Multiple equilibria in Spanish unemployment

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21st January 2009

Abstract

The dynamics of Spanish unemployment in the last thirty years has been characterized by a high and persistent unemployment period (from 1982 to 1999) and by two transition periods, one of massive employment destruction (from 1972 to 1982) and one of massive employment creation (from 1999 to 2007). This behavior is well captured by a non-linear smooth transition autoregressive (STAR) model and the analysis in this paper indicates the existence of two regimes with a fast transition between them: a high regime with an equilibrium value of unemployment of 18.3% and a low regime with a equilibrium value of 7.6%.

Classification J.E.L.: C22, E24.
Key words: unemployment, smooth transition, multiple equilibria, Spain.

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1 Introduction

Over the last thirty years Spanish unemployment has moved dramatically; from a low value of 2-3% at the beginning of the 70's to a value of 21% in the mid eighties and after a brief drop in the second half of the eighties, it has achieved a peak of 24.5% in the first quarter of 1994. From then onwards, it has rapidly fallen to 8% in 2007. Nowadays[1] is around 11.3%.

The transition periods have respectively preceded and followed almost twenty years of stubbornly high unemployment. What is remarkable about this experience is the fast transition between low and high, and later from high to low unemployment rates.

This kind of behavior has been the focus of much theoretical and empirical literature (see among others, Bentolila and Blanchard (1990), Bentolila and Dolado (1994), Dolado and Jimeno (1997), Dolado, et al (2002), Romero-Ávila and Usabiaga (2008), and Juselius and Ordóñez (2008)). Although the conclusions of these studies differ to some extent, they all stress the two following points: first, Spanish unemployment can only be explained in terms of a combination of shocks and, second, persistence appears as a result of institutional factors related to high unemployment protection and benefits from wage bargaining.

From a methodological point of view, these papers share in common the use of linear models to characterize unemployment behavior. However, one of the main characteristics of unemployment is its asymmetric and countercyclical nature, i.e. unemployment rate increases faster during recessions than it decreases during expansions, and this asymmetric behavior cannot be captured by linear models.

The asymmetric nature of unemployment is well documented in the theoretical literature: the insider-outsider model of Lindbeck and Snower (1988) suggests that, under certain conditions, insiders would be able to prevent employment from rising during expansions. Bentolila and Bertola (1990) argue that asymmetric labor cost adjustment function[2] explains much of the development in the European unemployment rates after the first oil shock in 1973.

Empirical support for the cyclical asymmetry of unemployment is also well established in the literature, see Neftci (1984), DeLong and Summers (1986), Falk (1986), Rothman (1991), Sichel (1993), Mills (1993) and Peel and Speight (1998), who provide evidence that job destruction is highly asymmetric over the business cycle. Burgess (1992) shows that asymmetric employment cycles can arise in a nonlinear variant of the Diamond (1982) model of labor search and matching and the empirical literature has well documented the nonlin-

[1]2008:Q3.

[2]See Hamermesch and Pfann (1996) for a survey on asymmetric adjustment costs of labor.

ear dynamics in unemployment (Luukkonen and Teräsvirta (1991), Teräsvirta and Anderson (1992), Mills, (1993), Acemoglu and Scott, (1994), Skalin and Teräsvirta (2002)).

The aim of this paper is to show that the dynamics of Spanish unemployment is well described by a nonlinear model with two equilibria and a fast transition between them. Moreover, we provide evidence in favour of the asymmetric behavior of unemployment in response to shocks and of the hysteresis hypothesis.

The rest of the paper is organized as follows. Section 2 outlines the class of empirical models considered, the smooth transition autoregressive (STAR) processes. Section 3 provides evidence supporting multiple equilibria as a good description of Spanish unemployment and shows evidence of parameter instability when modelling Spanish unemployment rate by means of a linear autoregressive process. In Section 4 we explore the possibility that such instabilities are caused by multiple equilibria and asymmetries and estimate a logistic STAR model. Section 5 summarizes the main findings and concludes.

2 Methodology

In univariate settings, multiple unemployment equilibria can be captured by means of a smooth transition autoregressive (STAR) model which can be formulated as follows:

$$U_t = (\alpha + \sum_{i=1}^{q} \phi_i U_{t-i})(1 - G(\gamma, U_{t-d} - c)) + (\tilde{\alpha} + \sum_{i=1}^{q} \tilde{\phi}_i U_{t-i})G(\gamma, U_{t-d} - c) + \varepsilon_t \tag{1}$$

where α, $\tilde{\alpha}$, ϕ_i, $\tilde{\phi}_i$, γ and c are parameters to be estimated and ε_t is an i.i.d. error term with zero mean and constant variance σ^2. The transition function $G(\gamma, U_{t-d} - c)$ is continuous, non decreasing and bounded between 0 and 1.

