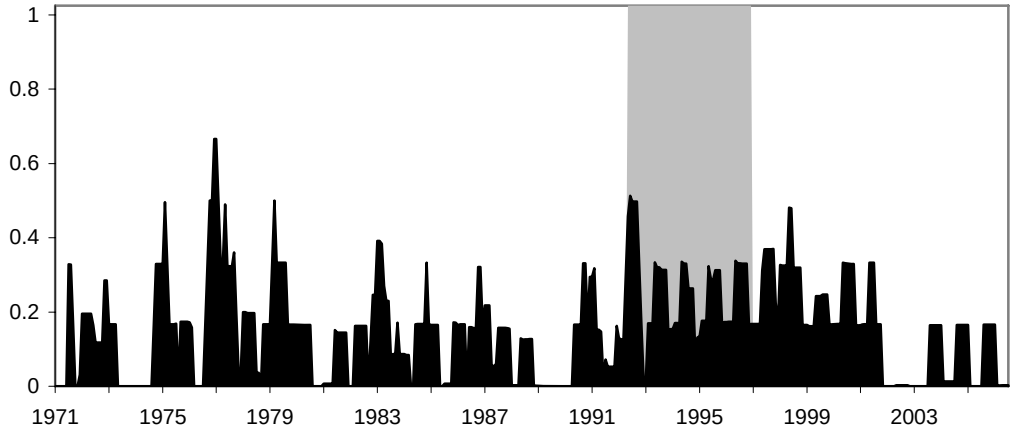


Figure 2
Full changes specification probabilities – UK

Regime 1



Regime 2



Regime 3

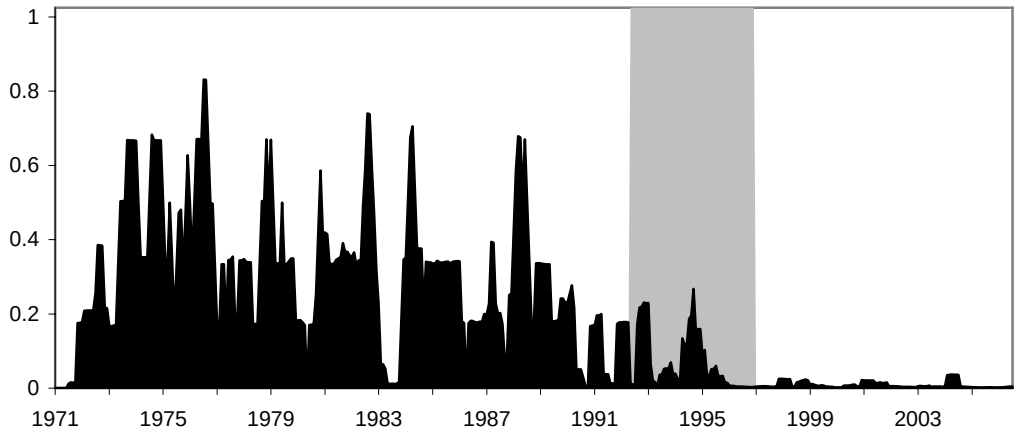
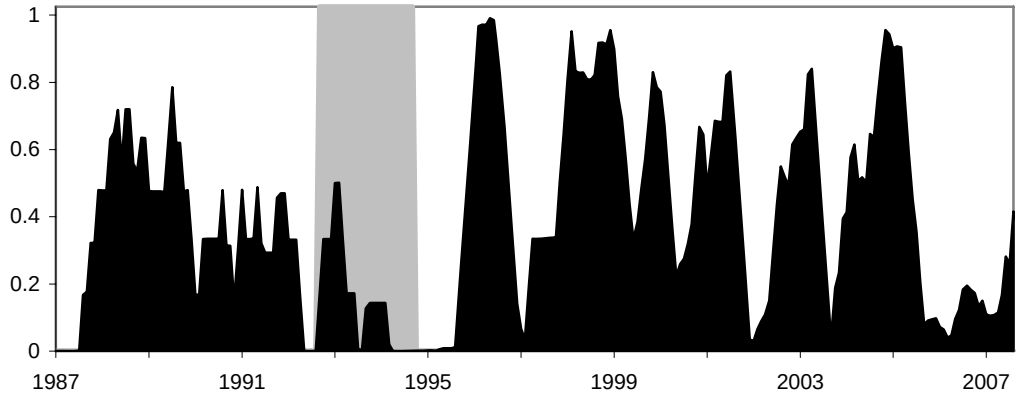
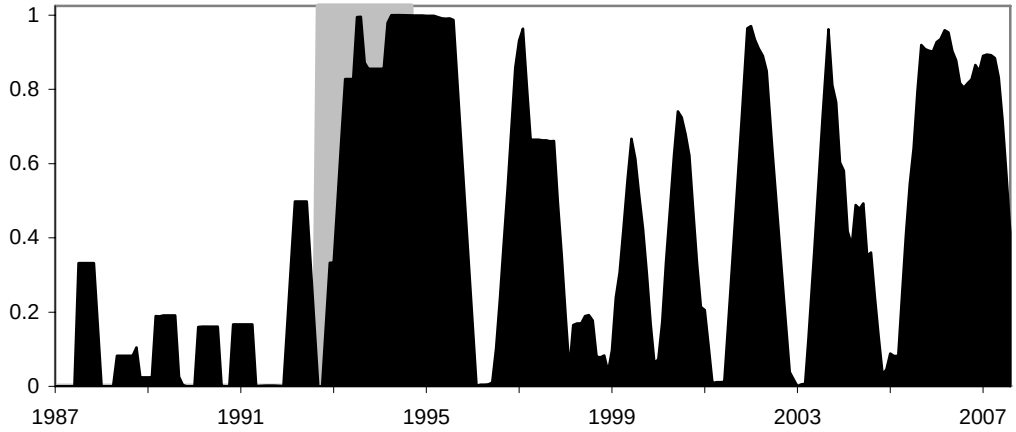


Figure 3
Full changes specification probabilities – Sweden

Regime 1



Regime 2



Regime 3

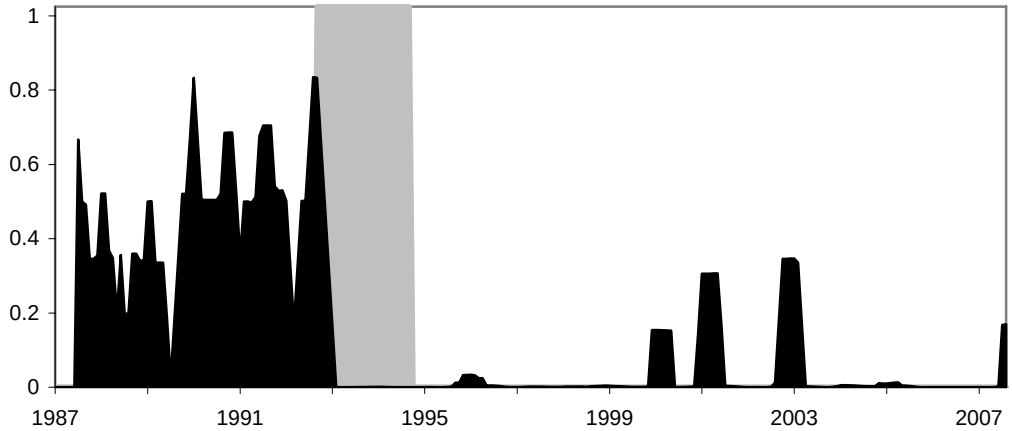
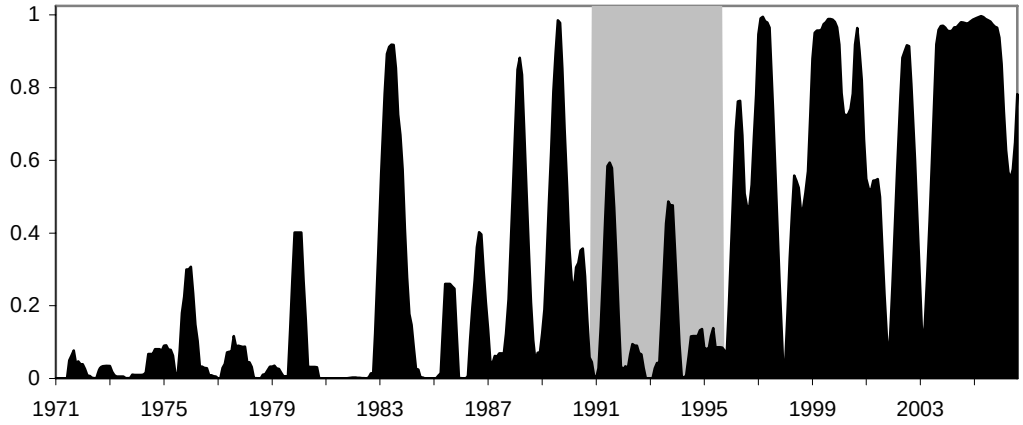
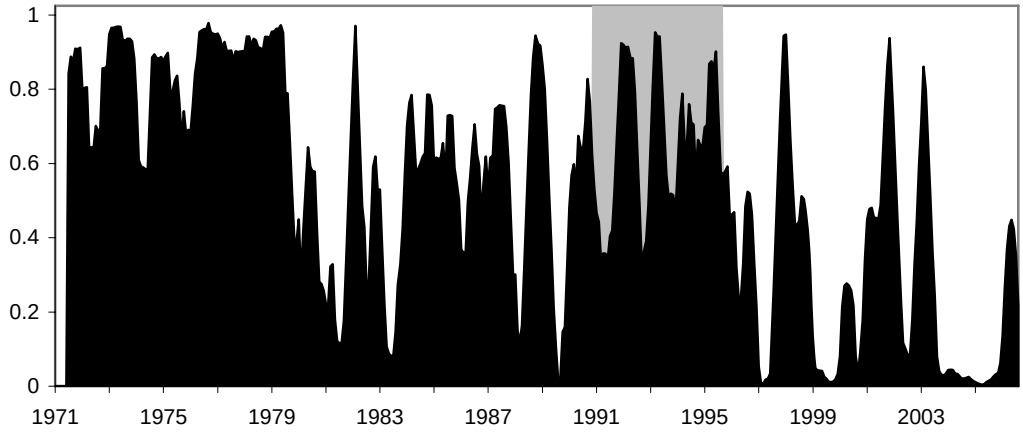


