Non-linearities in exchange rate pass-through: Evidence from smooth transition models

Ben Cheikh, Nidhaleddine

Centre de Recherche en Économie et Management (CREM)

April 2012

Non-linearities in Exchange Rate Pass-Through: Evidence from Smooth Transition Models

Nidhaleddine Ben Cheikh *

CREM, University of Rennes 1, 7 Place Hoche, 35065, Rennes Cedex, France

Abstract

This paper examines the presence of nonlinear mechanisms in the exchange rate pass-through (ERPT) to CPI inflation for 12 euro area (EA) countries. Using smooth transition models, we explore the existence of non-linearities with respect to three macroeconomic factors, namely inflation rate, exchange rate fluctuations and business cycle. Our results reveals that the transmission of exchange rate is higher when inflation rate surpass some threshold. We give a supportive evidence to the Taylor's view that pass-through is decreasing in a lower and more stable inflation environment. Next, we check the asymmetry of pass-through with respect to both direction and magnitude of exchange rate. In one hand, results provide an asymmetrical ERPT to appreciations and depreciations, but there is no clear direction of asymmetry. In the other hand, the degree of pass-through is found to be higher for large exchange rate changes than for small ones, which seems to be an evidence of the presence of menu costs. Finally, when we examine the non-linearities of ERPT relative to business cycle, we report that pass-through depends positively on economic activity; that is, when real GDP is growing above some threshold, the extent of ERPT becomes higher.

J.E.L classification: C22, E31, F31, F41

Keywords: Exchange Rate Pass-Through, Inflation, Smooth transition regression models, Euro area

*Tel.: +33 223 23 35 48. *E-mail address*: nbeneche@univ-rennes1.fr.

Contents

1 Introduction

The issue of non-linearities is one of the burgeoning topics in the literature of Exchange Rate Pass-Through (ERPT). In fact, there are various circumstances that could generate asymmetric adjustment of prices to exchange rate changes which can't be modeled within a simple linear framework. Some spectacular exchange rate movements like those experienced by the US dollar in the 1980s seems to be an illustration of an asymmetric pattern[1]. Similarly, at the launch the creation of the euro area (EA), there has been a large depreciation of the European currency against the US dollar from 1999 till the last of 2001. After that date, the euro started appreciating to become a strong and well established currency. Thereby, these exchange rate developments may rise the question of the possible existence of an asymmetric pass-through behavior in the monetary union (Bussière (2007)).

In spite of its policy relevance, studies dealing with the non-linearities in pass-through mechanisms are still relatively scarce. The existing empirical literature on this area of research has put forth the role of exchange rate in generating non-linearities. In one hand, asymmetry is tested with respect to the direction of currency movements, i.e. whether ERPT respond asymmetrically to appreciations and depreciations episodes. In the other hand, what matters is the size of exchange rate changes, i.e. if ERPT would be higher for large exchange rate changes than for small ones. However, as pointed by Marazzi *et al.* (2005), previous studies provide mixed results with no clear support for the existence of important non-linearities. If the existing literature is not conclusive, there are two important caveats should be noted in this regard. First, ERPT is not depending exclusively on exchange rate changes, there are various factors, including macroeconomic variables, which might influence the pass-through mechanisms. Thus, other sources of non-linearities may exist. For instance, Goldfajn & Werlang (2000) report an asymmetric reaction of the ERPT over the business cycle. Second, a relevant econometric implement is required. Several empirical studies on asymmetries in ERPT experiment a standard linear model augmented with interactive dummy variables. These added terms would account for some specific events such as unusual exchange rate developments (see Yang (2007)). To analyze the asymmetry of pass-through relative to exchange rate magnitude, Coughlin & Pollard (2004) use threshold dummy variables to distinguish between large and small exchange rate changes. The authors choose an arbitrary threshold value for all US industries which is equal to 3%, while it is more appropriate to estimate it from the data. An alternative methodology is to estimate a non-linear regime-switching model where a grid search is used to select the appropriate threshold. Amongst this class of models, two popular non-linear models can be

[1]In spite of the dramatic changes in the value of the dollar during this period, Yang (2007) provide a weak evidence of asymmetric ERPT between appreciation and depreciation.

mentioned. First, the so-called threshold regression model where the transition across regimes is abrupt[2]. Second, the smooth transition regression (STR) model with the transition between states is rather smooth.

Recently, there has been an increasing interest for models with regime-switching behavior in modeling the ERPT, although the number of studies is still sparse. Correa & Minella (2006) estimate a threshold regression model for the Brazilian economy in order to check for possible non-linearities in ERPT. In addition to exchange rate changes, the authors test for other sources of nonlinearity, namely exchange rate volatility and business cycle. Their results reveal that pass-through is higher when the economy is growing faster, when the exchange rate depreciates above a certain threshold, and when exchange rate volatility is lower. Concerning the STR models, to the best of our knowledge, there are only two studies that using a smooth non-linear regression in the context of pass-through. Shintani *et al.* (2009) estimated the ERPT to US domestic prices with respect to inflation level. They find that the period of low ERPT would be associated with the low inflation environment. In a more complete study, Nogueira Jr. & Leon-Ledesma (2008) examine the possibility of non-linear pass-through for a set of inflation target countries. They found that asymmetric adjustment of prices to exchange rate changes can be related to several macroeconomic factors, including inflation rate, the size of exchange rate changes, two measures of macroeconomic instability and output growth[3].

Therefore, our study aims at contributing to fill the gap in empirical evidence on the non-linearities in ERPT. More precisely, we follow Shintani *et al.* (2009) and Nogueira Jr. & Leon-Ledesma (2008) by using a STR models to estimate the extent of pass-through. We are interested to the second stage of ERPT, i.e. the transmission of exchange rate changes to consumer prices. Unlike the cited studies, we focus on the EA countries since the different exchange rate development experienced by the monetary union members seems to generate a non-linear mechanism in ERPT. To our knowledge, there is no other study has applied a non-linear STR estimation approach in this context. We note that the presence of non-linearities is tested with respect to different macroeconomic determinants, namely the inflation environment, the direction and the size of exchange rate changes and the economic activity.

To preview our results, we found that the degree of pass-through respond non-linearly to the inflation environment, that is, ERPT is higher when the inflation level surpasses some limit. The time-varying ERPT coefficient point out that exchange rate pass-through has declined

[2] The univariate case is known as the Threshold Autoregressive (TAR) Model

[3] More details on these studies in section 4. We note that Herzberg *et al.* (2003) analyzed the ERPT into UK import prices using a STR model but did not find any evidence of non-linearity.

over time in the EA countries, this is due to the shift to a low-inflation environment. When considering the direction of exchange rate change as a potential source of non-linearities, we report mixed results with no clear-cut about the direction of asymmetry. This is not surprising since, in theory, an appreciation can lead to either a higher or lower rate of pass-through than depreciation. Next, we check the asymmetry of pass-through with respect exchange rate magnitude. We find that large exchange rate changes elicit greater pass-through than small ones. Results give a broad evidence of the presence of menu costs, when exchange rate changes exceed some threshold, firms are willing to pass currency movements through their prices. These findings seem to explain why ERPT was during the EMS Crisis and at the launch of the euro. The last source of non-linearities considered in our study is relative to business cycle. We report that pass-through depends positively on economic activity; that is, when real GDP is growing above some threshold, the extent of ERPT becomes higher.

The structure of the Chapter 4 is as follows: Section 2 gives the reasons for the potential existence of a non-linear ERPT. In section 3, the modeling strategy of estimating a STR model is presented. Section 4 discusses the existing empirical literature using STR model to measure the pass-through. Section 5 describes data set and the final specification to estimate. Section 6 presents the main empirical results and Section 6 concludes.

2 ERPT and non-linearities

2.1 Why ERPT could be non-linear?

The empirical literature has paid little attention to the issue of non-linearities and asymmetry in ERPT in spite of its strong policy relevance. The number of studies which have investigating for nonlinearities in this context is to date relatively scarce, and most of papers assume linearity rather than testing it. In fact, there are various circumstances that could generate asymmetry in the pass-through mechanisms. The sparse empirical evidence on this area of research has put forth the role of exchange rate in generating non-linearities. According to this literature, potential pass-through asymmetries can rise with respect to exchange rate change direction i.e., in response to currency depreciations and appreciations (Marston (1990), Gil-Pareja (2000) and Olivei (2002), among others). In the other hand, the extent of pass-through may also respond asymmetrically to the size of exchange rate movements, since there is differential effect of large versus small exchange rate changes (Coughlin & Pollard (2004) and Bussière (2007)). There is some theoretical (microeconomic) arguments behind the potential asymmetric relationship between the exchange rate and prices. Mainly, we mention three explanations of a possible ERPT asymmetry:

- *Market share objective*: faced with a depreciation of the importing country's currency, foreign firms can follow pricing-to-market (PTM) strategy by adjusting their markups to maintain market. However, with an appreciation, they maintain their markups and allow the import price to fall in the currency of destination market. Consequently, the extent of ERPT would be different with respect to exchange rate change direction. If firms attempt to keep competitiveness and maintain market share, then an appreciation of the importing country's currency might cause higher pass-through than a depreciation.

- *Capacity constraints*: as mentioned in the microeconomic literature of ERPT, quantities may be rigid upwards in the short run. In fact, faced with a currency's importing country appreciation, exporters would gain in price competitiveness by passing this exchange rate change into their prices. But, if firms have already reached full capacity, the ability of increasing sales in destination market is limited, and they may be tempted to increase their mark-up instead of lowering prices in importer's currency[4]. As argued by Knetter (1994), if exporting firms are subject to binding quantity constraints, then an appreciation of the currency of the importing country might cause lower pass-through than a depreciation.

It is important to note that the two first arguments have a clear implication for possible non-linearities in ERPT, but in the same time they give rise to opposite interpretations of asymmetry. According to market share explanation, pass-through will be higher when the importer's currency is appreciating than when it is depreciating. While, the quantity constraint hypothesis suggest the opposite result, and ERPT would be highest when exchange rate is depreciating. Empirically, previous studies provide also no clear-cut evidence on the direction of asymmetry. In some cases the pass-through associated with depreciations exceeded appreciations; however, in other cases this result is quite the opposite. Gil-Pareja (2000) analyzed the differences in pass-through in a set of industries across a sample of European countries. He found that the direction of asymmetry varied across industries and countries. According to Coughlin & Pollard (2004), the contrasting direction of the results highlights the importance of analyzing pass-through at the industry level. If the direction of asymmetry varies across industries then aggregation may obscure asymmetry that is present at the industry level.

- *Menu Costs*: because of the costs associated with changing a price, exporters may leave their price in importer's currency unchanged if exchange rate changes are small. However, when exchange rate changes exceed some threshold i.e., with large magnitude, firms do change their prices. Thus, according to menu costs hypothesis, ERPT may be asymmetric

[4]Capacity constraints may also arise because of trade restrictions that limit imports, such as quotas or voluntary export restraints (Coughlin & Pollard (2004)).

with respect to the size of the exchange rate shocks, since price adjustment is more frequent with large exchange rate changes than with small ones. This asymmetric dynamic behavior has been put forth by Coughlin & Pollard (2004). In their study on U.S. import prices of 30 industries, they found that most firms respond asymmetrically to large and small changes in the exchange rate with ERPT positively related to the size of the change.

We can notice that the existing literature has focused notably on non-linearities in ERPT related to the size and the direction of exchange rate changes. Besides, there is some macroeconomic factors that would change foreign firms behavior, and thus could be sources of non-linearities in pass-through. One of these macroeconomic determinant is the inflation environment. As argued by Taylor (2000), the shift towards low and stable inflation regime has entailed a decline in the degree of ERPT in many industrialized countries. Accordingly, ERPT would be lower in a stable inflation environment than in a higher inflation episodes. Therefore, one can think that dynamic behaviour of pass-through depends upon inflation regime, which can be modeled in a non-linear way. To our knowledge, only three papers analyzed ERPT with respect to inflation level in a non-linear framework. Using a threshold model based on the Phillips curve, Przystupa & Wróbel (2011) reject the hypothesis of an asymmetric pass-through due to inflation environment in Poland. On the other side, Shintani *et al.* (2009) and Nogueira Jr. & Leon-Ledesma (2008) found a strong positive correlation between ERPT and inflation in STR framework[5].

Another important sources of pass-through non-linearities is the business cycle. It is expected that when economy is booming, ERPT would be higher than in periods of slowdown. Intuitively, firms would find it easier to pass-through exchange rate changes when the economy is growing fast, rather then when it is in a recession and its sales are already falling. Empirically, This intuition was confirmed by Goldfajn & Werlang (2000). Using a panel data model for 71 countries, they have found that depreciations have a higher pass-through to prices when economic activity is higher. Correa & Minella (2006) and Przystupa & Wróbel (2011) corroborated an asymmetric behavior between ERPT and growth in a Phillips curve threshold framework[6]. Also, in their STR model, Nogueira Jr. & Leon-Ledesma (2008) find that for three countries out of six pass-through responds nonlinearly to the output growth.