The STAR model can be interpreted as a regime-switching model that allows for two regimes, associated with the extreme values $G(\gamma, U_{t-d} - c) = 0$ and $G(\gamma, U_{t-d} - c) = 1$, each corresponding to a specific state of the economy. When U_{t-d} deviates from the constant threshold value c, transition between regimes takes place and its speed is governed by the parameter γ.

Two popular choices of transition functions are the first-order logistic function,

$$\text{LSTAR: } G(\gamma, U_{t-d} - c) = (1 + exp\{-\gamma(U_{t-d} - c)\})^{-1}, \;\; \gamma > 0, \tag{2}$$

and the exponential function,

$$\text{ESTAR: } G(\gamma, U_{t-d} - c) = 1 - exp\{-\gamma(U_{t-d} - c)^2\}, \ \ \gamma > 0. \tag{3}$$

The first one delivers the logistic STAR (LSTAR) model. When $\gamma \to 0$, the logistic function approaches 0.5 and the LSTAR model becomes a two-regime threshold autoregressive (TAR) model, whereas when $\gamma = 0$, the LSTAR model reduces to a linear AR model. Thanks to the different response to positive and negative deviations of U_{t-d} from c, the LSTAR specification is convenient for modelling unemployment in the presence of asymmetric behavior.

This is not the case for the ESTAR specification, in which positive and negative deviations from the threshold have the same effect. This model is therefore only able to capture non-linear symmetric adjustment.

Granger and Teräsvirta (1993) and Teräsvirta (1994) developed a technique for the specification and estimation of parametric STAR models. The data-based modelling cycle for STAR models put forward by these authors follows the "specific-to-general" strategy for building nonlinear time series models suggested by Granger (1993). As pointed out by van Dijk et al. (2002), this approach consists of the following steps: (a) Specify a linear AR model of order p for the time series under investigation. This model will be the starting point for further analysis. (b) Test the null hypothesis of linearity against the alternative of STAR. (c) If linearity is rejected for some transition variable, select the appropriate transition function. (d) Estimate and evaluate the model. (e) Use the model for descriptive or forecasting purposes.

Our analysis is conducted on the basis of this strategy.

Testing linearity against STAR is complicated since the parameter defining the STAR model are not identified under the null hypothesis of linearity. Teräsvirta (1994) suggests a sequence of tests to evaluate the null of an AR model against the alternative of STAR model. These tests are conducted by estimating the following auxiliar regression for a chosen set of values of the delay parameter d, with $1 < d < q$:

$$U_t = \beta_0 + \sum_{i=1}^{q} \beta_{1i} U_{t-i} + \sum_{i=1}^{q} \beta_{2i} U_{t-i} U_{t-d} + \sum_{i=1}^{q} \beta_{3i} U_{t-i} U_{t-d}^2 + \sum_{i=1}^{q} \beta_{4i} U_{t-i} U_{t-d}^3 + \epsilon_t \tag{4}$$

Equation (2) is obtained by replacing the transition function in the STAR model by a suitable Taylor series approximation. The null of linearity against a STAR model corresponds to: $H_0 : \beta_{2i} = \beta_{3i} = \beta_{4i} = 0$ for $i = 1, 2, ..., q$. The corresponding LM test, denoted as LM_3 in van Dijk et al. (2002), has an asymptotic χ^2 distribution with $3(p + 1)$ degrees of freedom under the null of linearity[3]. If linearity is rejected for more than one value of d, the value of d corresponding to the lowest p-value of the joint test is chosen.

Escribano and Jordà (2001) proposed an extension of the Teräsvirta (1994) linearity test by adding a fourth order regressor. These authors claim that this provides better results when the data are mainly in one of the regimes and when there is uncertainty about the lag length of the autoregressive part. The corresponding LM test statistic, denoted LM_4 in van Dijk et al. (2002), has an asymptotic χ^2 distribution with $4(p+1)$ degrees of freedom under the null of linearity.

If linearity is rejected, we need to test for LSTAR against ESTAR nonlinearity. For this purpose, Granger and Teräsvirta (1993) and Teräsvirta (1994) propose a sequence of tests within the auxiliar regression:

$$H_{04} : \beta_{4i} = 0 \;\; i = 1, 2, ..., q$$
$$H_{03} : \beta_{3i} = 0 | \beta_{4i} = 0 \;\; i = 1, 2, ..., q$$
$$H_{02} : \beta_{2i} = 0 | \beta_{3i} = \beta_{4i} = 0 \;\; i = 1, 2, ..., q$$

An LSTAR model is selected if H_{04} or H_{02} is rejected for at least one value of i and an ESTAR model is selected if H_{03} is rejected for at least one i. Escribano and Jordá (2001) also suggest a modification of this sequence of tests and propose two test statistics for distinguishing between LSTAR and ESTAR, named H_{0E} and H_{0L}. An LSTAR is chosen if the minimum p-value is obtained for H_{0L}.

The adequacy of the estimated STAR model can be finally tested using the data-based misspecification technique proposed by Eitrheim and Teräsvirta (1996). They proposed three LM test for the hypotheses of no error autocorrelation, no remaining linearity and parameter constancy.