Figure 4
Variances only specification probabilities – Canada

Regime 1



Regime 2



Regime 3

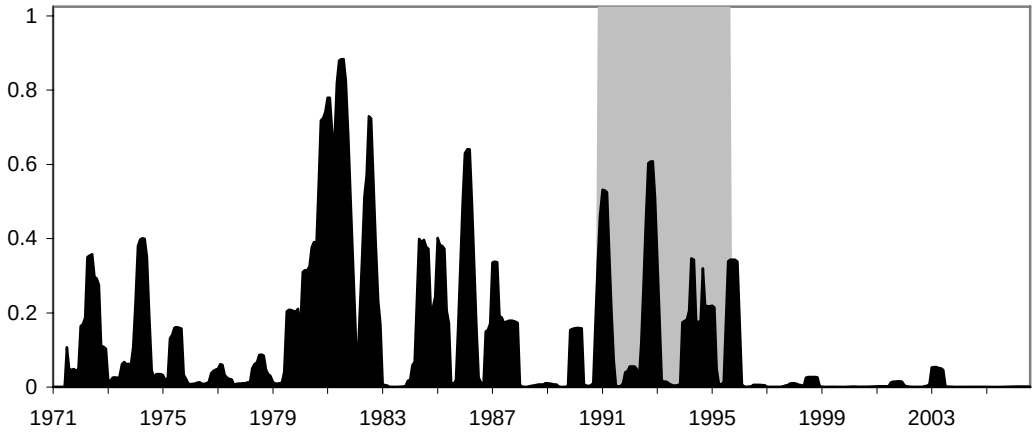
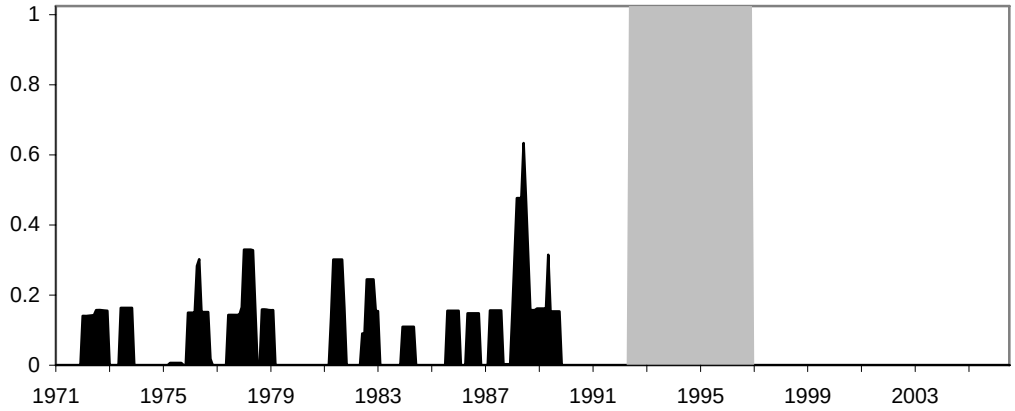
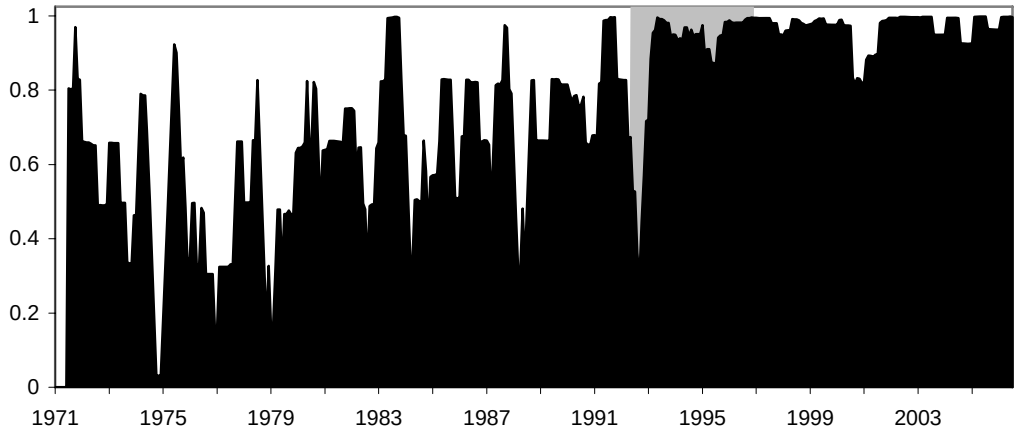


Figure 5
Variances only specification probabilities – UK

Regime 1



Regime 2



Regime 3

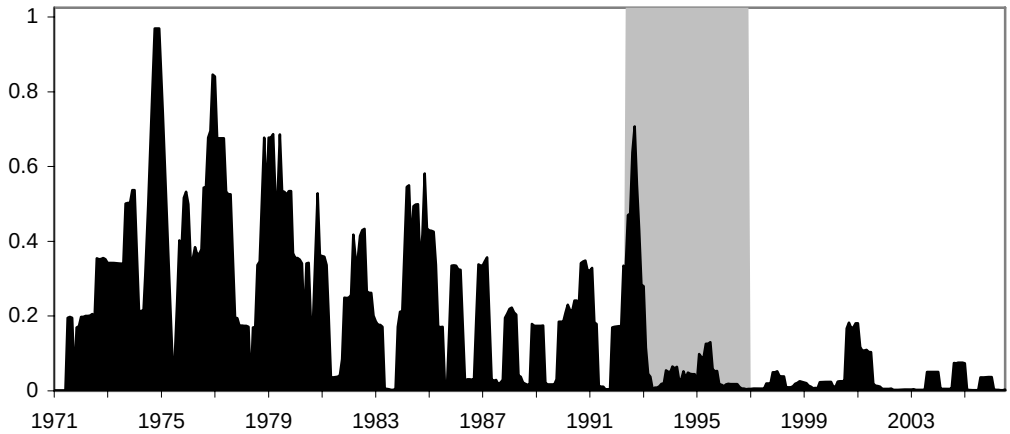
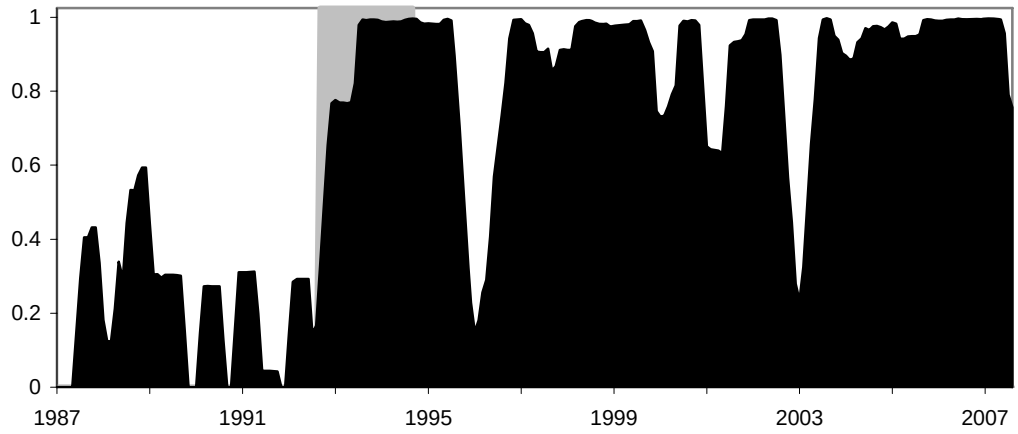
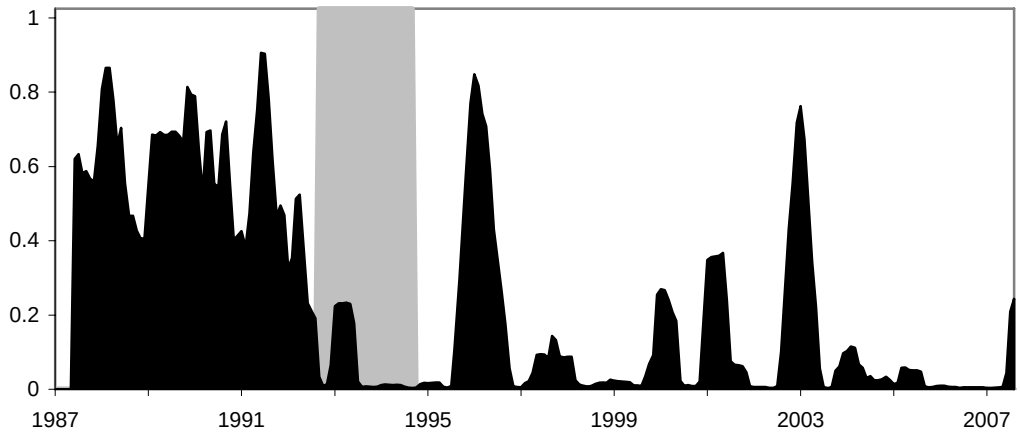