Therefore, in this paper we aim to fill the gap in literature on sources of non-linearities in ERPT. We analyse non-linearities not only with respect to the size and the direction of exchange rate changes, but also to the inflation level and output growth.

[5] These two papers are discussed in section 4 with more details.
[6] Correa & Minella (2006) was concerned by the Brazilian case.

2.2 Analytical framework

Let us consider a foreign firm that exports its product i to an importing country. Under monopolistic competition, the first-order conditions for exporter profit maximization, with price set in importing country currency P_i, yield the following expression:

$$P_i = E\mu_i W_i^* \tag{1}$$

Where E is the exchange rate measured in units of the domestic currency per unit of the foreign currency, μ_i is the markup of price over marginal cost W_i^* of foreign producer. The markup is defined as $\mu_i \equiv \eta_i/(1-\eta_i)$, where η_i is the price elasticity of demand for the good i in the importing country. As in Bailliu & Fujii (2004), μ_i is assumed to depend essentially on demand pressures in the destination market: $\eta_i = \eta_i(Y)$, with Y is the income (expenditures) level in the importing country. The log-linear form of equation (1) gives the standard ERPT regression traditionally tested throughout the exchange rate pass-through literature[7]:

$$p_t = \alpha + \beta e_t + \gamma y_t + \delta w_t^* + \varepsilon_t, \tag{2}$$

From equation (2), the ERPT coefficient is given by coefficient β and is expected to be bounded between 0 and 1. If $\beta = 1$, exporter markup will not respond to fluctuations of the exchange rates, price is set in foreign country currency (producer currency pricing, PCP) and then the pass-through is complete. If $\beta = 0$, the ERPT is zero, since foreign firm decide not to vary the prices in the destination country currency and absorb the fluctuations within the markup. This is a purely local currency pricing (LCP).

In the other hand, pricing strategies of firms depend not solely on demand conditions in the market. One can think that foreign firm may adjust price after exchange rate movements with respect to certain macroeconomic factors. For example, a stable inflation environment in the destination country may lead exporters to set prices in the importer's currency by adopting LCP strategy, which is leading to markup adjustment and lesser extent of pass-through. Consequently, we assume that the markup pricing of the foreign firm to depend on the importing country macroeconomic environment in a nonlinear fashion. We consider $\kappa(M)$ as a function including those macroeconomic determinants such as inflation level, exchange rate depreciation and output growth. This macroeconomic stability dependence is seen as a firm's

[7] The good index j is dropped and time index t is added. Lower cases variables denote logarithms.

strategic decision on how much to translate exchange rate changes into prices given different macroeconomic scenarios in the importing country.

Taking into account these factors, we can re-write foreign firm mark-up as follow:

$$\mu_i = \mu_i = (Y, E^{\kappa(M)}), \quad \kappa(M) \geq 0, \tag{3}$$

According to equation (1) and (3), ERPT equation in logarithms becomes:

$$\begin{aligned} p_t &= \alpha + \beta e_t + \psi y_t + \kappa(M) e_t + \delta w_t^* + \varepsilon_t \\ &= \alpha + [\beta + \kappa(M)]\, e_t + \psi y_t + \delta w_t^* + \varepsilon_t, \end{aligned} \tag{4}$$

According to the function $\kappa(M)$, there is an indirect channel of pass-through which depends on the macroeconomic environment. We have assumed macroeconomic factors affect firm's markup in a nonlinear way. We consequently consider that there is some threshold M^* which provide two extreme macroeconomic regimes, and we assume that transition from one regime to the other is smooth. For example, if our macroeconomic variable is inflation rate, this enable us to distinguish between high and low inflation environment regimes.

$$\kappa(M) = \begin{cases} 0 & \text{for } M \leq M^* \\ \phi & \text{for } M \geq M^* \end{cases} \tag{5}$$

There is two different ERPT for these two extreme cases. If the importing country has a small or a negative (in the case where $M^* = 0$) value of a macroeconomic variable, then ERPT is equal to β. If the importing country has a macroeconomic variable value beyond some threshold (high or a positive (if $M^* = 0$) value), then ERPT is equal to $(\beta + \phi)$. We can see that ERPT would be different and depends on whether the macroeconomic determinant is above or below a threshold level. For example, as mentioned in the literature, higher inflation environment would raise ERPT, however, with a stable inflation level pass-through would be lower. Thus, the advantage of equation (5) is to describe the changing behavior in the exchange rate in a non-linear fashion, unlike previous empirical studies.

3 Empirical approach

3.1 Smooth transition regression models

To capture the nonlinearity in the exchange rate transmission, we use the family of smooth transition regression (STR) models as a tool. A STR model is defined as follows:

$$\begin{aligned} y_t &= \beta' \mathbf{z}_t + \phi' \mathbf{z}_t G(s_t; \gamma, c) + u_t \\ &= [\beta + \phi G(s_t; \gamma, c)]' \, \mathbf{z}_t + u_t, \end{aligned} \tag{6}$$

Where $u_t \sim \text{iid}(0, \sigma^2)$, $\mathbf{z}_t = (\mathbf{w}_t', \mathbf{x}_t')'$ is an $((m+1) \times 1)$ vector of explanatory variables with $\mathbf{w}_t' = (y_{t-1}, ..., y_{t-d})'$ and $\mathbf{x}_t' = (x_{1t}, ..., x_{kt})'$[8]. $\beta = (\beta_0, \beta_1, ..., \beta_m)'$ and $\phi = (\phi_0, \phi_1, ..., \phi_m)'$ are the parameter vectors of the linear and the nonlinear part respectively. $G(s_t; \gamma, c)$ is the transition function bounded between 0 and 1, and depends upon the transition variable s_t, the slope parameter γ and the location parameter c[9]. The transition variable s_t is an element of $\mathbf{z}_t$, and then is assumed to be a lagged endogenous variable ($s_t = y_{t-d}$) or an exogenous variable ($s_t = x_{kt}$). According to (1), the model can be interpreted as a linear model with stochastic time-varying coefficients $\beta + \phi G(s_t; \gamma, c)$ depending on the value of s_t.

There are two standard choice of the transition function:

- Logistic Function

$$G(s_t; \gamma, c) = [1 + \exp\{-\gamma(s_t - c)\}]^{-1} \tag{7}$$

- Exponential Function

$$G(s_t; \gamma, c) = 1 - \exp\left\{-\gamma(s_t - c)^2\right\} \tag{8}$$

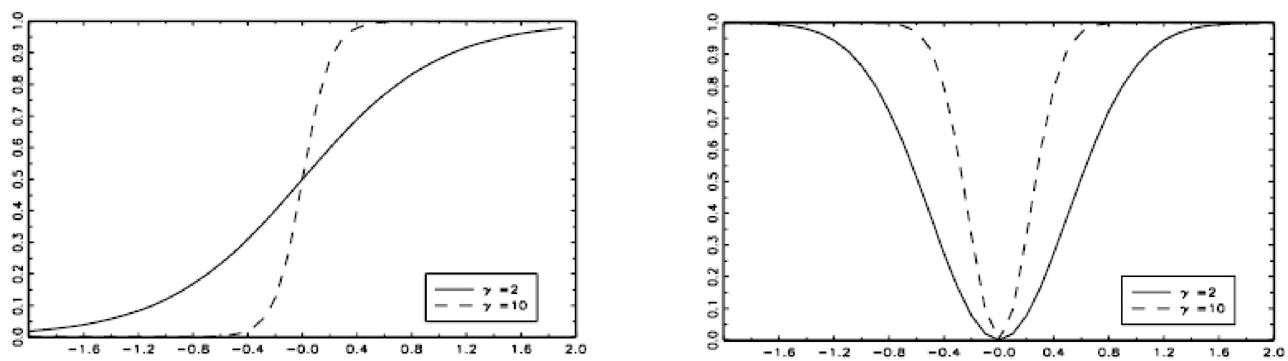
[8] When $\mathbf{x}_t$ is absent from (1) and $s_t = y_{t-d}$, the STR model becomes a univariate smooth transition autoregressive (STAR) model.

[9] The parameter γ is also called the speed of transition which determines the smoothness of the switching from one regime to the other.

Equations (1) and (2) jointly define the logistic STR (LSTR) model and the pattern formed jointly by (1) and (3) is called the exponential STR (ESTR) model. In Both models, the parameter c can be interpreted as the threshold between two regimes corresponding to $G(s_t;\gamma,c)=0$ and $G(s_t;\gamma,c)=1$. For the LSTR model, the nonlinear coefficients would take different values depending on whether the transition variable is below or above the threshold. So, the parameters $\phi+\theta G(s_t;\gamma,c)$ changes monotonically as a function of s_t from ϕ to $(\beta+\phi)$. In this sense, as $(s_t-c)\to-\infty$, $G(s_t;\gamma,c)\to 0$ and coefficients become β; if $(s_t-c)\to+\infty$, $G(s_t;\gamma,c)\to 1$ and coefficients are $(\beta+\phi)$; and if $s_t=c$, then $G(s_t;\gamma,c)=1/2$ and coefficients will be $(\beta+\phi/2)$. It should be noted that LSTR model would follow the same pattern as the threshold model described in the theoretical model (equation (5)) but assuming a smooth adjustment. One feature of LSTR model is that when $\gamma\to\infty$, LSTR model approaches the two-regime switching regression model with an abrupt transition. But when $\gamma=0$, the transition function $G(s_t;\gamma,c)\equiv 0$, and thus the LSTR model reduces to a linear model.

Concerning ESTR model, this specification is appropriate in situations in which the dynamic behavior is different for large and small values of s_t (what matters is the magnitude of shock, if they are large or small). In other words, the coefficient changes depending on whether s_t is near or far away from the threshold, regardless of whether this difference (s_t-c) is positive or negative. Therefore, the exponential transition function $G(s_t;\gamma,c)\to 1$ as $(s_t-c)\to\pm\infty$ and the coefficients are $(\beta+\phi)$. And if $s_t=c$, $G(s_t;\gamma,c)=0$ and coefficients becomes β. A drawback of ESTR specification is that for either $\gamma\to\infty$ and $\gamma\to 0$, the model becomes practically linear and thus it does not nest a threshold model (with steep transition) as a special case.

Figure 1: Transition Functions



Logistic Function

Exponential Function

The implied nonlinear dynamics under logistic and exponential functions are drastically different (Figures 1). LSTR model is pertinent in describing asymmetric dynamic behaviour.

As mentioned in the STR literature (van Dijk *et al.* (2002)), when modelling business cycle, LSTR can describe processes whose dynamic properties are different in expansions from what they are in recessions. For example, if the transition variable s_t is a business cycle indicator (such as output growth), and if $c \simeq 0$, the model distinguishes between periods of positive and negative growth, that is, between expansions and contractions. On the other hand, an ESTR allow for symmetric dynamics with respect to negative and positive deviations of s_t from the threshold level. The function rather depends on whether the transition variable is close or far away from the threshold c. Exponential specification was popularly employed in analyzing the nonlinear adjustment of real exchange rates (see Michael *et al.* (1997), Taylor & Peel (2000), Taylor *et al.* (2001), and Kilian & Taylor (2003), among others).

Non-linearities can be attributed to the existence of different relationships between the variables involved depending on whether a transition variable is near, above or below a threshold. Therefore, we must be careful in our implementation of these models in our ERPT analysis. LSTR and ESTR models must allow respectively for symmetric and asymmetric response of domestic prices to changes in the exchange rate with respect to negative and positive deviations of s_t from c. For example, when considering exchange rate as transition variable and $c \simeq 0$, LSTR model can account for ERPT asymmetry during currency appreciations and depreciations episodes. For ESTR model interpretation is different, and what matters is the size of exchange rate change. According to ERPT literature, firms are willing to absorb small changes in exchange rate rather than larger ones. This is due to the costs of changing prices. Then, the presence of "menu costs" may result in asymmetric pass-through of large and small exchange rate shocks (Coughlin & Pollard (2004)). In such case, ESTR specification would be more appropriate in describing this non-linearity in ERPT mechanism (Nogueira Jr. & Leon-Ledesma (2008)). Nevertheless, our choice for relevant transition function must be also conducted with non-linearity specification tests in addition to the economic intuition.