The LM tests discussed along this section are sensitive to several kinds of misspecification of the model under the null hypothesis. Robust LM test against heteroskedasticity can be found in Lundbergh and Teräsvirta (1998) whereas van Dijk et al. (1999) suggest robustified LM test to control for the presence of outliers.

[3] van Dijk et al. (2002) also proposed a test for linearity based on a first-order Taylor approximation of the transition function around $\gamma = 0$. The null $\gamma = 0$ is then test as a LM type test, denoted LM_1, which is asymptotic χ^2 distributied with $(p+1)$ degrees of freedom under the null. In addition, these authors suggest an "economy version" of the LM_3 statistic which consists of augmenting the auxiliar regression in the first-order Taylor expansion with regressors U_{t-d}^2 and U_{t-d}^3. The resultant test, denoted LM_3^e, has an asymptotic χ^2 distribution with $(p+3)$ degrees of freedom under the null of linearity.

3 Data and linear estimation

In this section we provide some informal evidence supporting multiple equilibria as a good description of Spanish unemployment behavior. For this purpose we first describe the unemployment data and plot his density to check whether its shape is consistent with multiple equilibria or not. Next, we estimate a linear autoregressive model for Spanish unemployment and explore its properties. As shown below, parameter constancy tests reveal clear instabilities in the coefficients of the linear model. Such instabilities might be caused by misspecification in the linear model as a consequence of possible transitions between multiple equilibria.

Figure 1 plots the quarterly Spanish unemployment series. The covered span is 1972:Q2 to 2007:Q2. The series have been taken from the Main Economic Indicators database. As it is well known, the Spanish economy has traditionally suffered the highest unemployment rate in the OECD, though this situation has been partly reversed given the outstanding decrease of unemployment experienced over the last ten years. The analyzed period starts with the long recession period of 1972-1985. The roots of these recession can be traced back to the oil crisis in the seventies, which hit the Spanish economy very severly[4]. These shocks increased product prices and decreased labour demand. Downward wage rigidities prevented the necessary real wage adjustment that could have restored the demand for labor. Strong bargaining power of labor unions[5] resulted in wage claims which substantially exceeded productivity growth. The result was stagflation: inflation as well as unemployment increased in this period. Thus, whereas at the beginning of the 70s the Spanish unemployment rate stood at 2% on average, from 1975 to 1985 Spain experienced a huge employment reduction (about two million jobs) which raised the unemployment rate to 21.6% of the labour force. In the following years, from 1986 to 1991, Spain experienced a short period of employment creation and the unemployment rate fell back to 16.3%. This reduction can be explained by two factors. First, Spain entered into the European Community (EC) in 1986 and the economy took advantage of lower barriers to trade. Second, Spain joined the European Monetary System in 1989. As a consequence Spain benefitted from high growth which delivered in turn a huge increase in employment, though mainly through temporary jobs[6]. From 1991 to 1994 unemployment shot up again, peaking at 24.5% in the first quarter of 1994. Even though productivity continued to increase, there was a sign of a slowdown at the end of the period. With high real interest rates, Spain experienced large inflows of

[4] In 1977 approximately 66% of the consumed energy was imported.

[5] In 1977 was signed the Worker's Statute, which legalized trade unions and established collective bargaining.

[6] The labor reform in 1984 fuelled employment creation by introducing more flexibility specially for temporary employment.

foreign capital, and the consequent appreciation of the Spanish peseta eroded competitiveness in the export sector. At the same time, a steady increase of real wages in excess of productivity resulted in a serious loss of competitiveness. Because the membership in the ERM prevented competitive devaluations, the economy got stuck in external and internal imbalances that gradually became unsustainable. This was spotted by the financial market which launched a speculative attack on the Spanish peseta in September 1992 forcing Spain to leave the narrow bands of the ERM and to devaluate its currency. From 1995 onwards Spain has experienced a prolonged period of employment creation as a result of the labor market reforms of the end of the nineties[7] and of the Spanish Government determination, shared by the Spanish central bank, to meet the conditions of the Maastricht Treaty. In a context of strong trade liberalization, the de-regulation of good markets and privatizations caused a moderation in wages and prices, real interest rates came down, and the housing sector fuelled the economy and activity increased.

The dynamics of Spanish unemployment in the last thirty years has thus been characterized by the following features: a high and persistent unemployment period (from 1982 to 1999), when the unemployment rate is at average levels of 19.5%, and by two transition periods, one of massive employment destruction (from 1972 to 1982) and one of massive employment creation (from 1999 to 2007), which respectively preceeded and followed the high and persistent unemployment period.

This yet informal impression about multiple equilibria is supported by the bimodal distribution of Spanish unemployment, in which the modes are centered around 10% and 20%, as shown in figure 2.