Figure 6
Variances only specification probabilities – Sweden

Regime 1



Regime 2



Regime 3

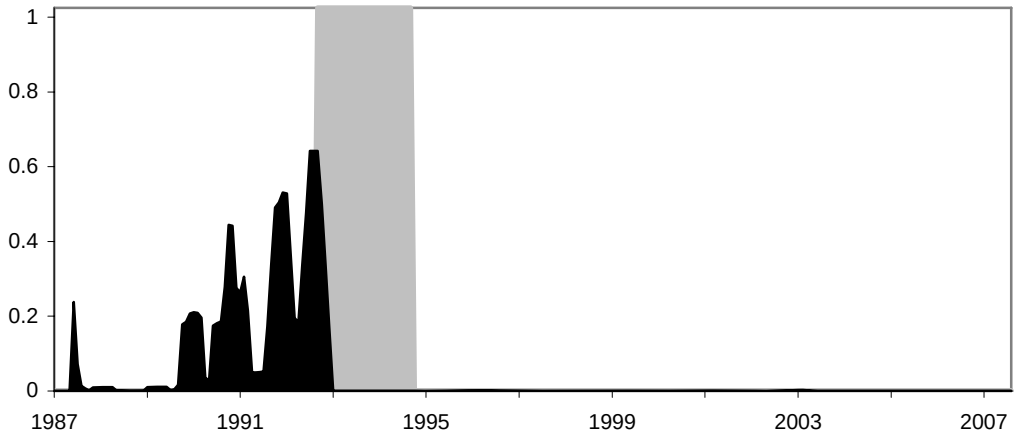
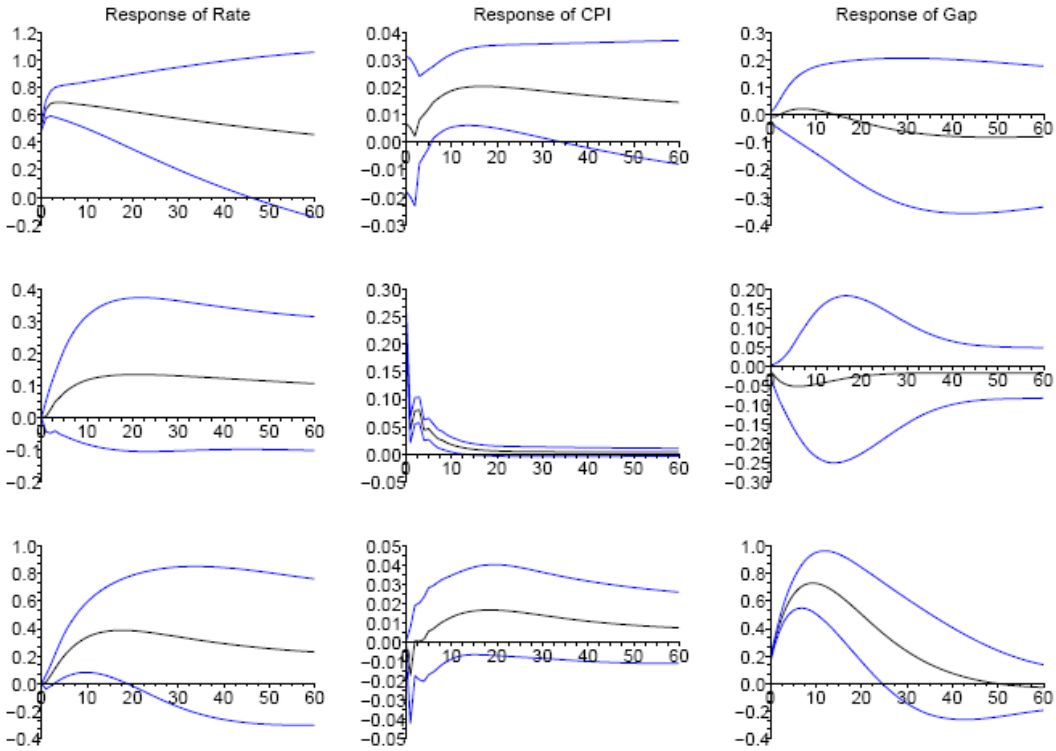


Figure 7
Impulse Response Function, Intercept and Variances Only Model
Canada



Note: First line reports central bank rate shock, second line CPI shock and third line output gap shock.