3.2 Modelling strategy of STR models

The modeling procedure follows Teräsvirta (1994) approach and is similar to the modelling cycle for linear models of Box and Jenkins (1970). It is consisting of three stages: specification, estimation, and evaluation:

3.2.1 Specification stage

As a starting point for the analysis, adequate linear representation must be specified. This can be modelled by using a VAR framework. For lag selection, we adopt a general-to-specific approach, as suggested by van Dijk *et al.* (2002), to reach the final specification. We start with a model with maximum lag length $N = 4$, and sequentially we remove the lagged variables for which the t statistic of the corresponding parameter is less than 1 in absolute value. Second step of specification consists in testing for nonlinearity, choosing the appropriate s_t and the most suitable form of the transition function (LSTR or ESTR models).

Linearity is tested against a STR model with a predetermined transition variable. Economic theory may give an idea of which variables should be selected as s_t. Alternatively, the test is repeated for each variable in the set of potential transition variables, which is usually a subset of the elements in $\mathbf{z}_t$. If the null hypothesis of linearity is rejected for at least one of the candidate models, the model against which the rejection is strongest is chosen to be the STR model to be estimated. Once linearity has been rejected and a transition variable subsequently selected, the final decision to be made at this stage concerns the appropriate form of the transition function.

In order to derive a linearity test, Teräsvirta (1994, 1998) suggest to approximate the logistic function (7) in (6) by a third-order Taylor expansion around the null hypothesis $\gamma = 0$. The resulting test has power against both the LSTR and ESTR models. Assuming that the transition variable s_t is an element in $\mathbf{z}_t$ and let $\mathbf{z}_t = (1, \tilde{\mathbf{z}}_t^{'})^{'}$, where $\tilde{\mathbf{z}}_t^{'}$ is an $(m \times 1)$. Taylor approximation yields the following auxiliary regression:

$$y_t = \alpha_0^{'}\mathbf{z}_t + \sum_{j=1}^{3} \alpha_j^{'}\widetilde{\mathbf{z}}_t s_t^j + u_t^*, \quad t = 1, ..., T, \tag{9}$$

Where $u_t^* = u_t + R_3(\gamma, c, s_t)\theta^{'}\mathbf{z}_t$, with $R_3(\gamma, c, s_t)$ the residual of Taylor expansion. The null hypothesis of linearity is $H_0 : \alpha_1 = \alpha_2 = \alpha_3 = 0$. Luukkonen *et al.* (1988) suggest a Lagrange Multiplier (LM) statistic with a standard asymptotic $\chi^2(3m)$ distribution under the null hypothesis. In small and moderate samples, the χ^2-statistic may be heavily oversized. The F version of the test is recommended instead, which has an approximate F-distribution with $3m$ and $T - 4m - 1$ degrees of freedom under H_0 (van Dijk *et al.* (2002)). Linearity tests are executed for each of the candidates potential transition variables. If the null hypothesis is rejected for several transition variables, select the one with the strongest test rejection (the smallest p-value). The logic behind this suggestion is that the rejection of H_0 is stronger against the correct alternative than other alternative models. However, if several small p-values are close to each other, it may be useful to proceed by estimating the corresponding STR models and leaving the choice between them to the evaluation stage.

Once linearity has been rejected, one has to choose whether an LSTR or an ESTR model should be specified. The choice between these two types of models can be based on the auxiliary regression (1). Teräsvirta (1994, 1998) suggested that this choice can be based on testing the following sequence of nested null hypotheses:

1. Test $H_{04} : \alpha_3 = 0$
2. Test $H_{03} : \alpha_2 = 0 | \alpha_3 = 0$
3. Test $H_{02} : \alpha_1 = 0 | \alpha_2 = \alpha_3 = 0$

According to Teräsvirta (1994), the decision rule is the following: if the test of H_{03} yields the strongest rejection measured in the p-value, choose the ESTR model. Otherwise, select the LSTR model. All three hypotheses can simultaneously be rejected at a conventional significance level, that is why the strongest rejection counts. This procedure was simulated in Teräsvirta (1994) and appeared to work satisfactorily. According to van Dijk *et al.* (2002), recent increases in computational power have made these decision rules less important in practice. Since it is easy to estimate a number of both LSTAR and ESTAR models and to choose between them at the evaluation stage by misspecification tests. In practice, this is a sensible way of proceeding if the test sequence does not provide a clear-cut choice between the two alternatives in the sense that p-values of the test of H_{03}, on the one hand, and of H_{02} or H_{04} on the other, are close to each other. Nevertheless, carrying out the tests still be recommended even if the actual decision were postponed to the evaluation stage of the modelling strategy.

3.2.2 Estimation stage

The parameters of the STR model are estimated by nonlinear least squares (NLS) estimation technique which provides estimators that are consistent and asymptotically normal. As discussed in van Dijk *et al.* (2002), under the assumption that the errors are normally distributed, NLS is equivalent to maximum likelihood. Otherwise, the NLS estimates can be interpreted as quasi maximum likelihood estimates. Finding good starting values is crucial in this procedure. Thus, STR literature suggests to construct a grid search for estimating γ and c. The values for the grid search for γ were set between 0 and 100 for increments of 1, whereas c was estimated for all the ranked values of the transition variable s_t. For each value of γ and c the residual sum of squares is computed. The values that correspond to the minimum of that sum are taken as starting values into the NLS procedure. This procedure increases the precision of the estimates and ensures faster convergence of the NLS algorithm. It should also be noted that when constructing the grid, γ is not a scale-free. The transition parameter γ is therefore standardized by dividing it by the sample standard deviation of the transition variable s_t, which will call $\widehat{\sigma}_s$. Then, the transition functions becomes:

$$G(s_t;\gamma,c) = \begin{cases} \Big[1+\exp\big(-(\gamma/\widehat{\sigma}_s)(s_t-c)\big)\Big]^{-1} & \text{for Logistic Function} \\ 1-\exp\big(-(\gamma/\widehat{\sigma}_s)(s_t-c)^2\big) & \text{for Exponential Function} \end{cases} \tag{10}$$

3.2.3 Evaluation stage

In the final stage, the quality of the estimated STR model should checked against misspecification as in the case of linear models. Several misspecification tests are used in the STR literature, such as LM test of no error autocorrelation, LM-type test of no ARCH and Jarque-Bera normality test. Eitrheim & Terasvirta (1996) suggested two additional LM-type misspecification tests: an LM test of no remaining nonlinearity and LM-type test of parameter constancy. We briefly describe the two latter tests.

Test of no remaining nonlinearity: After estimating STR model parameters, it is important to ask whether some nonlinearity remains unmodeled. The test assumes that the type of the remaining nonlinearity is again of the STR type. The alternative can be defined as:

$$y_t \; = \beta^{'}\mathbf{z}_t + \phi^{'}\mathbf{z}_t G(s_{1t};\gamma_1,c_1) + \psi^{'}\mathbf{z}_t H(s_{2t};\gamma_2,c_2) + u_t, \tag{11}$$

Where H is another transition function and $u_t \sim \text{iid}(0,\sigma^2)$. To test this alternative, the following auxiliary model is used:

$$y_t = \alpha_0^{'}\mathbf{z}_t + \phi^{'}\mathbf{z}_t G(s_{1t};\gamma_1,c_1) + \sum_{j=1}^{3}\alpha_j^{'}\widetilde{\mathbf{z}}_t s_{2t}^{j} + u_t^{*}, \tag{12}$$

The null hypothesis of no remaining nonlinearity is that $\alpha_1 = \alpha_2 = \alpha_3 = 0$. The choice of s_{2t} can be a subset of available variables in $\mathbf{z}_t$ or it can be s_{1t}. It is also possible to exclude certain variables from the second nonlinear part by restricting the corresponding parameter to zero. The resulting F-statistics are given in the same way as for the test on linearity.

Test of parameter constancy : This is a test against the null hypothesis of constant parameters against the alternative of smooth continuous change in parameters[10]. To consider the test, rewrite (1) as follows:

$$y_t \; = \beta(t)^{'}\mathbf{z}_t + \phi(t)^{'}\mathbf{z}_t G(s_{1t};\gamma_1, c_1) + u_t, \tag{13}$$

Where

$$\beta(t)^{'} = \beta + \lambda_\beta + H_\phi(\gamma_\beta, c_\beta, t^*) \tag{14}$$

And

$$\phi(t)^{'} = \phi + \lambda_\phi + H_\phi(\gamma_\phi, c_\phi, t^*) \tag{15}$$

With $t^* = t/T$ and $u_t \sim \text{iid}(0, \sigma^2)$. $H_\beta(\gamma_\beta, c_\beta, t^*)$ and $H_\phi(\gamma_\phi, c_\phi, t^*)$ are transition functions with $s_t = t^*$. The null hypothesis of no change in parameters is $\gamma_\beta = \gamma_\phi = 0$. The parameters γ and c are assumed to be constant. The following nonlinear auxiliary regression is used:

$$y_t = \alpha_0^{'}\mathbf{z}_t + \sum_{j=1}^{3} \alpha_j^{'}\widetilde{\mathbf{z}}_t(t^*)^j + \sum_{j=1}^{3} \alpha_{j+3}^{'}\widetilde{\mathbf{z}}_t(t^*)^j G(s_t;\gamma, c) + u_t^*, \tag{16}$$

Where $\alpha_j = 0$, $j = 1, ..., 6$, if and only if the null hypothesis $\gamma_\beta = \gamma_\phi = 0$ holds. As usual, the F-version of the LM test is recommended instead of the χ^2 variants which may be heavily oversized in small samples.

In the STR literature, error autocorrelation, parameter nonconstancy and remaining nonlinearity tests are the most obvious ones used in the evaluation stage, nevertheless, other tests such as the LM-type test for the null hypothesis of no ARCH and the Jarque-Bera normality test may be useful[11].

[10] This is different from parameter constancy test in linear model, where the alternative is a single structural break. The present alternative does, however, contain a structural break as a special case.

[11] Jarque-Bera normality test is sensitive to outliers, and the result should be considered jointly with a visual examination of the residuals.

4 Empirical literature of STR pass-through model

The empirical literature that utilizing the STR models in examining the extent of ERPT is to date relatively scarce, although it constitutes an important extension to look for (Herzberg *et al.* (2003)). Only a very few number of studies have tested for nonlinearities and asymmetries in this context. Essentially, we can mention three studies who estimates a STR pass-through model: Shintani *et al.* (2009) for US, Nogueira Jr. & Leon-Ledesma (2008, 2011) for 6 countries adopting Inflation Target (IT) regime and Herzberg *et al.* (2003) for UK. The latter papers was interested in measuring the ERPT into import prices but did not find any evidence of non-linearity. Therefore, we will introduce the only two first studies in this section, namely, Shintani *et al.* (2009) and Nogueira Jr. & Leon-Ledesma (2008, 2011).

4.1 Shintani *et al.* (2009)

In their paper, the authors use a STR model to measure US domestic price adjustment to exchange rate movements from 1975 to 2007 using monthly data. Primarily, they estimate a bivariate version of the STAR model specified as follow:

$$\begin{aligned}\pi_t = \phi_0 + \sum_{j=1}^{N} \phi_{1,j}\pi_{t-j} + \sum_{j=0}^{N-1} \phi_{2,j}\Delta(e_{t-j} + p^*_{t-j}) \\ + \left(\sum_{j=1}^{N} \phi_{3,j}\pi_{t-j} + \sum_{j=0}^{N-1} \phi_{4,j}\Delta(e_{t-j} + p^*_{t-j})\right) G(s_t;\gamma) + \varepsilon_t,\end{aligned} \tag{17}$$

Where π_{t-j} is the inflation rate of the producer price index and $\Delta(e_t + p^*_t)$ US dollar prices paid by the US importer[12]. According to their theoretical model the ERPT is a symmetric function of the past inflation rates around zero. To capture this feature, an exponential *U-shaped* symmetric transition function is used:

$$G(s_t;\gamma) = 1 - \exp\left\{-\gamma s_t^2\right\}, \tag{18}$$

Only one transition variable is used in this empirical analysis, which is a moving average of the past inflation rates, $s_t = d^{-1}\sum_{j=1}^{d} \pi_{t-j}$. In addition to the ESTAR model, they also

[12]Shintani *et al.* (2009) employ the producer price index rather than the consumer price index since they consider that the domestic price in their model is the price at which the final good producer sells its product.

consider another STAR model constructed from a combination of two logistic functions, which gives a different *U-shaped* transition function. Thus, the transition function in this is given by:

$$G(s_t; \gamma_1, \gamma_2, c) = (1 + \exp\{-\gamma_1(s_t - c_1)\})^{-1} + (1 + \exp\{-\gamma_2(s_t + c_2)\})^{-1} \tag{19}$$

Shintani *et al.* (2009) call it dual LSTAR (DLSTAR) model to emphasize the presence of two logistic functions, which is different from the STAR model with "second-order" logistic function[13]: $G(s_t; \gamma, c_1, c_2) = (1 + \exp\{-\gamma(s_t - c_1)(s_t - c_2)\})^{-1}$. According to Shintani *et al.* (2009), there are two reasons behind the use of DLSTR model (equation (19)). First, as mentioned above, the transition function in the ESTAR model collapses to a constant when γ approaches infinity, and then the model does not nest the TAR model with an abrupt transition. In contrast, the DLSTAR model includes the TAR model by letting γ_1, γ_2 tend to infinity. Second, and more importantly, the model can incorporate both symmetric ($\gamma_1 = \gamma_2$ and $c_1 = c_2$) and asymmetric ($\gamma_1 \neq \gamma_2$ and $c_1 \neq c_2$) adjustments between the positive and negative regions. Therefore, this enable investigating a symmetric relationship between the ERPT and the inflation rate.