Next, we test if the Spanish unemployment behavior can be adequately captured by a linear autoregressive model. Table 1 presents an estimated AR(5) model where only the significant coefficients are reported. The order of the lag has been determined by excluding the statistically insignificant lags of higher order, starting with a lag of 8. Even though the AR model does not seem to suffer from misspecification, with the important exception that normality is not accepted due to both skewness and excess kurtosis, the presence of non-constancy in the estimated parameters is evident from figure 3, which shows the recursive OLS estimates of the parameters over time, and from figure 4, which displays the one-step ahead Chow test and residuals. Both figures indicate noticeable changes in the parameters[8] in 1989, 1992 and 1999. We take these results as evidence against the linear representation of the process[9].

[7] The 1994 labor reform gave more flexibility to the wage setting process with preference to descentralized bargaining, whereas the 1997 and 2002 reforms introduced further flexibility in the labor market.

[8] The initial estimation period is 1972:Q4-1980:Q4.

[9] Following Priestly (1981), a linear model even with white residuals might not be an appropriate representation of the underlying process, since linearity requires that the residuals

A second word of caution on the linear specification is related to the persistence of the shocks: the estimates of the autoregressive coefficients sum up to 0.98 and both the ADF and Phillips-Perron unit root tests do not reject the null of unit root. This implies unemployment hysteresis in the unit root sense. However, standard unit root tests are not able to reject the I(1) hypothesis in the presence of breaking deterministic linear trends as shown in Perron (1989) for the Nelson and Plosser (1982) database and U.S. real GNP and in Perron (1990) where unemployment is also considered. The same might happen when in the presence of multiple structural breaks the unit root test allow for a single structural break under the null. In previous research, Franchi and Ordóñez (2008) provide evidence that Spanish unemployment appears to be well described as a stationary process around multiple structural breaks, and thus we abandon the linear specification in favor of the STAR formulation in (1).

4 The LSTAR model

Table 2 presents the test statistics for the null hypothesis of linearity against STAR nonlinearity. According to the results, linearity is rejected when the transition variable is U_{t-4}. Rejection is stronger when using robust outlier tests. Table 3 shows that for U_{t-4}, the LSTAR representation of the data is preferred to the ESTAR, see (2) and (3): H_{04} and H_{02} are both rejected whereas H_{02} can not be rejected. This result is corroborated by the Escribano and Jordà (2001) statistics, since H_{0L} presents a lower p-value compared to H_{0E}. These results indicate that an LSTAR model is a more appropriate description of the unemployment process than either a linear or an ESTAR model. Not only the unemployment rate presents nonlinear behavior, but this behavior is asymmetric.

Table 4 presents the estimated LSTAR model. The estimation has been carried out by the method of maximum likelihood. The outcome indicates the existence of two unemployment regimes: a high regime with an equilibrium value of 18.3% and a lower unemployment regime with a equilibrium value of 7.6%. The first regime corresponds to the average of the process when $G(\hat{\gamma}, U_{t-4}-\hat{c}) = 1$ while the low equilibrium is attained when $G(\hat{\gamma}, U_{t-4}-\hat{c}) = 0$. It is important to notice that as far as the transition function does not take its extremes values, any observed rate of unemployment is a weighted average of the high and low regimes, where the weights are given by the value of the transition function. The threshold value is $\hat{c} = 12.36\%$ rate of unemployment. Thus, unemployment evolves around distinct rates with different dynamics in expansions, $U_{t-4} < 12.36\%$, and contractions, $U_{t-4} > 12.36\%$.

be strictly independent random variables. Therefore, while ARMA residuals may be white, they may still contain nonlinear structure that ARMA processes are unable to capture.

The sum of the coefficients in each regime, $\sum \phi_i = 0.87$ for the low regime and $\sum \tilde{\phi}_i = 0.95$ for the high regime, measures the degree of persistence in each of the two regimes. Unemployment is highly persistent in the high regime, whereas the low regime appears to have less persistence[10]. That is, unemployment increases faster when the economy is hit by negative shocks rather than it decreases when positive shocks occur. Similar results are foundby Faria and León-Ledesma (2008). Using a Markov Switching in mean model, they find an equilibrium value of 19.52% for the period 1982-1999, whereas a value of 10.77% for the period 1978-1981 and 1999-2007.

The estimate of the transition parameter γ is fairly large (4.83), so that small changes in unemployment are sufficient to bring the estimated transition function close to 0 or 1. Similar values for γ have been found in the empirical literature for different European countries. Skalim and Teräsvirta (2002) compute LSTAR models for the unemployment rates in Austria, Denmark, Finland, Germany, Italy, Norway and Sweden. The estimate γ for these countries[11] are, respectively, 2.23, 13.37, 2.87, 4.29, 11.56, 93.98 and 1.95.

Figure 1 displays the time path behavior of unemployment as well as both equilibria and the threshold. Movements between equilibria are fast, as suggested by the estimate value for γ: from 1995 and in less than five years, the Spanish unemployment rate left the high unemployment rate, felt down the 12.36% threshold and approached to the lower unemployment equilibrium. The reverse situation took place in the beginning of the seventies, when Spanish unemployment jumped from a very low level of unemployment to a high one. Thus a success period of job creation could be easily reversed and might be followed by a sharp increase in unemployment. It turns out that the estimated model might contain a limit cycle.