Figure 8
Impulse Response Function, Intercept and Variances Only Model
UK

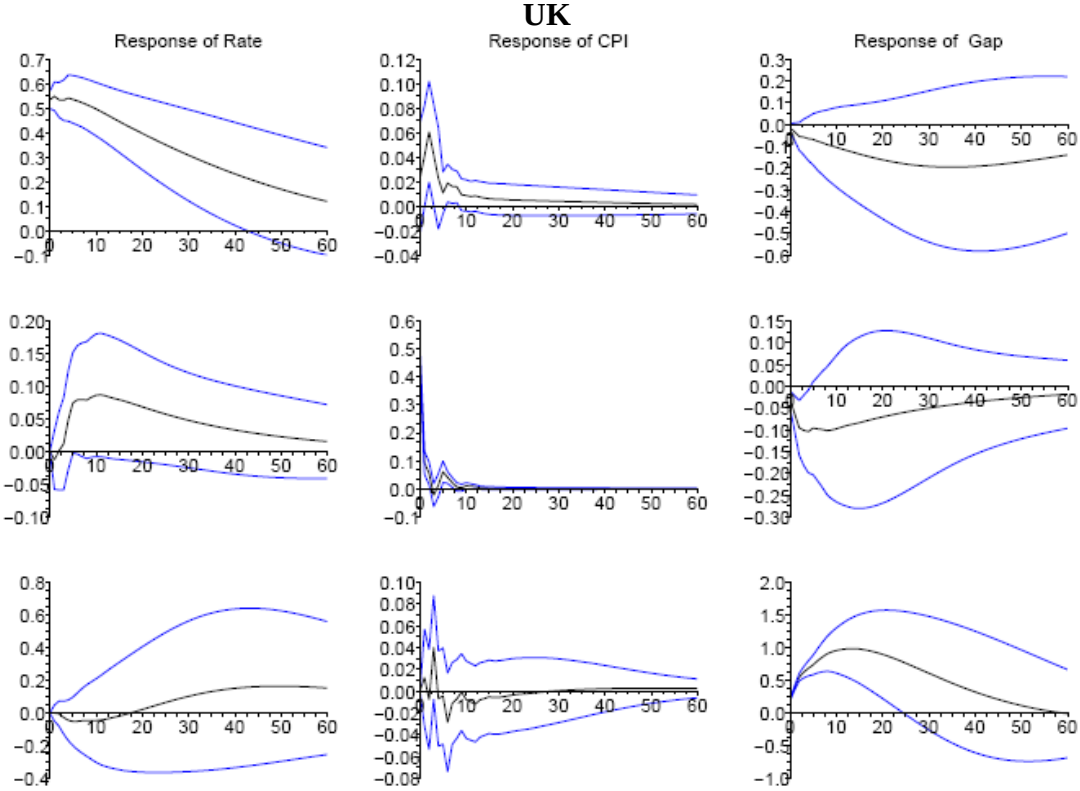


Figure 9
Impulse Response Function, Intercept and Variances Only Model
Sweden

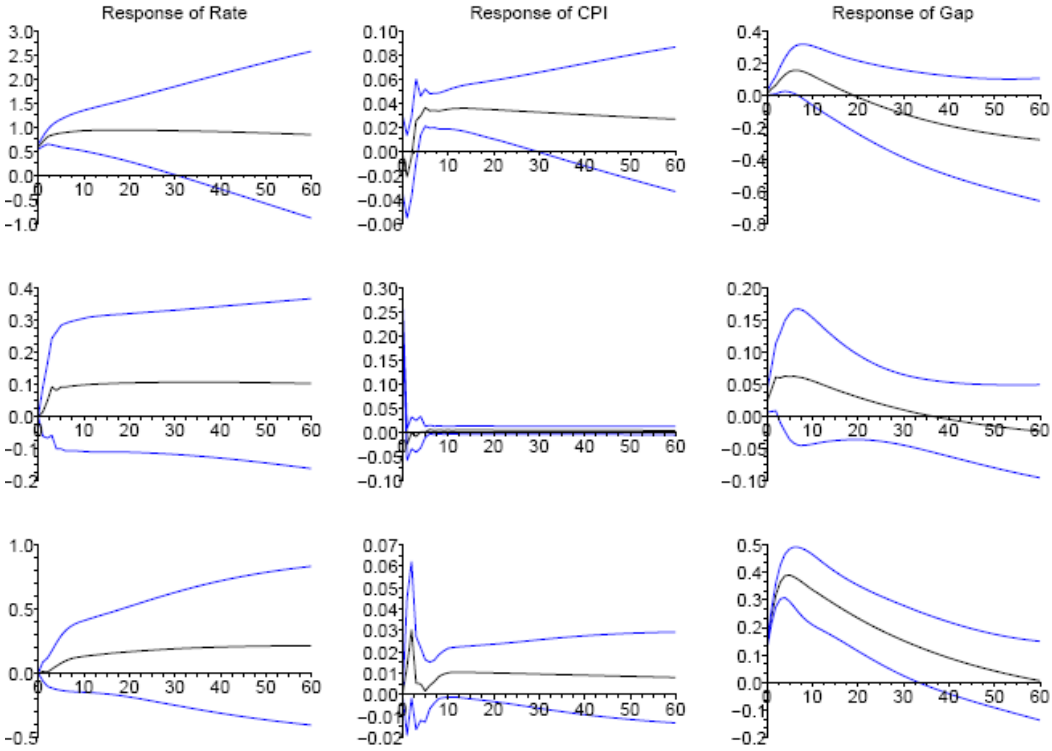
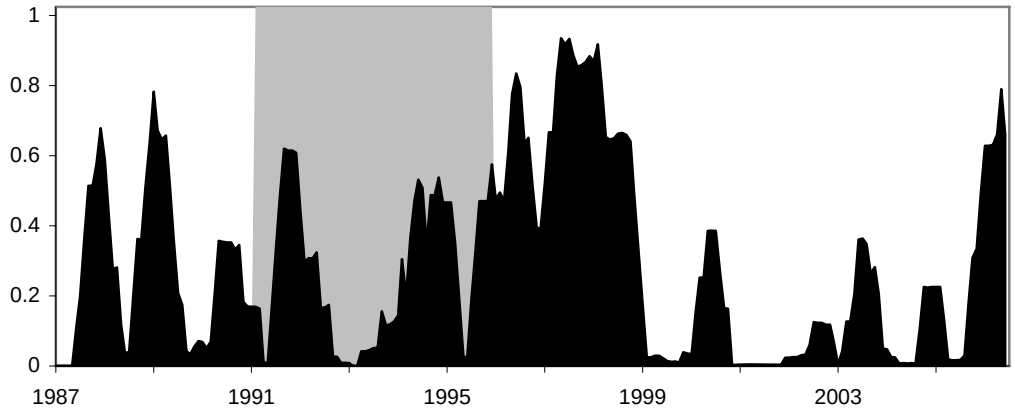
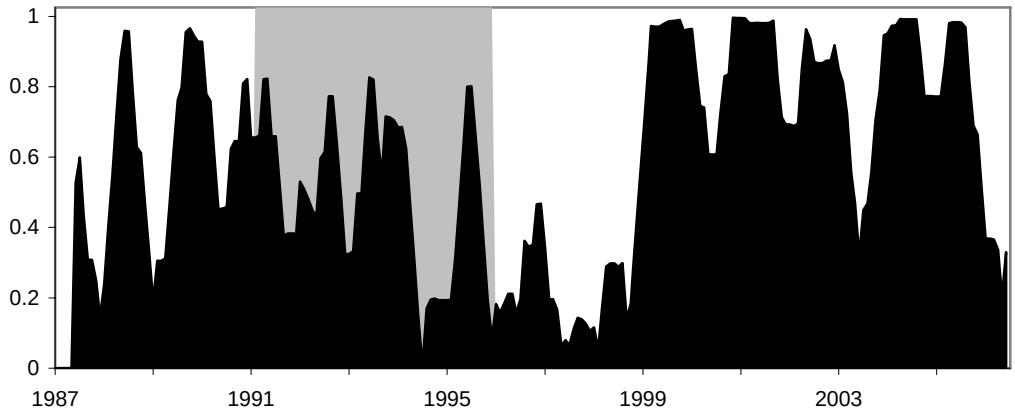


Figure 10
Variances only specification probabilities – Canada
Short sample: 1987-2006

Regime 1



Regime 2



Regime 3

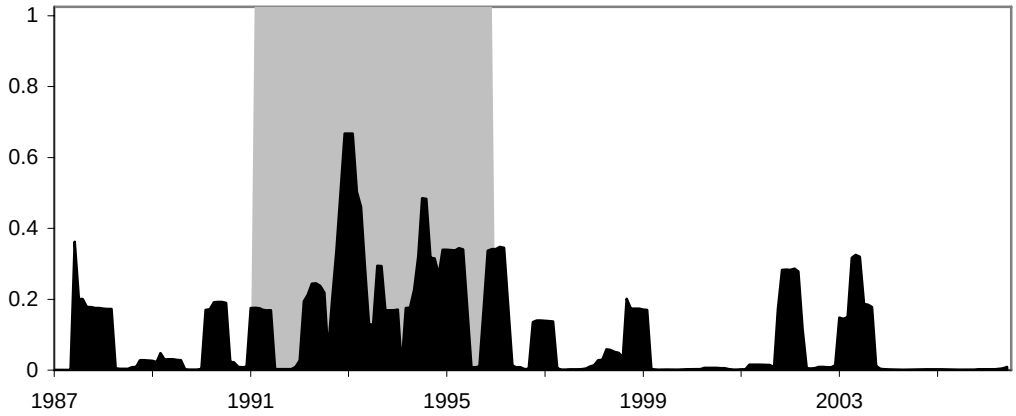
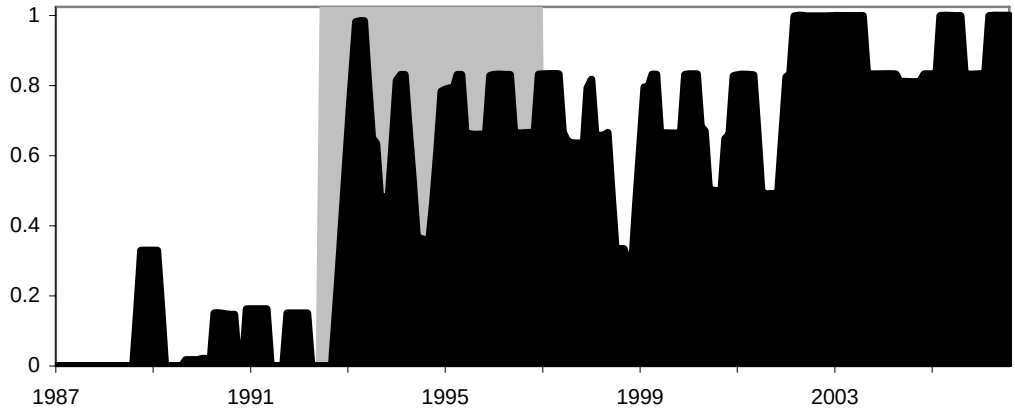
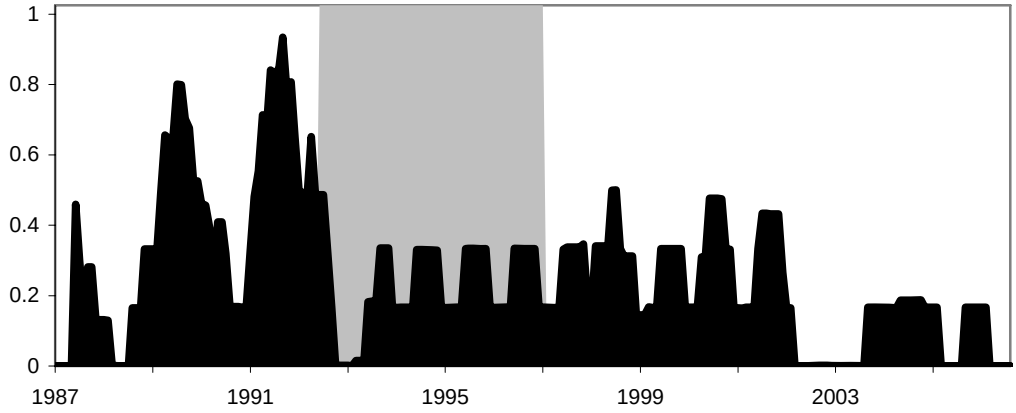


Figure 11
Variances only specification probabilities – UK
Short sample: 1987-2006