Concerning their results, the authors found that the degree of ERPT becomes largest when the transition variable becomes above 2 percent in absolute term. They detect three distinct high ERPT episodes. The first high ERPT period corresponds to the second oil shock in the 1970s. During the 1980s and 1990s, the ERPT is relatively stable except for the early 1990s when the producer price index is relatively volatile. During the decade beginning in 2000, the ERPT becomes high again due to the increased volatility of inflation. Therefore, Shintani *et al.* (2009) conclude that the period of low ERPT is likely to be associated with the low inflation environment, and vice versa.

4.2 Nogueira Jr. & Leon-Ledesma (2008, 2011)

Nogueira Jr. & Leon-Ledesma (2008, 2011) investigate the ERPT into CPI inflation for a set of emerging and developed IT countries. Using monthly data, the period of estimation is ranging from 1983 to 2005 for the developed economies, and 1992 to 2005 for the emerging markets. Empirically, the authors consider the following model:

[13]See van Dijk *et al.* (2002).

$$
\begin{aligned}
\pi_t = \beta_0 + & \sum_{j=1}^{N} \beta_{1,j}\pi_{t-j} + \sum_{j=0}^{N} \beta_{2,j}\Delta p_{t-j}^{imp} + \sum_{j=0}^{N} \beta_{3,j}\Delta y_{t-j} \\
& + \sum_{j=0}^{N} \beta_{4,j}\Delta e_{t-j} + \left(\beta_0^* + \sum_{j=0}^{N} \beta_{4,j}^*\Delta e_{t-j}\right) G(s_t;\gamma,c) + \varepsilon_t,
\end{aligned} \tag{20}
$$

Where π_t is the CPI inflation rate, Δp_t^{imp} is the change in import prices (in foreign currency), Δy_t is the output growth and Δe_t is the rate of exchange rate depreciation. Nogueira Jr. & Leon-Ledesma (2008, 2011) experiment both traditional logistic and exponential (equations (7) and (8) respectively) as a transition function. They test several potentially important transition variables in order to capture possible nonlinearities and asymmetries in ERPT. So, they consider a set of macroeconomic variables which affecting the ERPT mechanism, namely inflation rate, exchange rate, output growth and two measures of macroeconomic instability[14]. For more accuracy, an ESTR model was used to capture asymmetry of pass-through with respect to the size of exchange rate change, i.e. asymmetry between large and small shocks. On the other hand, LSTR model was employed for the rest of transition variables (inflation, output and instability measures), as dynamic behavior would be different on either of the threshold.

Nogueira Jr. & Leon-Ledesma (2008, 2011) paper results highlights several sources of linearities in ERPT which vary considerably across countries. First, four out of six countries show a positive relationship between ERPT and the inflation level. According to the author, the adoption of IT, which was followed by lower inflation in this countries sample, has contributed in moderating pass-through. Also, the authors find that ERPT seem to increase in periods of macroeconomic distress, which highlights the importance of a stable macroeconomic environment in reducing ERPT. When considering exchange rate as transition variable only two countries indicate a positive correlation between pass-through and exchange rate change magnitude. Finally, ERPT seems to be affected nonlinearly by output growth, when the economy is growing fast above a threshold, ERPT would be higher. This latter result is valid for Three out of six countries in the sample.

[14] Nogueira Jr. & Leon-Ledesma (2008, 2011) use two potential indicators of macroeconomic instability: real interest rates differentials to the United States and Emerging Markets Bond Index Plus (EMBI+) spreads which is a leading indicator of confidence crises.

5 Data and specification

In our empirical analysis, we define a STR pass-through equation which is derived from the theoretical model (equation (4)). It consists of an extension of Bailliu & Fujii (2004) ERPT model to a non-linear case. Then, the estimated model has the following form:

$$\begin{aligned}\pi_t = \alpha + \sum_{j=1}^{N} \lambda_j \pi_{t-j} + \sum_{j=0}^{N} \psi_j \Delta y_{t-j} + \sum_{j=0}^{N} \delta_j \Delta w^*_{t-j} \\ + \sum_{j=0}^{N} \beta_j \Delta e_{t-j} + \left(\sum_{j=0}^{N} \phi_j \Delta e_{t-j} \right) G(s_t; \gamma, c) + \varepsilon_t,\end{aligned} \tag{21}$$

Where π_t is the consumer price inflation rate, Δw^*_t is the changes in foreign producer cost, Δy_t is the output growth and Δe_t is the rate of depreciation of the nominal effective exchange rate. $G(s_t; \gamma, c)$ is the transition function which drive the non-linear dynamic. According to (21), we can define both short-run and long-run time-varying ERPT:

- Short-run pass-through:

$$SR\ ERPT = \beta_0 + \phi_0 G(s_t; \gamma, c) \tag{22}$$

- Long-run pass-through:

$$LR\ ERPT = \frac{\sum\limits_{j=0}^{N} \beta_j + \sum\limits_{j=0}^{N} \phi_j G(s_t; \gamma, c)}{1 - \sum\limits_{j=1}^{N} \lambda_j} \tag{23}$$

$G(s_t; \gamma, c)$ is assumed to be either logistic or exponential function as specified in the equations (7) and (8). For the LSTR model, ERPT coefficient would take different values depending on whether the transition variable is below or above the threshold.

- If $(s_t - c) \to -\infty$, pass-through elasticities are equal to:

$$SR\ ERPT = \beta_0 \tag{24}$$

and

$$LR\ ERPT = \frac{\sum\limits_{j=0}^{N} \beta_j}{1 - \sum\limits_{j=1}^{N} \lambda_j} \tag{25}$$

- If $(s_t - c) \to +\infty$, pass-through coefficients become:

$$SR\ ERPT = \beta_0 + \phi_0 \tag{26}$$

and

$$LR\ ERPT = \frac{\sum\limits_{j=0}^{N} \beta_j + \sum\limits_{j=0}^{N} \phi_j}{1 - \sum\limits_{j=1}^{N} \lambda_j \pi_{t-j}} \tag{27}$$

In the case of the ESTR model, pass-through elasticities change depending on whether s_t is near or far away from the threshold c, regardless of whether the difference $(s_t - c)$ is positive or negative. Therefore, if $(s_t - c) \to \pm\infty$, short-run and long-run ERPT correspond, respectively, to equation (26) and (27); and if $s_t = c$, short-run and long-run pass-through coefficients will be equal to (24) and (25) respectively.

The STR pass-through equation (21) is estimated for 12 euro area countries (Austria, Belgium, Germany, Spain, Finland, France, Greece, Ireland, Italy, Luxembourg, Netherlands and Portugal), using quarterly data spanning the period 1975:1 to 2010:4. All the data we use are taken from the OECD's *Economic Outlook* database, except for exchange rate series which are obtained from *International Financial Statistics* (IFS) of the International Monetary Fund (IMF). Inflation rates series represents the change in consumer prices index (CPI). Output growth is constructed using the rate of growth of the real GDP. The nominal exchange rate is defined as domestic currency units per unit of foreign currencies, which implies that an increase represents a depreciation for home country. Finally, to capture changes in foreign costs, we follow Bailliu & Fujii (2004) by constructing an exporter partners' cost proxy. In logarithms, this latter is measured as follow: $w_t^* \equiv q_t + ulc_t - e_t$, where q_t is the unit labour cost (ULC) based real effective exchange rate, ulc_t is the ULC in domestic country and e_t the nominal effective exchange rate.

We have checked the possibility of cointegrating relationship among our variables in ERPT equation (4). Individual series in level are non-stationary but do not appear to be cointegrated according to Engle & Granger (1987) tests results. According to de Bandt *et al.* (2007), the long run equilibrium relation may be restored once we take into account the possibility of structural breaks in the data. Since we use long sample period (144 time observations for each country), we use Gregory & Hansen (1996) methodology which test the null of no cointegration against the alternative of cointegration with an estimated structural break[15]. In spite of allowing for possible breaks in ERPT equation, we failed to reject the hypothesis of no cointegration for most of country sample (see results in Table (12) in Appendix A). As a result, log differences of the variables are used in the estimation the pass-through equation as shown in equation (21). Augmented Dickey Fuller (ADF) tests suggest that variables in differences are appropriately described as stationary series. In addition to ADF tests, we have implemented Zivot & Andrews (1992) and Lumsdaine & Papell (1997) unit root tests which allow for possible breaks in series (see Tables (8),(9),(10) and (11) in Appendix A)[16].

To determine the lag length of the variables, we follow van Dijk *et al.* (2002) by adopting a general-to-specific approach to select the final specification. Then, we start with a model with maximum lag length of $N = 4$, and then dropping sequentially the lagged variables for which the t-statistic of the corresponding parameter is less than 1.0 in absolute value. The next step consists in testing for nonlinearity, selecting the appropriate s_t and choosing the adequate form of the transition function, namely logistic or exponential. In our empirical analysis, three potential transition variable are considered: inflation rate, exchange rate and output growth. Then, the linearity tests are conducted for the delayed variables i.e, π_{t-i} Δe_{t-i} and Δy_{t-i}, with lag length up to four periods ($i = 4$).

As mentioned in the specification stage (section (3.2.1)), we follow Teräsvirta (1994, 1998) procedure. Tables (1), (2) and (3) provides the p-values of the F version of the LM test with the different lags for the transition variables. In the first row, we report the test of the null hypothesis of linearity against the alternative of STR non-linear model[17]. The following rows in each table show the sequence of null hypotheses for choosing the LSTR or the ESTR model. The decision rule for the test is as follow: if the p-value of the test corresponding to H_{03} is the smallest, we choose an ESTR model, while in all other cases an LSTAR model should be selected. According to Teräsvirta (1994), all three hypotheses (H_{04}, H_{03} and H_{02}) can simultaneously be rejected at a conventional significance level, that is why the strongest

[15]Two alternative versions of Gregory & Hansen (1996) test are used: a first model which allows for break in constant and a second model with break both in constant and slope.

[16]Lumsdaine & Papell (1997) test is the extension of Zivot & Andrews (1992) model by allowing for two structural breaks under the alternative hypothesis in stead of a single break.

[17]Additionally, in our choice of the transition variable we also test whether some nonlinearity remains unmodeled with the test of no additive nonlinearity at the evaluation stage.

rejection counts.

As mentioned in the STR literature, it is also recommended to estimate a number of both LSTAR and ESTAR models and to choose between them at the evaluation stage by misspecification tests, such as error autocorrelation, parameter nonconstancy and remaining nonlinearity. This way of proceeding is advocated if the test sequence does not provide a clear-cut choice between the two alternatives in the sense that p-values of the test of H_{03}, on the one hand, and of H_{02} or H_{04} on the other, are close to each other. Therefore, the final decision can be postponed to the evaluation stage of the modelling strategy (Teräsvirta (1994, 1998, 2004) and van Dijk *et al.* (2002)).