From the results of the misspecification tests in table 4 we conclude that our model is well specified: there is no evidence of heteroscedasticity, autocorrelation and deviation from normality. In addition, the model captures all the nonlinear features of the data: the test for non remaining nonlinearity of STAR type does not indicate any remaining nonlinearity in the model. Finally, testing for parameter constancy is also important in this nonlinear framework since the model has been estimated assuming constant parameters. In contrast to the linear case where the alternative to the null of parameter constancy is,

[10] Bianchi and Zoega (1998) provide evidence that the observed persistence of unemployment is consistent with multiple equilibria.

[11] In the cases of Austria, Italy and Norway, Skalin and Teräsvirta (2002) use a time trend as a transition variable to allow for changes in the unemployment equilibrium over time. This could explain the abnormal high value of the estimated γ for Norway. As shown by Akram (2005), the sudden jump in Norwegian unemployment in 1988 can be explained this high value of γ when using a trend as a transition variable. Akram (2005) reestimates the smooth transition model for the Norwegian unemployment rate with the level of unemployment as a transition variable, and finds an estimate value for γ of 3.48.

if any, a single structural break, the statistics LM_{C1}, LM_{C2} and LM_{C3} in table 4 test for parameter constancy in LSTAR models under a parametric alternative which explicitly allows the parameters to change smoothly. Whereas LM_{C1} allows a monotonic parameter change, LM_{C2} considers a nonmonotonic change and LM_{C3} allows monotonically as well as nonmonotonically changing parameters. These tests show that the non-constancy in the parameters, either smooth or abrupt, has been modelled adequately. Moreover, the non rejection of the null hypothesis implies that there have not been significant changes in the two equilibria over time. Non remaining nonlinearity and non-constancy in variance has been also checked, concluding that variance does not exhibit any of these misspecifications.

The dynamic properties of the model are investigated by means of the generalized impulse response functions. We refer to Skalin and Teräsvirta (2002) for a definition and discussion. In figure 5 we plot the difference between the effect of positive and negative shocks on unemployment for several sizes of the shock (0.5, 3 and 5 standard deviation of the estimated errors) and different quantiles (median, 75% and 90%). The graphs are built as follows: for a given shock size we generate 10.000 shocks and compute the corresponding responses; then we group the responses into positive or negative according to the sign of the impact response, compute the corresponding quantiles and plot their difference. Because the endogenous variable is unemployment, a positive response means that unemployment raises after the shock, i.e. a negative shock hits the economy. Hence positive values in figure 5 mean that the effect of a negative shock of given size is greater than the effect of a positive shock of the same magnitude, i.e. that unemployment increases faster when the economy is hit by negative shocks rather than it decreases when positive shocks occur. This result is consistent for different magnitudes of the shocks. A second interesting conclusion that can be derived from figure 5 is that not only the response of unemployment is asymmetric, but the magnitude of the shocks matters in terms of their persistence. That is, small shocks (either positive or negative) are absorbed faster than larger shocks and thus the model is also able to capture the persistence (hysteresis) of Spanish unemployment.

5 Conclusions

The analysis indicates that a non-linear smooth transition autoregressive (STAR) model is well suited to describe the behavior of the Spanish unemployment in the last thirty years. In particular, we find the following results: *i)* the existence of two equilibria and a fast transition between them; *ii)* the high regime has an equilibrium value of unemployment of 18.3% and the low regime an equilibrium value of 7.6%; *iii)* the effect of a negative shock is greater than the effect of a positive shock of the same magnitude, i.e. unemployment increases faster when the economy is hit by negative shocks rather than it decreases when positive shocks occur. *iv)* small shocks (either positive or negative) are absorbed faster than larger shocks. Thus, the analysis provides evidence in favour of asymmetric behavior and hysteresis in the dynamics of the Spanish unemployment rate.

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Table 1: An AR model for the Spanish unemployment

Estimated model:		
$U_t = \underset{(0.001)}{0.002} + \underset{(0.091)}{1.482}\, U_{t-1} - \underset{(0.117)}{0.379}\, U_{t-2} - \underset{(0.033)}{0.122}\, U_{t-5} + \varepsilon_t$		
$\sum \theta_i = 0.98$	PP= -1.636	ADF= -2.393
Diagnostic tests:		
Autocorrelation 1-5:	$F(5, 105) =$	0.11105[0.9897]
ARCH 1-4:	$F(4, 102) =$	1.1938[0.3181]
Normality:	$\chi^2(2) =$	22.348[0.0000]
Heteroskedasticity, $F_{X_i X_j}$:	$F(6, 103) =$	0.52003[0.7920]
Heteroskedasticity, $F_{X_i^2}$:	$F(9, 100) =$	0.61805[0.7792]
Modelo specification, RESET test:	$F(1, 109) =$	2.5874[0.1106]