Regime 1



Regime 2



Regime 3

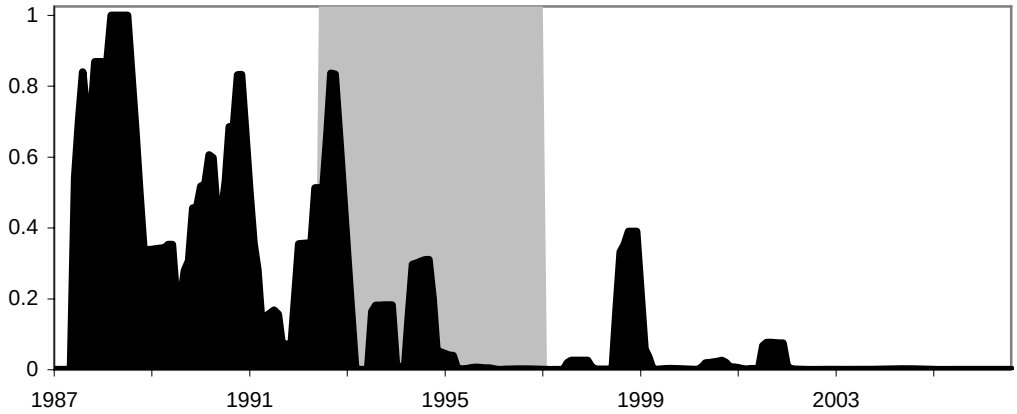
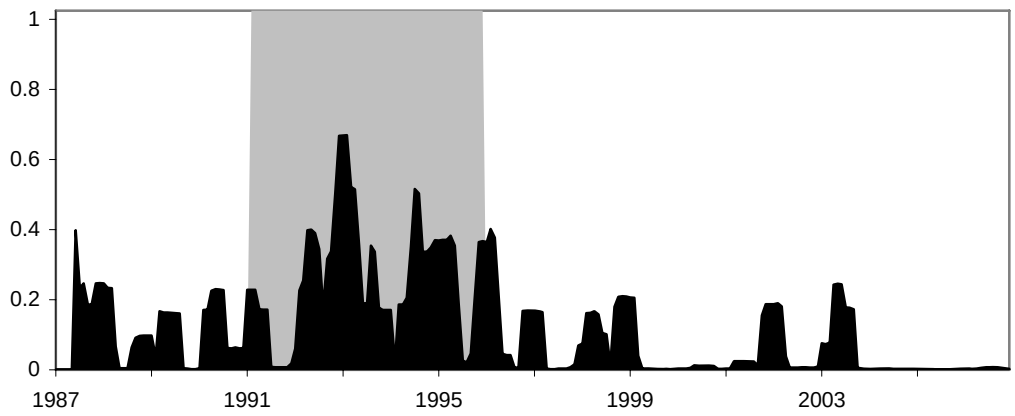


Figure 12
Variances only specification probabilities – Canada
Short sample: 1987-2006

Regime 1



Regime 2

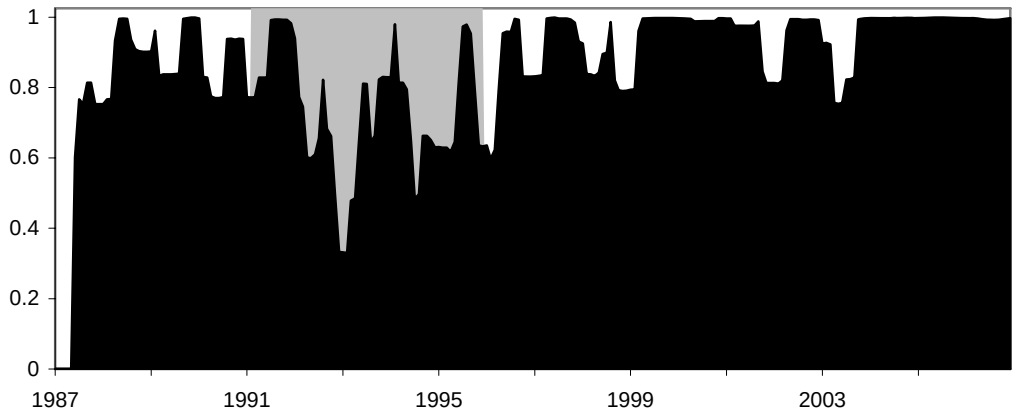


Figure 13
Variances only specification probabilities – UK
Short sample: 1987-2006

Regime 1

Regime 2

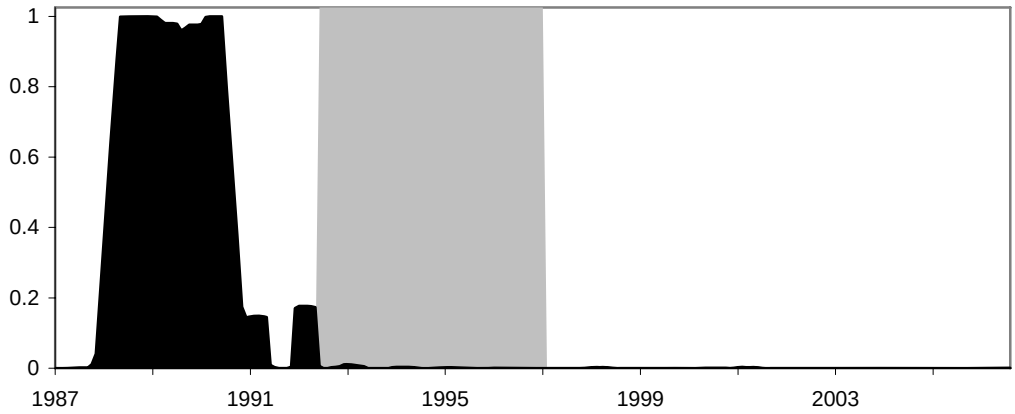
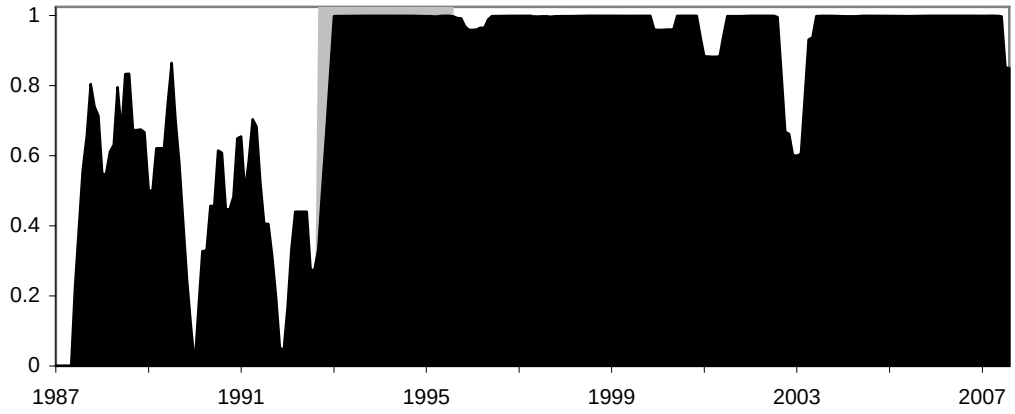


Figure 14
Variances only specification probabilities – Sweden
Short sample: 1987-2007

Regime 1



Regime 2

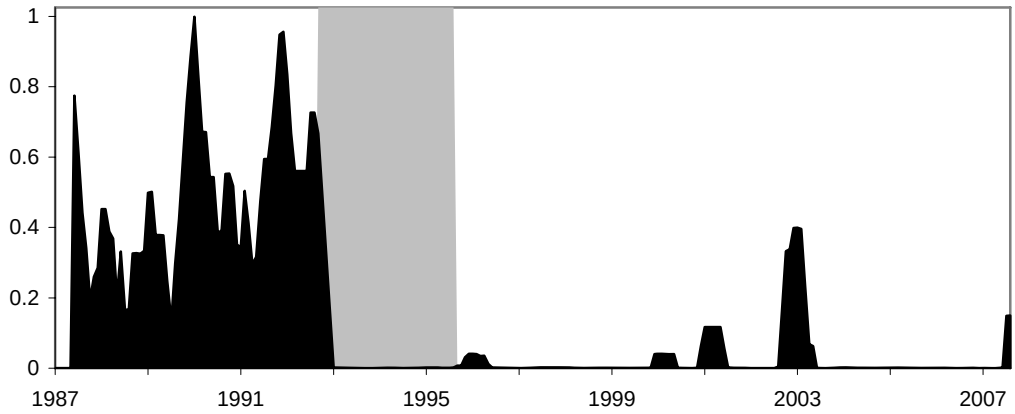
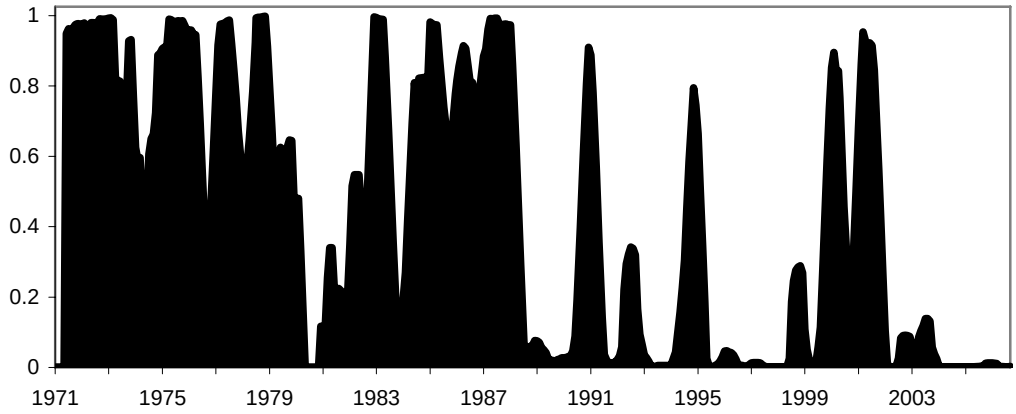
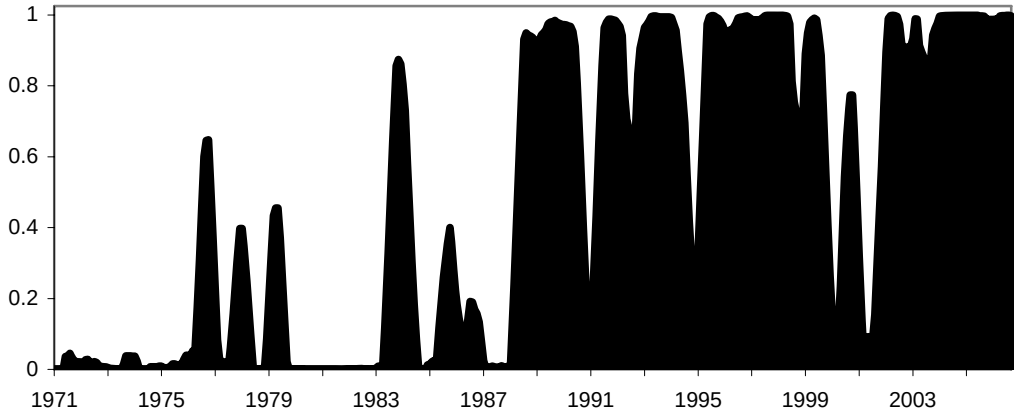