Table 1: Linearity tests against STR model ($s_t = \pi_{t-i}$)

	Austria				Belgium				Germany			
	π_{t-1}	π_{t-2}	π_{t-3}	π_{t-4}	π_{t-1}	π_{t-2}	π_{t-3}	π_{t-4}	π_{t-1}	π_{t-2}	π_{t-3}	π_{t-4}
H_0	0,455	0,930	0,552	0,013	0,017	0,054	0,000	0,174	0,359	0,549	0,003	0,691
H_{04}	0,588	0,883	0,427	0,019	0,461	0,592	0,123	0,038	0,295	0,394	0,007	0,981
H_{03}	0,285	0,567	0,860	0,262	0,038	0,096	0,514	0,910	0,739	0,866	0,032	0,033
H_{02}	0,238	0,880	0,329	0,229	0,020	0,025	0,000	0,252	0,294	0,433	0,601	0,078
Specification	Linear	Linear	Linear	LSTR	LSTR	Linear	LSTR	Linear	Linear	Linear	LSTR	Linear
	Spain				**Finland**				**France**			
	π_{t-1}	π_{t-2}	π_{t-3}	π_{t-4}	π_{t-1}	π_{t-2}	π_{t-3}	π_{t-4}	π_{t-1}	π_{t-2}	π_{t-3}	π_{t-4}
H_0	0,000	0,000	0,000	0,004	0,000	0,000	0,000	0,019	0,000	0,000	0,001	0,000
H_{04}	0,040	0,556	0,001	0,042	0,087	0,028	0,047	0,006	0,000	0,005	0,052	0,243
H_{03}	0,000	0,576	0,011	0,478	0,150	0,002	0,001	0,146	0,020	0,512	0,200	0,004
H_{02}	0,000	0,000	0,010	0,002	0,000	0,000	0,002	0,717	0,012	0,001	0,001	0,001
Specification	ESTR	LSTR	LSTR	LSTR	LSTR	LSTR	ESTR	LSTR	LSTR	LSTR	LSTR	LSTR
	Greece				**Ireland**				**Italy**			
	π_{t-1}	π_{t-2}	π_{t-3}	π_{t-4}	π_{t-1}	π_{t-2}	π_{t-3}	π_{t-4}	π_{t-1}	π_{t-2}	π_{t-3}	π_{t-4}
H_0	0,001	0,072	0,020	0,058	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,001
H_{04}	0,090	0,820	0,016	0,011	0,000	0,002	0,000	0,000	0,001	0,032	0,149	0,061
H_{03}	0,241	0,669	0,642	0,730	0,000	0,000	0,000	0,016	0,000	0,004	0,000	0,060
H_{02}	0,000	0,000	0,057	0,272	0,001	0,000	0,000	0,001	0,000	0,000	0,000	0,008
Specification	LSTR	Linear	LSTR	Linear	LSTR	ESTR	ESTR	LSTR	LSTR	LSTR	LSTR	LSTR
	Luxembourg				**Netherlands**				**Portugal**			
	π_{t-1}	π_{t-2}	π_{t-3}	π_{t-4}	π_{t-1}	π_{t-2}	π_{t-3}	π_{t-4}	π_{t-1}	π_{t-2}	π_{t-3}	π_{t-4}
H_0	0,028	0,004	0,256	0,017	0,215	0,011	0,001	0,000	0,003	0,001	0,016	0,036
H_{04}	0,207	0,000	0,501	0,008	0,464	0,349	0,495	0,010	0,058	0,045	0,489	0,228
H_{03}	0,031	0,525	0,193	0,201	0,583	0,025	0,009	0,199	0,018	0,001	0,000	0,138
H_{02}	0,197	0,450	0,286	0,456	0,042	0,025	0,001	0,000	0,000	0,000	0,000	0,000
Specification	ESTR	LSTR	Linear	LSTR	Linear	ESTR	LSTR	LSTR	LSTR	LSTR	LSTR	LSTR

Note: The numbers are p-values of F versions of the LM linearity tests. First row shows the test of linearity against the alternative of STR nonlinearity. The second row until the forth are the p-values of the sequential test for choosing the adequate transition function. The decision rule is the following: if the test of H_{03} yields the strongest rejection of null hypothesis, we choose the ESTR model. Otherwise, we select the LSTR model. The last row gives the selected specification.

Table 2: Linearity tests against STR model ($s_t = \Delta e_{t-i}$)

	Austria				**Belgium**				**Germany**			
	Δe_{t-1}	Δe_{t-2}	Δe_{t-3}	Δe_{t-4}	Δe_{t-1}	Δe_{t-2}	Δe_{t-3}	Δe_{t-4}	Δe_{t-1}	Δe_{t-2}	Δe_{t-3}	bf Δe_{t-4}
H_0	0,975	0,116	0,933	0,943	0,001	0,149	0,226	0,162	0,018	0,000	0,956	0,120
H_{04}	0,987	0,311	0,990	0,965	0,014	0,258	0,913	0,028	0,060	0,088	0,978	0,469
H_{03}	0,647	0,088	0,986	0,734	0,605	0,421	0,766	0,763	0,299	0,285	0,917	0,027
H_{01}	0,754	0,329	0,101	0,529	0,001	0,108	0,002	0,476	0,042	0,000	0,298	0,488
Specification	Linear	Linear	Linear	Linear	LSTR	Linear	Linear	Linear	LSTR	LSTR	Linear	Linear
	Spain				**Finland**				**France**			
	Δe_{t-1}	Δe_{t-2}	Δe_{t-3}	Δe_{t-4}	Δe_{t-1}	Δe_{t-2}	Δe_{t-3}	Δe_{t-4}	Δe_{t-1}	Δe_{t-2}	Δe_{t-3}	bf Δe_{t-4}
H_0	0,028	0,103	0,436	0,206	0,003	0,408	0,981	0,831	0,295	0,439	0,038	0,193
H_{04}	0,036	0,961	0,494	0,492	0,001	0,382	0,986	0,763	0,501	0,703	0,072	0,408
H_{03}	0,115	0,031	0,278	0,439	0,087	0,238	0,663	0,771	0,454	0,205	0,344	0,054
H_{01}	0,390	0,046	0,537	0,065	0,727	0,701	0,796	0,462	0,013	0,071	0,041	0,274
Specification	LSTR	Linear	Linear	Linear	LSTR	Linear	Linear	Linear	Linear	Linear	LSTR	Linear
	Greece				**Ireland**				**Italy**			
	Δe_{t-1}	Δe_{t-2}	Δe_{t-3}	Δe_{t-4}	Δe_{t-1}	Δe_{t-2}	Δe_{t-3}	Δe_{t-4}	Δe_{t-1}	Δe_{t-2}	Δe_{t-3}	bf Δe_{t-4}
H_0	0,527	0,392	0,600	0,012	0,000	0,000	0,000	0,018	0,004	0,000	0,004	0,119
H_{04}	0,261	0,444	0,239	0,073	0,020	0,060	0,000	0,041	0,057	0,001	0,0661	0,6194
H_{03}	0,796	0,236	0,922	0,042	0,003	0,000	0,319	0,170	0,013	0,8765	0,036	0,087
H_{01}	0,567	0,621	0,565	0,194	0,056	0,421	0,115	0,133	0,196	0,000	0,061	0,105
Specification	Linear	Linear	Linear	ESTR	ESTR	ESTR	LSTR	LSTR	ESTR	LSTR	ESTR	Linear
	Luxembourg				**Netherlands**				**Portugal**			
	Δe_{t-1}	Δe_{t-2}	Δe_{t-3}	Δe_{t-4}	Δe_{t-1}	Δe_{t-2}	Δe_{t-3}	Δe_{t-4}	Δe_{t-1}	Δe_{t-2}	Δe_{t-3}	bf Δe_{t-4}
H_0	0,010	0,062	0,618	0,463	0,177	0,124	0,095	0,037	0,012	0,011	0,926	0,908
H_{04}	0,222	0,417	0,877	0,198	0,336	0,780	0,090	0,129	0,192	0,032	0,900	0,842
H_{03}	0,098	0,121	0,306	0,497	0,198	0,160	0,459	0,384	0,050	0,076	0,790	0,948
H_{01}	0,012	0,056	0,372	0,778	0,271	0,018	0,182	0,028	0,041	0,251	0,544	0,322
Specification	LSTR	Linear	Linear	Linear	Linear	Linear	Linear	LSTR	LSTR	LSTR	Linear	Linear

Note: The numbers are p-values of F versions of the LM linearity tests. First row shows the test of linearity against the alternative of STR nonlinearity. The second row until the forth are the p-values of the sequential test for choosing the adequate transition function. The decision rule is the following: if the test of H_{03} yields the strongest rejection of null hypothesis, we choose the ESTR model. Otherwise, we select the LSTR model. The last row gives the selected specification.

Table 3: Linearity tests against STR model ($s_t = \Delta y_{t-i}$)

	Austria				Belgium				Germany			
	Δy_{t-1}	Δy_{t-2}	Δy_{t-3}	Δy_{t-4}	Δy_{t-1}	Δy_{t-2}	Δy_{t-3}	Δy_{t-4}	Δy_{t-1}	Δy_{t-2}	Δy_{t-3}	Δy_{t-4}
H_0	0,183	0,933	0,009	0,035	0,010	0,837	0,040	0,349	0,373	0,032	0,011	0,042
H_{04}	0,056	0,986	0,016	0,054	0,128	0,666	0,025	0,373	0,162	0,278	0,023	0,212
H_{03}	0,991	0,100	0,155	0,351	0,001	0,818	0,679	0,176	0,602	0,007	0,543	0,082
H_{01}	0,519	0,823	0,281	0,102	0,083	0,813	0,388	0,829	0,581	0,475	0,023	0,137
Specification	Linear	Linear	LSTR	LSTR	ESTR	Linear	LSTR	Linear	Linear	ESTR	LSTR	ESTR
	Spain				**Finland**				**France**			
	Δy_{t-1}	Δy_{t-2}	Δy_{t-3}	Δy_{t-4}	Δy_{t-1}	Δy_{t-2}	Δy_{t-3}	Δy_{t-4}	Δy_{t-1}	Δy_{t-2}	Δy_{t-3}	Δy_{t-4}
H_0	0,339	0,453	0,044	0,473	0,319	0,039	0,039	0,037	0,178	0,593	0,136	0,144
H_{04}	0,292	0,811	0,531	0,634	0,701	0,030	0,035	0,139	0,180	0,684	0,001	0,195
H_{03}	0,322	0,078	0,007	0,146	0,221	0,412	0,696	0,809	0,486	0,308	0,800	0,589
H_{01}	0,649	0,534	0,165	0,691	0,201	0,169	0,053	0,005	0,199	0,576	0,019	0,085
Specification	Linear	Linear	ESTR	Linear	Linear	LSTR	LSTR	LSTR	Linear	Linear	Linear	Linear
	Greece				**Ireland**				**Italy**			
	Δy_{t-1}	Δy_{t-2}	Δy_{t-3}	Δy_{t-4}	Δy_{t-1}	Δy_{t-2}	Δy_{t-3}	Δy_{t-4}	Δy_{t-1}	Δy_{t-2}	Δy_{t-3}	Δy_{t-4}
H_0	0,001	0,000	0,000	0,012	0,373	0,304	0,947	0,403	0,000	0,000	0,000	0,080
H_{04}	0,798	0,000	0,047	0,139	0,857	0,894	0,921	0,036	0,056	0,102	0,280	0,267
H_{03}	0,000	0,017	0,000	0,018	0,175	0,050	0,789	0,971	0,000	0,000	0,000	0,416
H_{01}	0,093	0,248	0,064	0,176	0,095	0,166	0,571	0,878	0,000	0,005	0,000	0,032
Specification	ESTR	LSTR	ESTR	ESTR	Linear	Linear	Linear	Linear	ESTR	ESTR	ESTR	Linear
	Luxembourg				**Netherlands**				**Portugal**			
	Δy_{t-1}	Δy_{t-2}	Δy_{t-3}	Δy_{t-4}	Δy_{t-1}	Δy_{t-2}	Δy_{t-3}	Δy_{t-4}	Δy_{t-1}	Δy_{t-2}	Δy_{t-3}	Δy_{t-4}
H_0	0,785	0,473	0,978	0,360	0,017	0,006	0,047	0,025	0,669	0,025	0,033	0,003
H_{04}	0,964	0,510	0,837	0,716	0,009	0,004	0,148	0,066	0,897	0,282	0,192	0,373
H_{03}	0,852	0,537	0,867	0,090	0,249	0,260	0,380	0,045	0,674	0,055	0,031	0,000
H_{01}	0,070	0,295	0,884	0,512	0,322	0,171	0,037	0,410	0,038	0,017	0,200	0,229
Specification	Linear	Linear	Linear	Linear	LSTR	LSTR	LSTR	ESTR	Linear	LSTR	ESTR	ESTR

Note: The numbers are p-values of F versions of the LM linearity tests. First row shows the test of linearity against the alternative of STR nonlinearity. The second row until the forth are the p-values of the sequential test for choosing the adequate transition function. The decision rule is the following: if the test of H_{03} yields the strongest rejection of null hypothesis, we choose the ESTR model. Otherwise, we select the LSTR model. The last row gives the selected specification.

It is noteworthy that our choice for relevant transition function must be also conducted with the economic intuition in addition to non-linearity specification tests. As mentioned in the pass-through literature, exchange rate transmission would be lower in a stable inflation environment than in a higher inflation periods, which is a proof of regime-dependence of ERPT to inflation environment. Then, when considering lagged inflation as transition variable, LSTR model would be more appropriate in describing this asymmetric behaviour. Similarly, when considering output growth as transition variable, the LSTR specification is preferred since pass-through mechanisms could be different in expansions from what they are in recessions. Finally, for the exchange rate case, there are two types of linearities that must be modeled. On one hand, we use a LSTR model to can account for ERPT asymmetry during currency appreciations and depreciations episodes. On the other hand, an ESTR is chosen to capture non-linearity in pass-through with respect to large and small exchange rate fluctuations.