Note: The standard errors are in parentheses below the estimates and p-values are in square brackets. Autocorrelation 1-5 tests for residuals up to 5 lags, ARCH 1-4 tests for autoregressive conditional heteroskedasticity (ARCH) up to order 4. The normality test is the Jarque-Bera. Heteroskedasticity are tests for residual heteroskedasticity due to omission of cross products of regressors and/or squares regressors, $F_{X_i X_j}$ and $F_{X_i^2}$ respectively. RESET is the standard regression specification test by Ramsey. $\sum \theta_i = 0.98$ stands for the sum of the linear coefficients in the AR model. ADF and PP are respectively the Dickey-Fuller and the Phillips-Perron unit root tests. The lag length for the ADF and PP test statistics has been chosen using the AIC criterion. The critical values for the ADF and PP tests at 5% significance level are respectively -2.88 and -3.47.

Table 2: LM-type Tests for STAR Nonlinearities

	Standard Tests			
Transition variable	LM_1	LM_3	LM_3^e	LM_4
Trend	0.747	0.738	0.368	0.512
U_{t-1}	0.165	0.392	0.291	0.515
U_{t-2}	0.739	0.852	0.849	0.502
U_{t-3}	0.356	0.431	0.349	0.202
U_{t-4}	0.054	0.010	0.016	0.025
U_{t-5}	0.239	0.461	0.184	0.573
U_{t-6}	0.979	0.589	0.633	0.720

	Heterosked. Robust Tests			
Transition variable	LM_1	LM_3	LM_3^e	LM_4
Trend	0.766	0.681	0.201	0.520
U_{t-1}	0.236	0.524	0.414	0.615
U_{t-2}	0.590	0.589	0.451	0.470
U_{t-3}	0.385	0.509	0.562	0.632
U_{t-4}	0.053	0.095	0.156	0.158
U_{t-5}	0.302	0.541	0.259	0.626
U_{t-6}	0.962	0.176	0.385	0.293

	Outlier Robust Tests			
Transition variable	LM_1	LM_3	LM_3^e	LM_4
Trend	0.666	0.538	0.134	0.359
U_{t-1}	0.189	0.459	0.299	0.560
U_{t-2}	0.769	0.806	0.887	0.500
U_{t-3}	0.133	0.286	0.112	0.365
U_{t-4}	0.023	0.004	0.009	0.008
U_{t-5}	0.190	0.385	0.096	0.496
U_{t-6}	0.962	0.507	0.529	0.681

Note: p-values of F variants of the LM-type tests for STAR nonlinearity of the quarterly Spanish unemployment rate, 1972:4-2007:2. LM_1, LM_3, LM_3^e and LM_4 statistics are based on the auxiliar regression model in equation (4). See footnote 1 for details.

Table 3: STAR Model Selection

	Teräsvirta			**Escribano and Jordà**	
Transition variable	H_{04}	H_{03}	H_{02}	H_{0L}	H_{0E}
Standard Tests					
Trend	0.909	0.249	0.747	0.741	0.201
U_{t-1}	0.464	0.460	0.165	0.435	0.510
U_{t-2}	0.969	0.369	0.739	0.248	0.244
U_{t-3}	0.751	0.190	0.356	0.474	0.173
U_{t-4}	0.021	0.379	0.054	0.009	0.158
U_{t-5}	0.391	0.622	0.239	0.353	0.863
U_{t-6}	0.635	0.159	0.979	0.966	0.290
Heteroskedasticity robust tests					
Trend	0.911	0.300	0.766	0.729	0.142
U_{t-1}	0.506	0.417	0.236	0.335	0.522
U_{t-2}	0.946	0.241	0.590	0.177	0.203
U_{t-3}	0.846	0.082	0.385	0.674	0.409
U_{t-4}	0.055	0.432	0.053	0.344	0.056
U_{t-5}	0.230	0.357	0.302	0.698	0.717
U_{t-6}	0.189	0.104	0.962	0.525	0.063
Outlier robust tests					
Trend	0.745	0.112	0.666	0.654	0.143
U_{t-1}	0.691	0.432	0.189	0.534	0.609
U_{t-2}	0.938	0.307	0.769	0.268	0.240
U_{t-3}	0.765	0.170	0.133	0.547	0.735
U_{t-4}	0.008	0.432	0.023	0.009	0.086
U_{t-5}	0.366	0.596	0.190	0.389	0.847
U_{t-6}	0.504	0.133	0.962	0.906	0.248

Note: p-values of F variants of the LM-type tests used in the specification procedure of Teräsvirta (1994) and Escribano and Jordà (2001).