Figure 15
Variances only specification probabilities – US
Full sample: 1971-2006

Regime 1



Regime 2



Regime 3

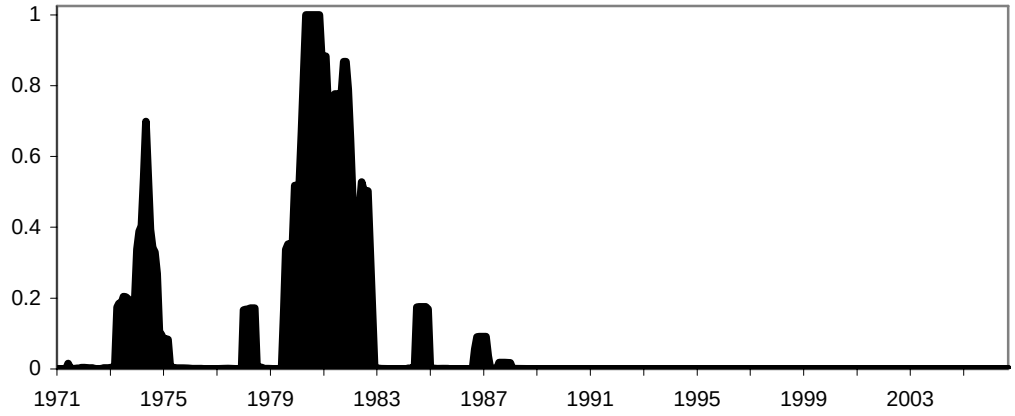
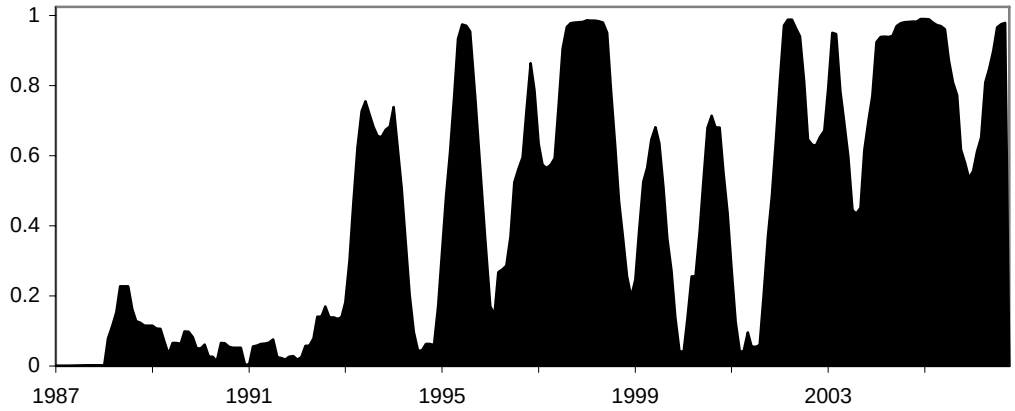


Figure 16
Variances only specification probabilities – US
Short sample: 1987-2006