6 Main Empirical Results

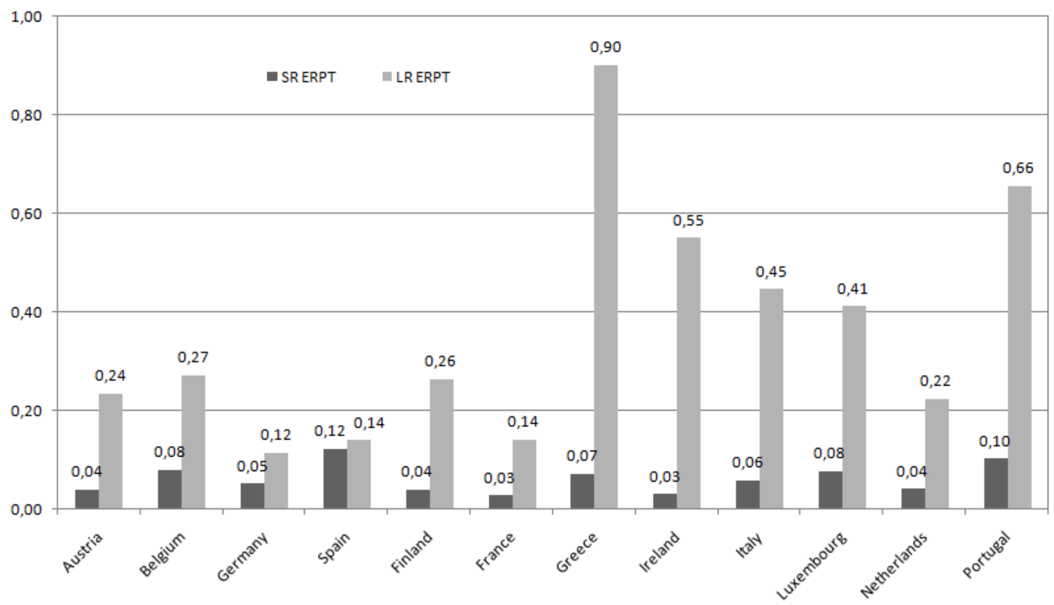
6.1 Linear model results

We begin our analysis by estimating a linear version of ERPT model which is the equation (21) without the non-linear part. The objective is twofold: first, we measure the extent of pass-through and compare this with results from the existing literature. Second, this enable us later to make a comparison with the non-linear model from statistical point of view, such as a comparison of R^2, residual standard deviation and Akaike Information Criterion (AIC). Therefore, we estimate the following linear ERPT equation:

$$\pi_t = \alpha + \sum_{j=1}^{4} \lambda_j \pi_{t-j} + \sum_{j=0}^{4} \psi_j \Delta y_{t-j} + \sum_{j=0}^{4} \delta_j \Delta w^*_{t-j} + \sum_{j=0}^{4} \beta_j \Delta e_{t-j} + \varepsilon_t, \tag{28}$$

Figure 2 reports OLS estimates of the short- and long-run ERPT for the 12 EA countries (detailed results are presented in the Table 13 in the Appendix). Our results suggest a moderate effect of exchange rate changes on consumer price inflation in the short run. The average of short-run elasticity in the EA sample is 0.06, suggesting that 1 per cent increase in the rate of currency depreciation leads to 0.06 per cent increase in the inflation rate. The higher rate was recorded in Spain with 0.12 per cent, and the lower was found in France and Ireland with 0.03 per cent. Our results are in line with estimates in the literature of pass-through. Using dynamic panel data model, Bailliu & Fujii (2004) found a pass-through to inflation CPI equal to 0.08 per cent . This lower rate is valid for 11 industrialized countries among them there is 6 euro area countries, namely Belgium, Finland, France, Italy, Netherlands and Spain. In a large database including 1979-2000 quarterly data for 71 countries, Choudhri & Hakura (2006) provide evidence of low short run ERPT for low inflation countries such as EA sample[18]. We can notice that, in our study, we have found the same elasticity as in Choudhri & Hakura (2006), especially for Austria, Belgium and Germany (respectively 0.04, 0.08 and 0.05 per cent).

Figure 2: Estimated short-run and long-run ERPT from linear model



Sources: Personal calculation

In the long run, as expected, ERPT is higher than in the short run due to the gradual adjustment of price to exchange rate movements. We note that the rates of pass-through varies substantially across countries, ranging from 0.12 in Germany to 0.90 in Greece. According to Figure 2, five countries out of twelve have price reaction exceeding 0.40 per cent. In their sample of 20 industrialized countries, Gagnon & Ihrig (2004) found that Greece and Portugal have the highest degree of pass-through with 0.43 and 0.52, respectively, and this corroborates our results. In Choudhri & Hakura (2006), these two countries has been classified among countries with medium inflation rate (between 10 and 30%), and, consequently, the long pass-though was found to be higher compared to low inflation countries[19]. As a result, the average

[18]Choudhri & Hakura (2006) classify their sample of countries into three groups: low inflation, moderate inflation and high inflation. Low, moderate and high inflation groups are defined as consisting of countries with average inflation rates less than 10%, between 10 and 30% and more than 30%, respectively. All the 12 EA countries was included in the low inflation group except Greece and Portugal.

[19]Choudhri & Hakura (2006) found that long-run ERPT for Greece and Portugal was equal to 0.42 and 0.44

long-run rate of pass-through for our 12 EA countries (which is equal to 0.36) is found to be close to the average of pass-through elasticity in medium inflation countries in Choudhri & Hakura (2006) (which is equal to 0.35). Obviously, this is due to the higher rate of ERPT in Greece and Portugal.

6.2 Results from the STR pass-through specification

Estimation results for the STR pass-through model are based on equation (21). As mentioned above, the parameters of STR model are estimated by non-linear least squares (NLS) estimation technique which provides estimators that are consistent and asymptotically normal. Regarding our choice of transition variable to be include in the final non-linear model, nonlinearity remaining tests are also conducted after estimation. Therefore, we select the transition variables that provided the strongest rejection of both the null of linearity of the baseline linear model, and of no additive linearity after estimation of the non-linear model. In choosing the transition function, we employ the sequence of null hypotheses for selecting the STR specification together with the economic intuition. As explained before, the LSTR model is preferred to ESTR model when using inflation rate and output growth as transition variables. And when considering the exchange rate as transition variable, both LSTR and ESTR specification can be used, but we must be careful in our interpretation of the induced dynamic by each specification. The LSTR model capture the pass-through asymmetry during currency appreciations and depreciations episodes, while the ESTR is appropriate to account for non-linearity in pass-through with respect to the size of exchange rate movements. In addition to this, we also gave preference for models that performs well in terms of misspecification tests, i.e. with no error autocorrelation, no additive linearity and with constant parameters[20].

6.2.1 Inflation rate as transition variable

In this section we investigate whether the ERPT responds nonlinearly to the inflation level in 12 EA countries. It is argued in the pass-through literature that the responsiveness of prices to exchange rate fluctuations depends positively on inflation. A high inflation environment would thus tend to increase the extent of pass-through. Consequently, we aim to explore this inflation regime-dependence of ERPT in a non-linear fashion. According to linearity tests (Tables 1), LSTR model is found to be the best specification to capture this kind of behaviour in most of EA countries. This is consistent with theoretical priors that pass-through mechanisms may be different whether inflation rate is above or below a given threshold. The NLS estimates of our

respectively, after 4 quarter, and 0.48 and 0.54 respectively, after 20 quarter.

[20] The highest R^2 and the lowest AIC value are also considered.

LSTR models are summarized in Table 4. We report both short-run and long-run pass-through coefficient as defined in equation (22) and (23)[21]. We compute sum of squared residuals ratio (SSR_{ratio}) between LSTR model and the linear specification which suggests a better fit for the non-linear model. Similarly, the R^2 and the AIC favor the LSTR model against the linear regression. We also check the quality of the estimated LSTR models by conducting several misspecification tests. In most of cases, the selected LSTR models passes the main diagnostic tests, i.e. no error autocorrelation, no conditional heteroscedasticity, parameters constancy and non remaining nonlinearity.

ERPT results in Table 4 show significant threshold inflation rate levels for most of the EA countries. Thresholds do not differ considerably across countries. Values are ranging from 1% to 3% with exception of portugal showing $c = 8\%$. Regarding speed of transition γ, our results indicate relatively moderate values which is a proof of smooth transition between the two inflation regimes[22]. When considering short-run ERPT, our results point a significative positive relationship between inflation rates and the extent of pass-through for 5 out of 12 countries. For those 5 EA countries, when inflation increases above the threshold, exchange rate transimission becomes higher. For example, when the italian CPI inflation exceed 3%, the rate of pass-through increases from 0.03% (when $G = 0$) to about 0.17% (when $G = 1$). For the long-run ERPT, the presence of regime-dependence is more apparent. There are 8 out of 12 EA countries showing a positive link between pass-through and inflation environment. For example, the ERPT in France is equal to 0.08% when inflation rate is below 1 per cent, but when it exceeds this threshold level, ERPT becomes more higher and reaches 0.18%.

Broadly speaking, our results are in line with Taylor's hypothesis, i.e. the responsiveness of prices to exchange rate fluctuations depends positively on inflation environment. The intuition behind this is relative to foreign firms behaviour. The latter are willing to set up their prices in the currency of importing countries with stable inflation environment. In such case ERPT would be lower. But when exporters perceive a higher inflation level, they may shift away from local-currency pricing by passing exchange rate changes through the prices in the importing country currency. This kind behaviour would entailing a higher degree of pass-through. From empirical point of view, our findings corroborate the scarce ERPT literature using STR models. As mentioned in section 4, Nogueira Jr. & Leon-Ledesma (2008) has employed LSTR model to capture non-linearities in pass-through. They conclude that the adoption of inflation target has entailed a lower pass-through for 4 countries in their sample, namely Canada, Mexico, South

[21] Full results from all STR models are presented in the Tables (14), (15), (16) and (17) in Appendix C.

[22] According to van Dijk *et al.* (2002) estimates of γ may appear to be insignificant. This should not be interpreted as evidence of weak nonlinearity.

Africa, United Kingdom. Similarly, Shintani *et al.* (2009) found that the period of low ERPT is likely to be associated with the low inflation environment in United States, event though the authors use a symmetric STR models with U-shaped transition function[23].

Additionally, we have plotted both the estimated transition functions and the ERPT as a function of the transition variable lagged inflation ($s_t = \pi_{t-i}$). Graphs of both short- and long-run pass-through are presented in Figure 3 and 4 respectively[24]. It is clear that the transition between both extreme regime, i.e. $G = 0$ and $G = 1$, is smooth in most of cases. Plots reveal the regime dependence of ERPT to inflation environment. The positive connection between the degree of the ERPT and inflation is quite clear, except for Belgium and Netherlands where the relationship is negative in the short-run.

To give further insight of inflation regime dependence, we plot the time-variation of ERPT over inflationary and disinflationary episodes between 1975-2010. Results of time-varying pass-through coefficients are given in Figure 5 and 6. We also report lagged inflation rates and the estimated threshold level of inflation on the same graph. A careful inspection of the plots show that the exchange rate transmission was higher during the second half of the 1970s and the early of 1980s for most of EA countries. Over this period, there had been an unstable inflation environment due to the two oil crisis of the 1970s. As shown in Figure 5 and 6, inflation rates was exceeding the threshold levels in our country sample which has resulted in increased degree of pass-through during this episode.

It is worth noting that since the late 1980s and the beginning of 1990s, most of EA countries has entered an era of low inflation regime. This shifting towards stable inflation has coincided with the decline of the extent of pass-through. The bulk of recent literature of pass-through has documented this lowering of the domestic price sensibility to exchange rate variation, including Bailliu & Fujii (2004), Gagnon & Ihrig (2004). Another important remark is that the low-inflation regime is more recent for Greece and Portugal compared to the rest of our country sample, i.e. late of 1990s for Greece and mid of the 1990s for Portugal. This may may explain why pass-through estimates based on linear model (equation (28)) are higher in Greece and Portugal in comparison with the other EA countries. During our sample period (1975-2010), there was unstable inflation environment for these two countries and this helps explain their relatively large rate of ERPT.