Table 4: The LSTAR model for the Spanish unemployment

Estimated model:

$$U_t = \underset{(0.41)}{0.95} + (\underset{(0.16)}{0.83}\,U_{t-1} - \underset{(0.16)}{0.29}\,U_{t-6} + \underset{(0.17)}{0.33}\,U_{t-7}) \times (1 - G(U_{t-4}; -\underset{(3.02)}{4.83}, \underset{(1.11)}{12.36})) +$$
$$+(\underset{(0.09)}{1.24}\,U_{t-1} - \underset{(0.11)}{0.22}\,U_{t-2} + \underset{(0.13)}{0.49}\,U_{t-4} - \underset{(0.10)}{0.56}\,U_{t-4}) \times G(U_{t-4}; -\underset{(3.02)}{4.83}, \underset{(1.11)}{12.36}) + \varepsilon_t$$

where $G(U_{t-4}; -\underset{(3.02)}{4.83}, \underset{(1.11)}{12.36}) = [1 + exp\{-\underset{(3.02)}{4.83}(U_{t-4} - \underset{(1.11)}{12.36})\}]^{-1}$

Sample: 1972:Q4-2007:Q2

Diagnostic tests:

Autocorrelation 1-5:	1.323 [0.262]
ARCH 1-4:	4.177 [0.382]
Normality:	

Test for constancy of parameters:

$LM_{C1} = 1.163\,[0.330]$
$LM_{C2} = 1.427\,[0.151]$
$LM_{C3} = 1.163\,[0.300]$

Test for non remaining nonlinearity:

Quadratic terms: 1.400 [0.215]
Cubic terms: 1.449 [0.131]
Fourth powers: 1.434 [0.131]

Test for constancy of variance:

$LM_{C1} = 0.631\,[0.428]$
$LM_{C2} = 0.573\,[0.565]$
$LM_{C3} = 0.465\,[0.707]$

Test for non remaining nonlinearity in variance:

Quadratic terms: 0.595 [0.442]
Cubic terms: 0.427 [0.653]
Fourth powers: 0.313 [0.815]

Long-run properties:

$G(U_{t-4}; \gamma, c) = 0 : \sum \phi_i = 0.875, \hat{\mu}_1 = 7.6$
$G(U_{t-4}; \gamma, c) = 1 : \sum \tilde{\phi}_i = 0.948, \hat{\mu}_2 = 18.3$

Note: The standard errors are in parentheses below the estimates and p-values are in square brackets. Autocorrelation 1-5 tests for residuals up to 5 lags, ARCH 1-4 tests for autoregressive conditional heteroskedasticity (ARCH) up to order 4. The normality test is the Jarque-Bera. LM_{C1}, LM_{C2} and LM_{C3} test for parameter constancy in LSTAR models under a parametric alternative which explicitly allows the parameters to change smoothly. LM_{C1} allows a monotonic parameter change, LM_{C2} considers a nonmonotonic change and LM_{C3} allows monotonically as well as nonmonotonically changing parameters (see Eitrheim and Teräsvirta (1996) for details).