Regime 1



Regime 2

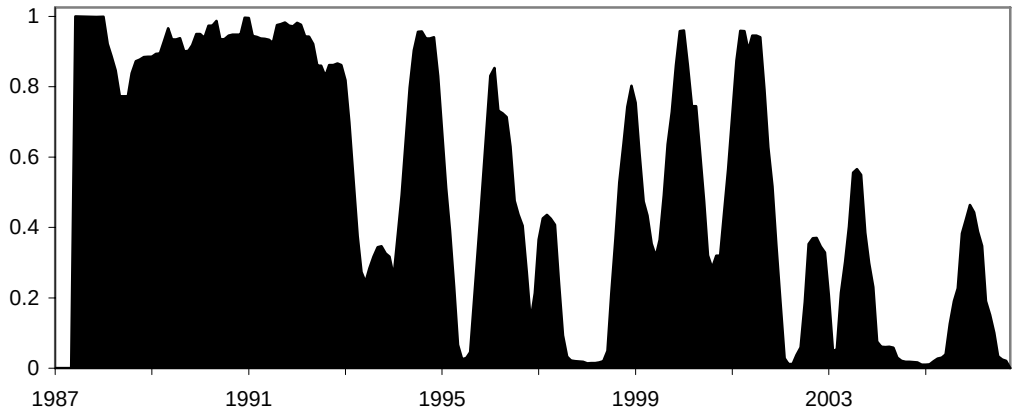


Figure 17
Actual (black thin line) versus Counterfactual (red thick line)
Canada

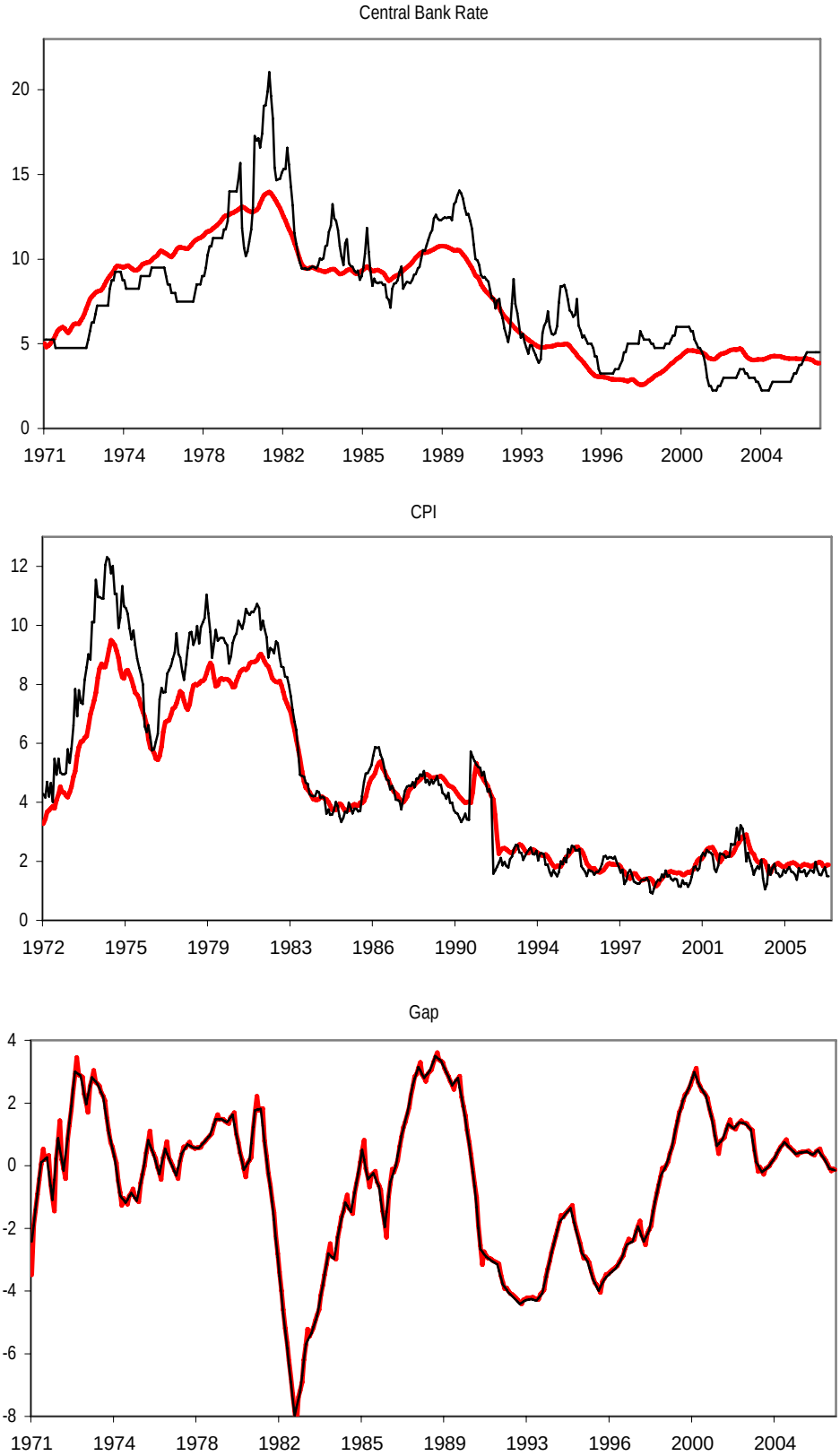


Figure 18
Actual (black thin line) versus Counterfactual (red thick line)
UK

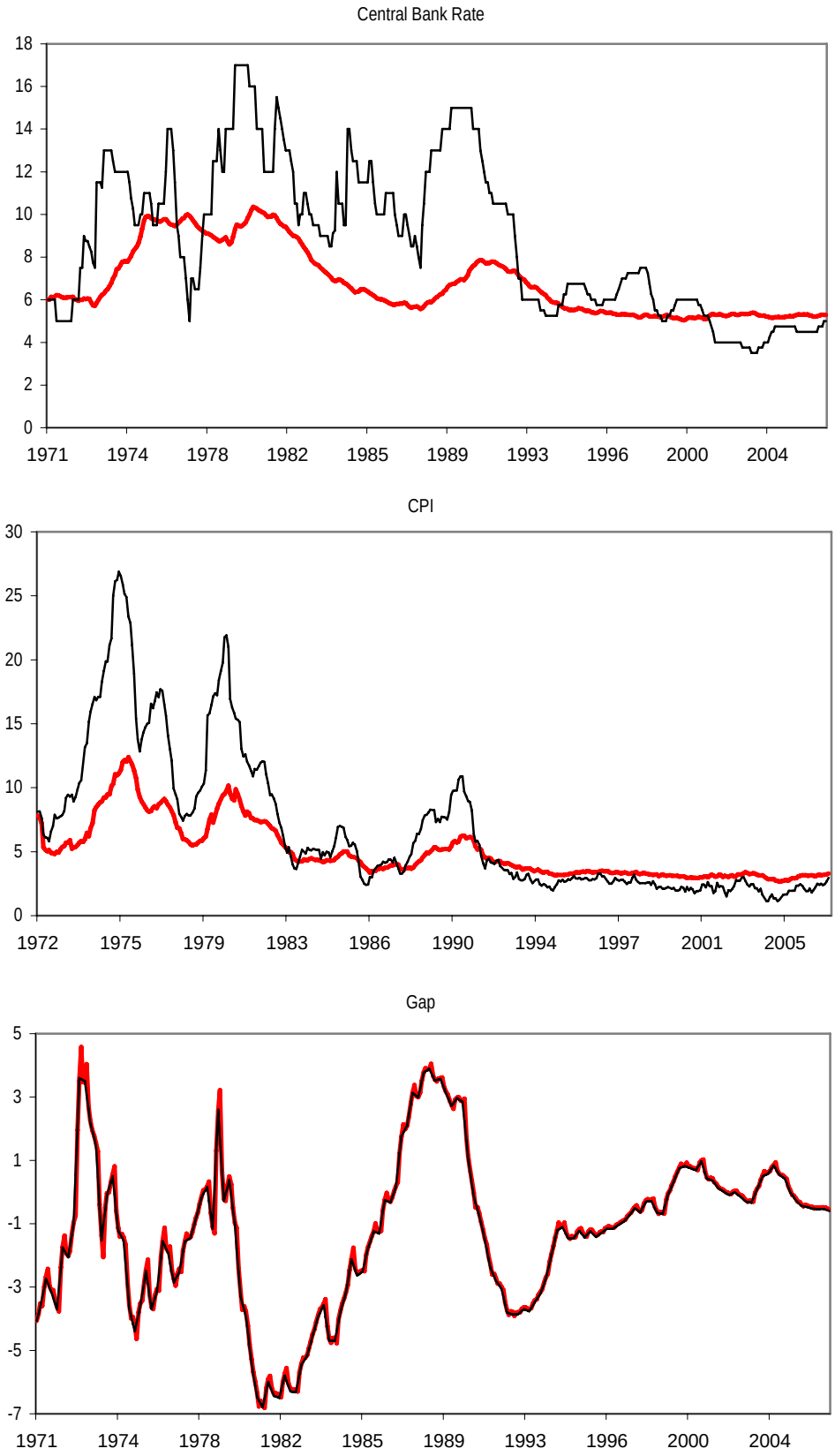


Figure 19
Actual (black thin line) versus Counterfactual (red thick line)
Sweden

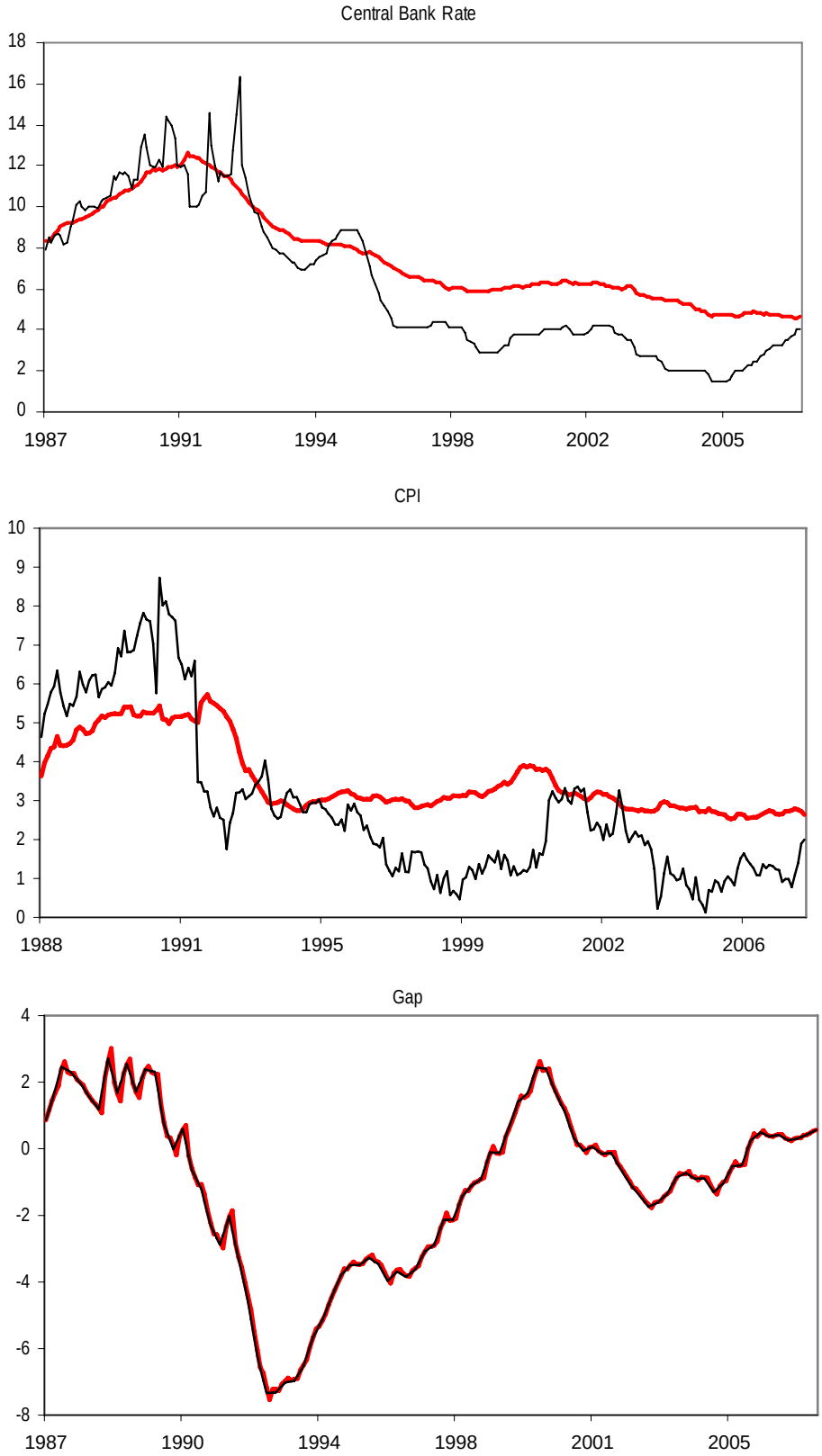


Table 1. Intercepts and variance in specification 2, full sample

	Regime 1		Regime 2		Regime 3	
	intercept	**variance**	**intercept**	**variance**	**intercept**	**variance**
CANADA		**IT**				
CPI Equation	0.008220		0.058003*		0.101542	
	(0.017639)	0.011019***	(0.029924)	0.059398***	(0.114412)	0.653884***
Gap Equation	0.010809	(0.001301)	0.005125	(0.006406)	0.000300	(0.091777)
	(0.013827)		(0.019499)		(0.043911)	
UK				**IT**		
CPI Equation	0.213095**		0.089906		0.830995***	
	(0.074676)	0.071268***	(0.034726)	0.043044***	(0.115325)	0.791094***
Gap Equation	0.064918	(0.020045)	0.015183	(0.002688)	-0.017008	(0.077882)
	(0.069232)		(0.035305)		(0.085425)	
SWEDEN		**IT**				
CPI Equation	0.006919		0.063408		0.047167	
	(0.018877)	0.012864***	(0.063326)	0.111488***	(0.425872)	2.071731***
Gap Equation	0.021899	(0.001140)	0.001512	(0.018923)	-0.022024	(0.557700)
	(0.018797)		(0.055976)		(0.483868)	