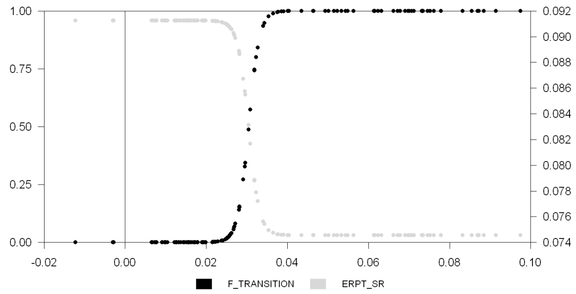
[23]Two kind of symmetric transition function has employed by the authors see section 4 for more details.
[24]We only report results for countries with significant coefficient of pass-through.

Table 4: Estimated ERPT elasticities from the LSTR model with $s_t = \pi_{t-i}$

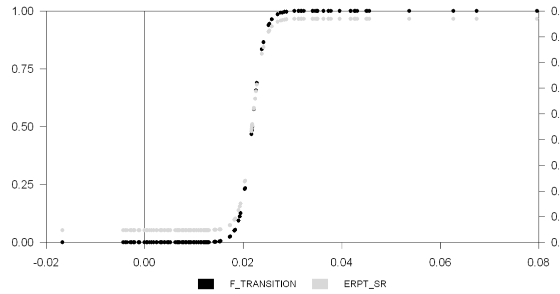
	Autriche	**Belgique**	**Allemagne**	**Espagne**	**Finlande**	**France**	**Grèce**	**Irlande**	**Italie**	**Luxembourg**	**Pays-Bas**	**Portugal**
Transition variable (s_t)	π_{t-4}	π_{t-1}	π_{t-3}	π_{t-4}	π_{t-3}	π_{t-2}	π_{t-3}	π_{t-4}	π_{t-2}	π_{t-4}	π_{t-3}	π_{t-1}
Threshold (c)	0,033	0,030	0,013	0,022	0,027	0,011	0,022	0,034	0,031	0,015	0,008	0,088
	0,000	0,000	0,000	0,000	0,000	0,000	0,024	0,000	0,000	0,000	0,000	0,000
Speed of transition (γ)	22,013	17,566	9,390	12,702	13,291	6,134	2,358	8,456	2,449	4,909	9,361	4,061
	0,547	0,312	0,208	0,437	0,531	0,067	0,120	0,003	0,002	0,056	0,333	0,053
Linear part : $G = 0$												
SR ERPT	0,043	0,091	0,063	0,085	0,044	0,066	0,105	0,043	0,032	0,053	0,049	0,040
	0,042	0,000	0,000	0,009	0,005	0,001	0,134	0,097	0,050	0,002	0,009	0,547
LR ERPT	0,154	0,140	0,115	0,438	0,415	0,086	0,168	0,440	0,183	0,436	0,131	0,059
	0,112	0,000	0,019	0,246	0,002	0,108	0,478	0,036	0,049	0,112	0,030	0,605
Non-linear part: $G = 1$												
SR ERPT	0,024	0,075	0,003	0,167	0,020	-0,005	0,056	1,913	0,167	0,159	0,036	0,085
	0,181	0,000	0,969	0,000	0,787	0,791	0,165	0,001	0,001	0,000	0,066	0,092
LR ERPT	0,328	0,155	0,251	0,608	0,781	0,183	0,568	2,377	0,904	1,049	0,179	0,492
	0,027	0,000	0,192	0,205	0,249	0,034	0,103	0,046	0,036	0,138	0,018	0,076
R^2	0,737	0,757	0,721	0,830	0,818	0,915	0,873	0,803	0,934	0,751	0,727	0,825
SSR_{ratio}	0,002	0,001	0,001	0,005	0,002	0,001	0,010	0,006	0,002	0,004	0,001	0,012
AIC	-8,087	-8,176	-8,338	-6,889	-7,755	-8,536	-6,337	-6,815	-7,940	-8,059	-8,184	-6,052
pJB	0,177	0,146	0,171	0,000	0,003	0,069	0,000	0,000	0,000	0,000	0,967	0,000
$pLM_{AR(4)}$	0,963	0,907	0,083	0,153	0,002	0,136	0,031	0,506	0,616	0,146	0,515	0,248
$pLM_{ARCH(4)}$	0,526	0,204	0,741	0,002	0,747	0,951	0,186	0,439	0,113	0,537	0,586	0,000
pLM_C	0,019	0,028	0,933	0,036	0,164	0,748	0,165	0,000	0,000	0,041	0,183	0,014
pLM_{RNL}	0,361	0,085	0,481	0,027	0,337	0,220	0,590	0,000	0,622	0,578	0,317	0,004

Note: Table reports elasticities of exchange rate pass-through into CPI inflation from LSTR models. Numbers in parentheses are p-values of estimates. R^2 denotes the coefficient of determination, SSR_{ratio} is the ratio of sum of squared residuals between LSTR model and the linear specification, and AIC is the Akaike Information Criterion. The following rows corresponds to the misspecification tests: pJB is the p-values of Jarque-Bera normality test, $pLM_{AR(4)}$ is the p-values of the LM test of no error autocorrelation up to forth order, $pLM_{ARCH(4)}$ is the p-values of the LM test of no ARCH effects up to forth order, pLM_C is the p-values of the LM test of parameter constancy and pLM_{RNL} is the p-values of the LM test of no remaining nonlinearity.

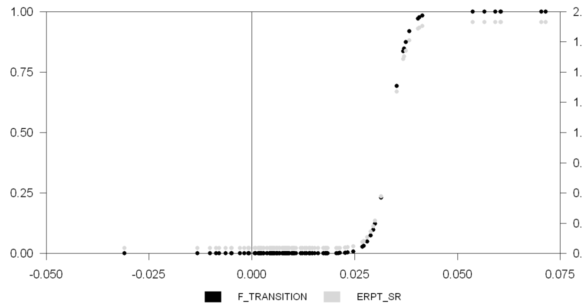
Figure 3: Estimated transition function and short-run ERPT as a function of past inflation rates



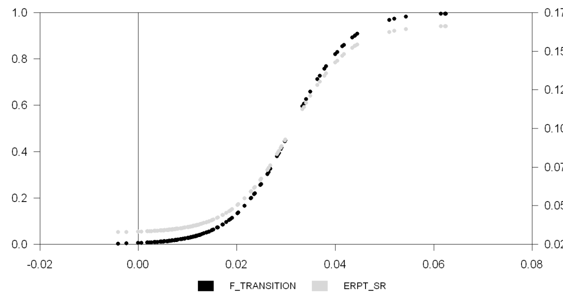
Belgium



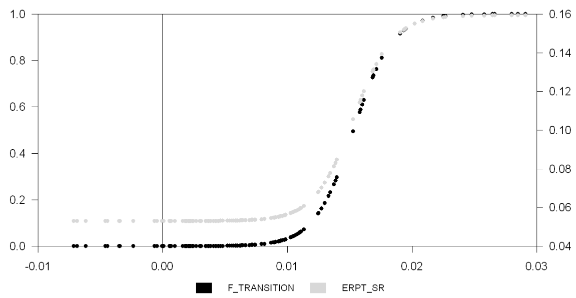
Spain



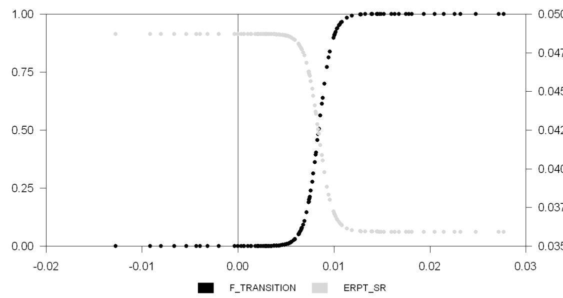
Ireland



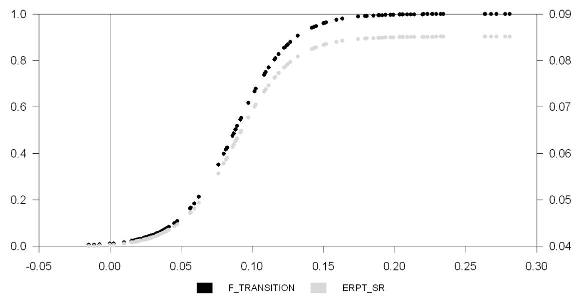
Italy



Luxembourg



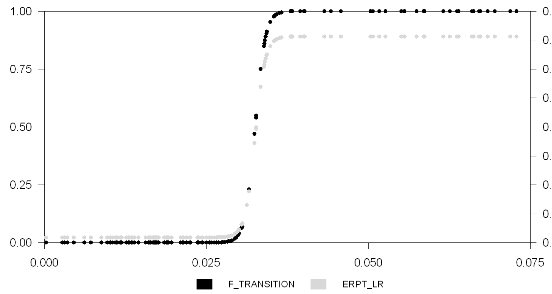
Netherlands



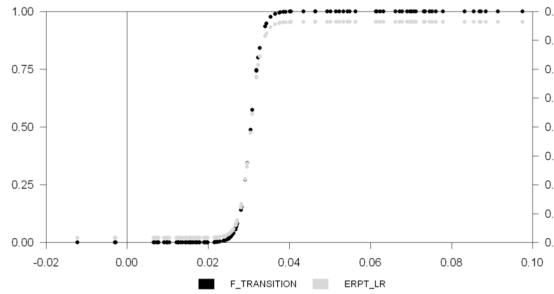
Portugal

Note: Estimated transition function and short-run ERPT as a function of past inflation rates. Results are from LSTR with $s_t = \pi_{t-i}$.

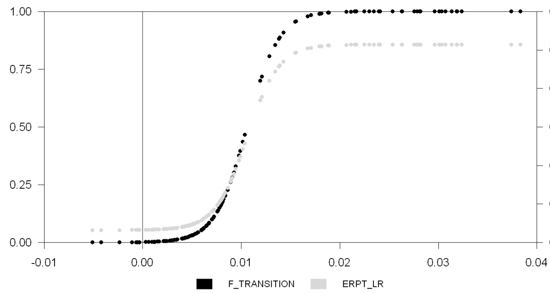
Figure 4: Estimated transition function and long-run ERPT as a function of past inflation rates



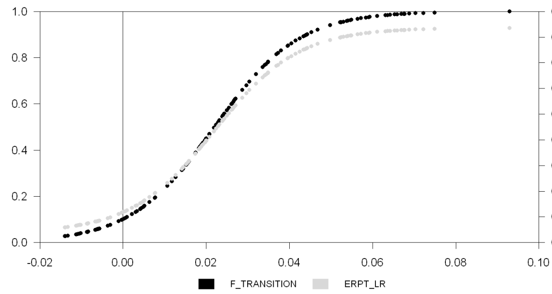
Austria



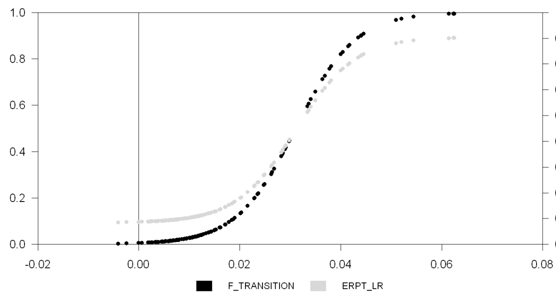
Belgium



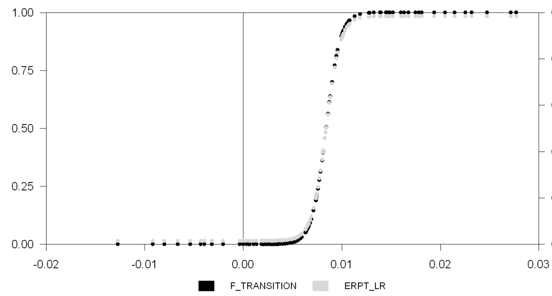
France



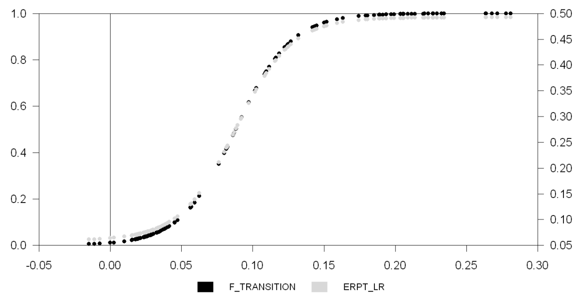
Greece



Italy



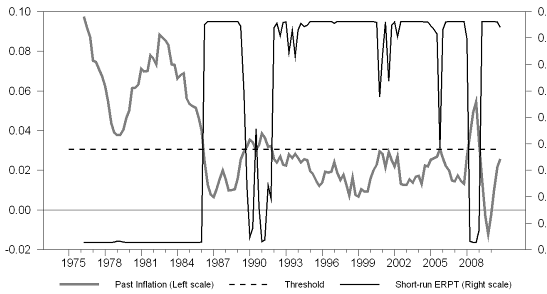
Netherlands



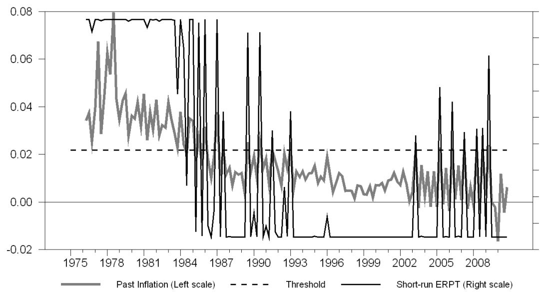
Portugal

Note: Estimated transition function and long-run ERPT as a function of past inflation rates. Results are from LSTR with $s_t = \pi_{t-i}$.