Figure 1: Quarterly series of Spanish unemployment

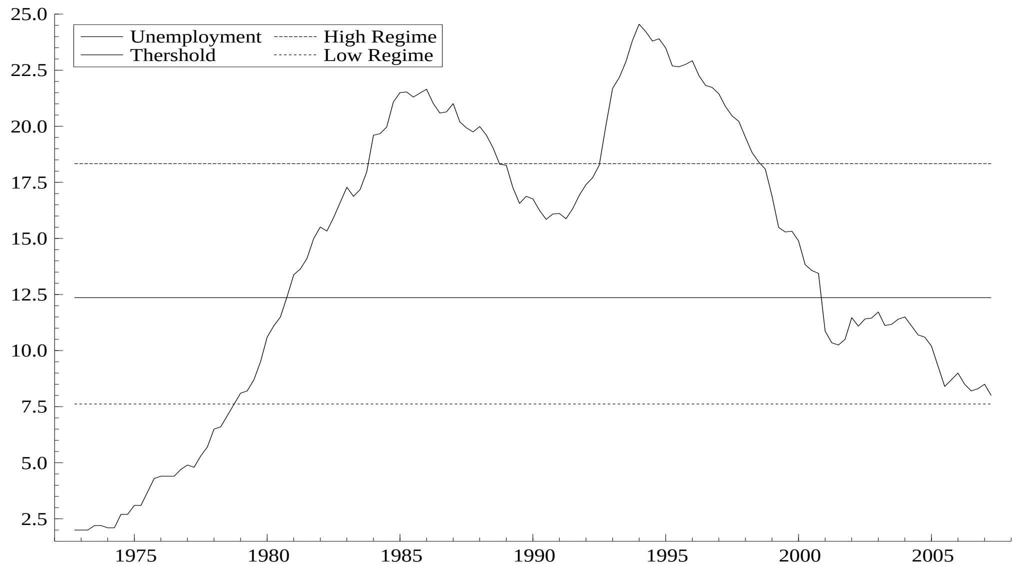


Figure 2: Nonparametric density estimation of Spanish unemployment

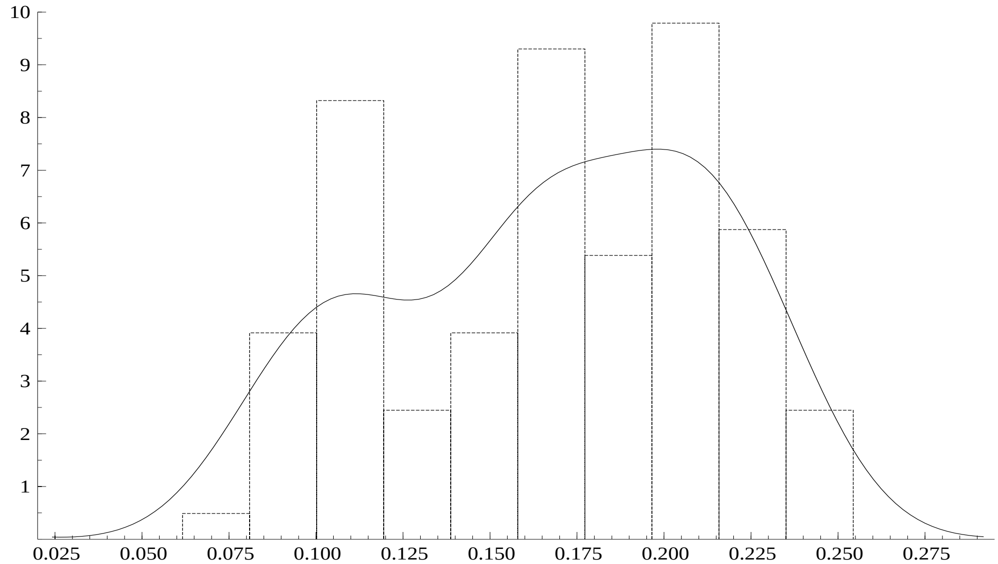
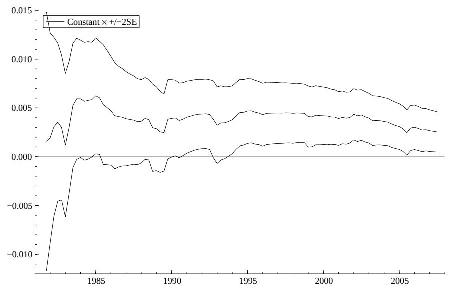
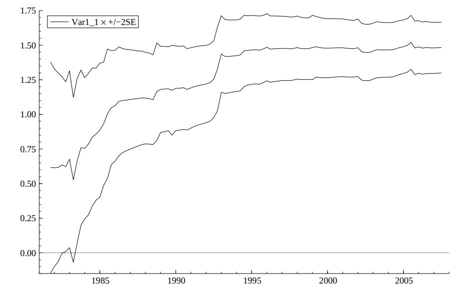


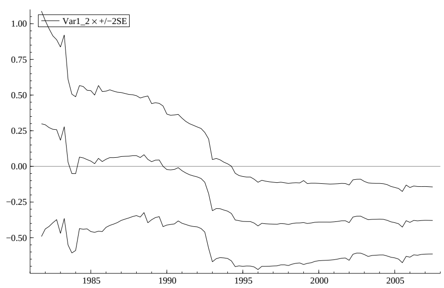
Figure 3: Recursive OLS estimates of the AR(5) coefficientes



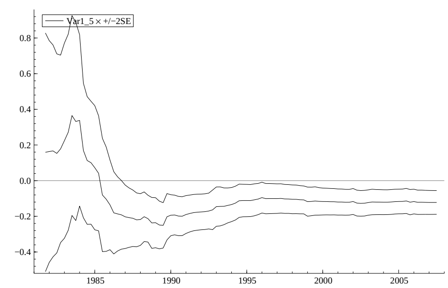
(a) Constant



(b) Beta 1

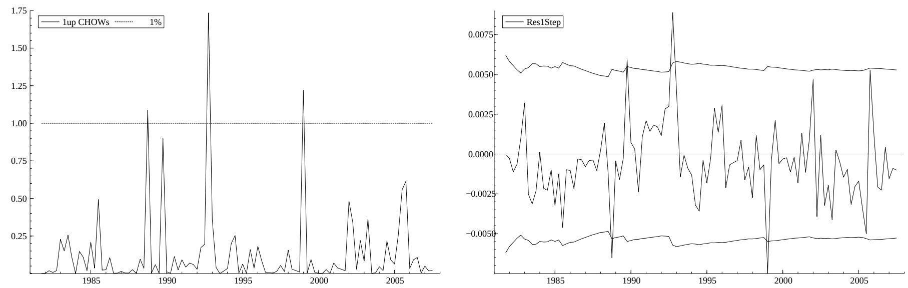


(c) Beta 2



(d) Beta 3

Figure 4: Recursive estimation of the AR(5) linear model



(a) One-step ahead Chow test

(b) One-step ahead residuals

Figure 5: Asymmetry in the quantiles.