Table 2.
Long Run Policy Responses

	Canada	UK	Sweden
Responses of R to			
inflation	1.4939	0.4422	2.4030
output gap	0.0150	0.3559	1.0942

Table 3. Intercepts and variance in specification 2, short sample

	Regime 1		Regime 2		Regime 3	
	intercept	**variance**	**intercept**	**variance**	**intercept**	**variance**
CANADA				**IT**		
CPI Equation	0.104700***		0.087920***		0.177222	
	(0.027687)	0.014653***	(0.022543)	0.013689***	(0.129125)	0.414223***
Gap Equation	0.002437	(0.002220)	0.008983	(0.001369)	-0.002306	(0.075378)
	(0.025252)		(0.021446)		(0.145360)	
UK		**IT**				
CPI Equation	-0.133035***		-0.811609***		-0.442344***	
	(0.035411)	0.015551***	(0.050815)	0.015011***	(0.101815)	0.250457***
Gap Equation	0.011208	(0.001245)	0.023691	(0.002438)	0.023825	(0.036258)
	(0.026774)		(0.039421)		(0.087944)	

Table 4. Intercepts and variance in specification 2, short sample

	Regime 1		Regime 2	
	intercept	**variance**	**intercept**	**variance**
CANADA			**IT**	
CPI Equation	0.174092		0.092911***	
	(0.111872)	0.356594***	(0.024477)	0.019361***
Gap Equation	0.002066	(0.068475)	0.006904	(0.001545)
	(0.226008)		(0.030491)	
UK	**IT**			
CPI Equation	0.234469***		1.070491***	
	(0.050196)	0.043142***	(0.146753)	0.186776***
Gap Equation	0.003676	(0.002690)	-0.018360	(0.027981)
	(0.045831)		(0.128010)	
SWEDEN	**IT**			
CPI Equation	0.013598		0.127047	
	(0.025301)	0.019316***	(0.147289)	0.770464***
Gap Equation	0.021904	(0.001890)	-0.004862	(0.130457)
	(0.021241)		(0.130172)	

Table 5. Intercepts and variance in specification 2, short sample

	Regime 1 (Post-93)		Regime 2	
USA	**intercept**	**variance**	**intercept**	**variance**
CPI Equation	0.074574***		0.136363***	
	(0.022270)	0.004250***	(0.032859)	0.024911***
Gap Equation	0.026762	(0.000655)	0.033974	(0.002286)
	(0.022809)		(0.036063)	

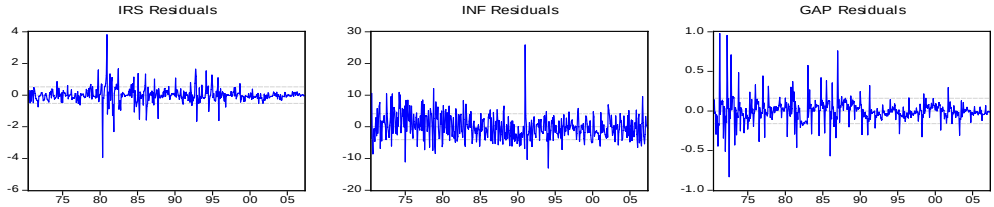
Table 6.
Coefficient of Reduction of Uncertainty between IT* regimes and its preceding regime

	Coefficient
UK	4.97
SWEDEN	16.61
US	3.11

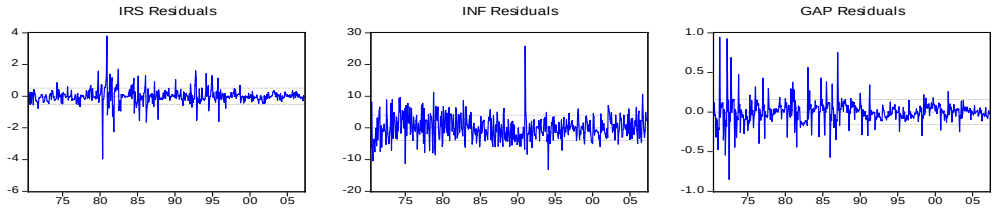
* For US, it corresponds to the regime starting in 1993 on the Figure 16

Appendix A – Canonical VAR residuals

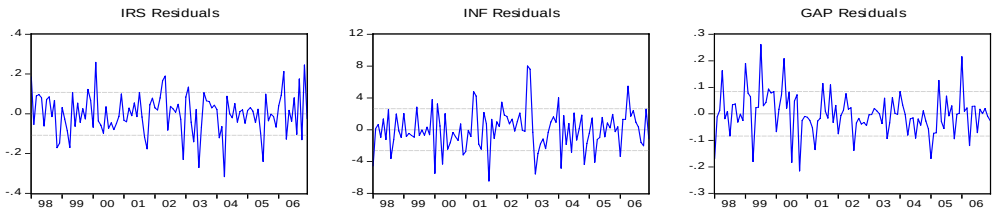
Canada - Canonical VAR without M2



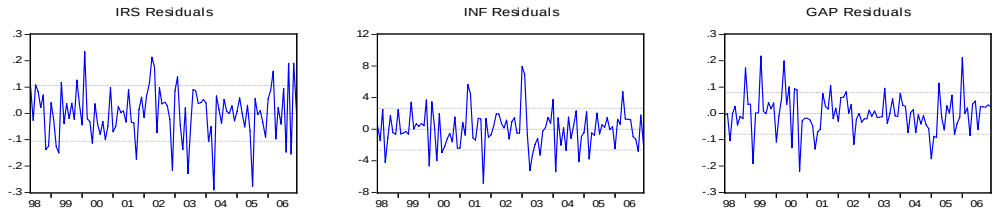
Canada - Canonical VAR with M2



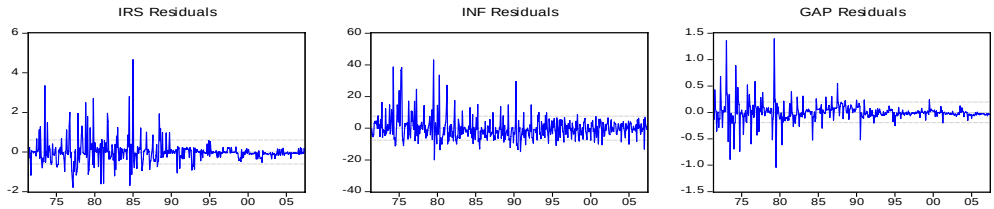
Sweden - Canonical VAR without M2



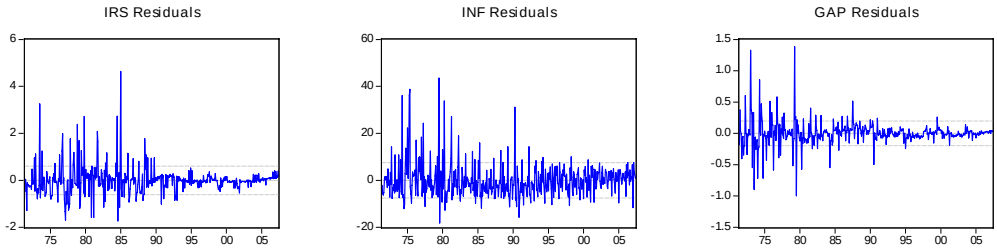
Sweden - Canonical VAR with M2



UK- Canonical VAR without M2



UK - Canonical VAR with M2



Appendix B – Full sample

Transition matrix for Full changes specification – Canada

0.7095	0.2781	0.3685
0.2158	0.6212	0.1820
0.0747	0.1007	0.4495

Transition matrix for Full changes specification – UK

0.6725	0.7229	0.4646
0.1636	0.1446	0.1760
0.1639	0.1325	0.3594

Transition matrix for Full changes specification – Sweden

0.6237	0.2032	0.3952
0.1857	0.7807	0.1020
0.1906	0.0161	0.5028

Transition matrix for Variances only specification – Canada

0.8252	0.1089	0.0010
0.1687	0.7692	0.5078
0.0061	0.1219	0.4912

Transition matrix for Variances only specification – UK

0.1794	0.0274	0.0982
0.6881	0.8110	0.5524
0.1325	0.1617	0.3494

Transition matrix for Variances only specification – Sweden

0.8928	0.2648	0.1473
0.1072	0.6267	0.3359
0.0000	0.1085	0.5168

Appendix C – Short sample

Transition matrix for Variances only specification – Canada

0.5679	0.1677	0.2568
0.3137	0.7587	0.4530
0.1185	0.0736	0.2903

Transition matrix for Variances only specification – UK

0.7545	0.4769	0.0906
0.2455	0.2749	0.2652
0.0000	0.2481	0.6442