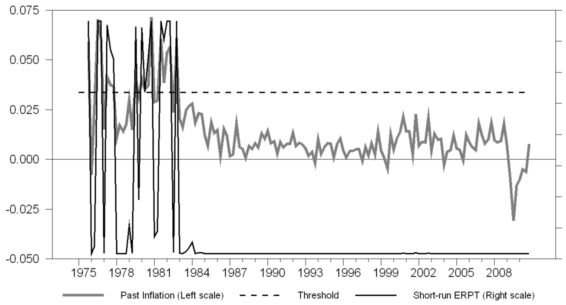
Figure 5: Time-varying short-run ERPT and past inflation during 1975-2010



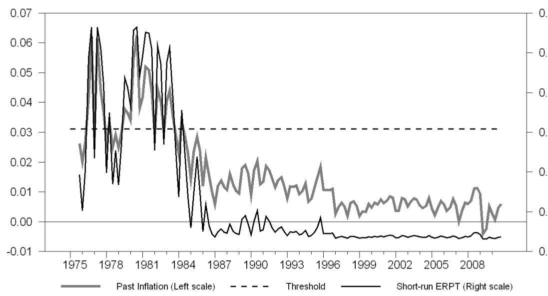
Belgium



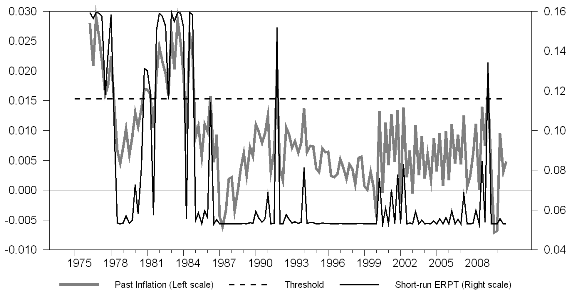
Spain



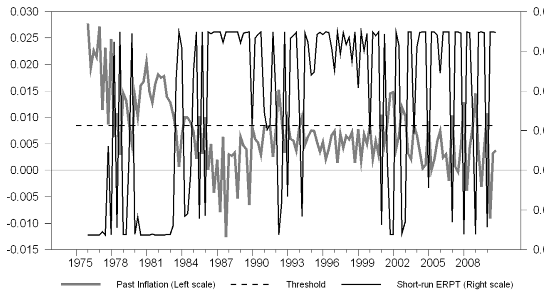
Ireland



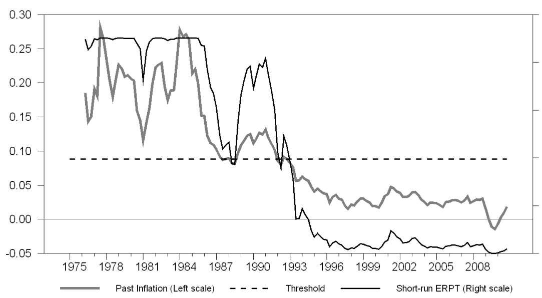
Italy



Luxembourg



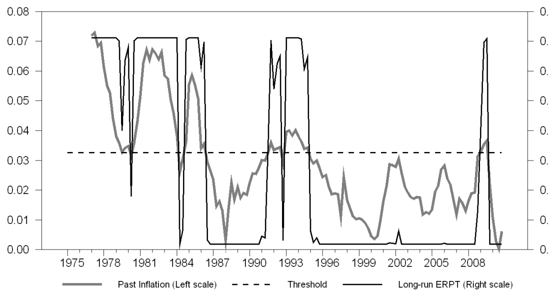
Netherlands



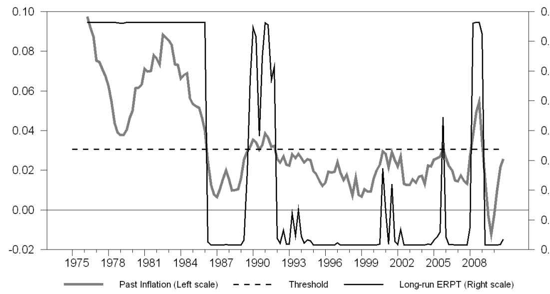
Portugal

Note: Time-varying short-run ERPT and past inflation during 1975-2010. Results are from LSTR model with $s_t = \pi_{t-i}$.

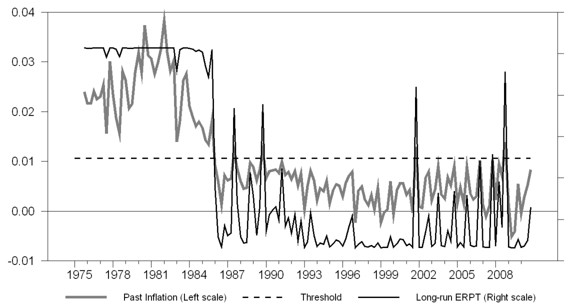
Figure 6: Time-varying long-run ERPT and past inflation between 1975-2010



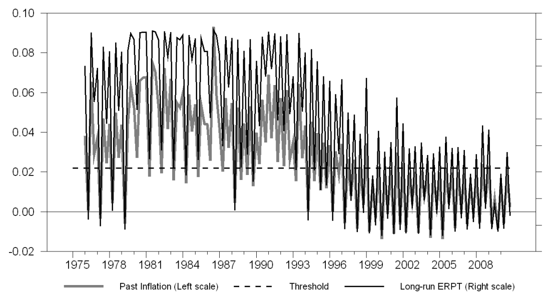
Austria



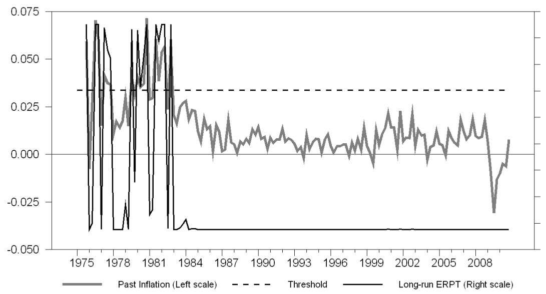
Belgium



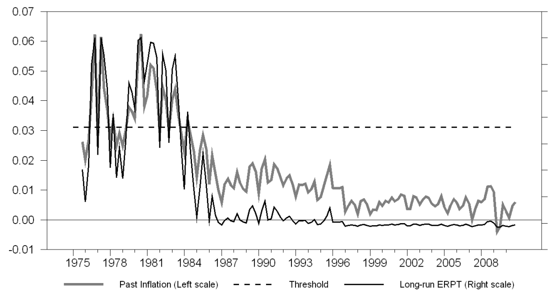
Ireland



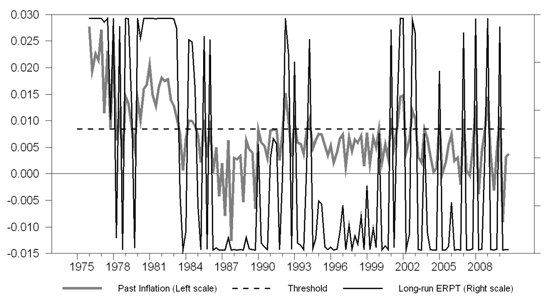
Greece



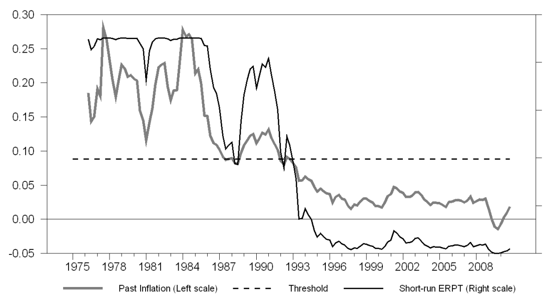
Ireland



Italy



Netherlands



Portugal

Note: Time-varying long-run ERPT and past inflation during 1975-2010. Results are from LSTR model with $s_t = \pi_{t-i}$.

6.2.2 Exchange rate as transition variable

In this section, we consider the rate of exchange rate depreciation (Δe_{t-i}) as the driving factor of the nonlinearity. As mentioned above, there is two types of linearities can be modeled. In one hand, pass-through asymmetries can rise with respect to exchange rate change direction i.e., in response to currency depreciations and appreciations. We saw that LSTR specification is pertinent in situations in which the dynamic behavior is different whether the transition variable is below or above the threshold. Therefore, we employ LSTR model to capture ERPT asymmetry during currency appreciations and depreciations episodes, especially when the threshold level of Δe_{t-i} is close to zero. In the other hand, there is second type of linearities which is related to the size of exchange rate movements. If firms are willing to absorb small changes in exchange rate rather than larger ones due to the presence of "menu costs", this may result in asymmetric pass-through of large and small exchange rate shocks. In such case, ESTR specification would be more appropriate in describing this non-linearity in ERPT mechanism.

In their study, Nogueira Jr. & Leon-Ledesma (2008) emphasized only on the role of menu cost, and therefore on the size of exchange rate movement, in generating asymmetry in pass-through by using an ESTR specification. Nevertheless, in our work we aim to explore the two possible sources of linearities in ERPT, i.e. with respect to both direction and size of exchange rate. Therefore, both LSTR and ESTR are used here to estimate ERPT in a non-linear way. We begin by testing linearity when transition variable is the rate of depreciation of exchange rate ($s_t = \Delta e_{t-i}$) as reported in Table 2. Once linearity has been rejected, we follow van Dijk *et al.* (2002) approach by estimating a number of both LSTAR and ESTAR models and choose between them at the evaluation stage by misspecification tests. This is a sensible way of proceeding since there are two potential sources of non-linearities which can be modeled either by LSTR or ESTR model.

Results from LSTR model As summarized in Table 5, we report only results for countries with significant ERPT coefficient. As can we can see, the non-linear model provides a better fit to the data than the linear model with respect to R^2, SSR and AIC. We note that there are only 5 out of 12 EA countries show a significant response of CPI to exchange rate movements in a non-linear way. The threshold levels are very close for Italy, Luxembourg and Portugal (around 4%), but differ greatly in comparaison to belgium and Greece. The same thing for the speed of transition which varies across those countries[25]. Concerning ERPT estimates, our results are to some extent mixed. For Italy, Luxembourg and Portugal, when exchange rate

[25]We note that in Belgium the paramaters γ is very high which indicates an abrupt transition rather than a smooth one.

is depreciating above some threshold level, the short-run pass-through becomes higher. For example, short-run ERPT coefficient rise from 0.07% to 0.27% in Portugal once the rate of currency depreciation is exceeding 4.5%. We can say that exchange transmision is lower for small depreciation and in appreciation episodes but it becomes higher for large rate of currency depreciation[26]. These results seem to be consistent with what we call *capacity constraints* hypothesis. Since quantities may be rigid upwards in the short run, exporters may not be able to increase sales when importing coutnry currency is appreciating. So, they are willing to rise marku-up and let quantity unchanged. In this case, pass-through would be greater when the importerŠs currency is appreciating than when it is depreciating.

In the other hand, when we look to the ERPT estimates for Belgium and Greece, results are quietly different. The short-run response of CPI inflation to exchange rate is negatively correlated with the rate of depreciation (See Figure 7)[27]. For Belgium, threshold level is close to zero ($c = 0.004$), and we can say that short-run ERPT decreases significantly from 0.1% to 0.04% as the exhange rate is depreciating. As a result, the extent of pass-through is smaller during the depreciation than in appreciation episodes. This is in line with the thesis of *Market share objective.* Faced with a depreciation of the importing country's currency, foreign firms can follow pricing-to-market strategy by adjusting their markups to maintain market. However, in the case of an appreciation, they maintain their markups and allow the import price to fall in the currency of destination market. Consequently, an appreciation of the importing country's currency might cause higher pass-through than a depreciation.

[26]We have the same pattern in the long run for luxembourg and Portugal (See Figure 8).

[27]The same thing is found for Belgium in the long run (see Figure 8).

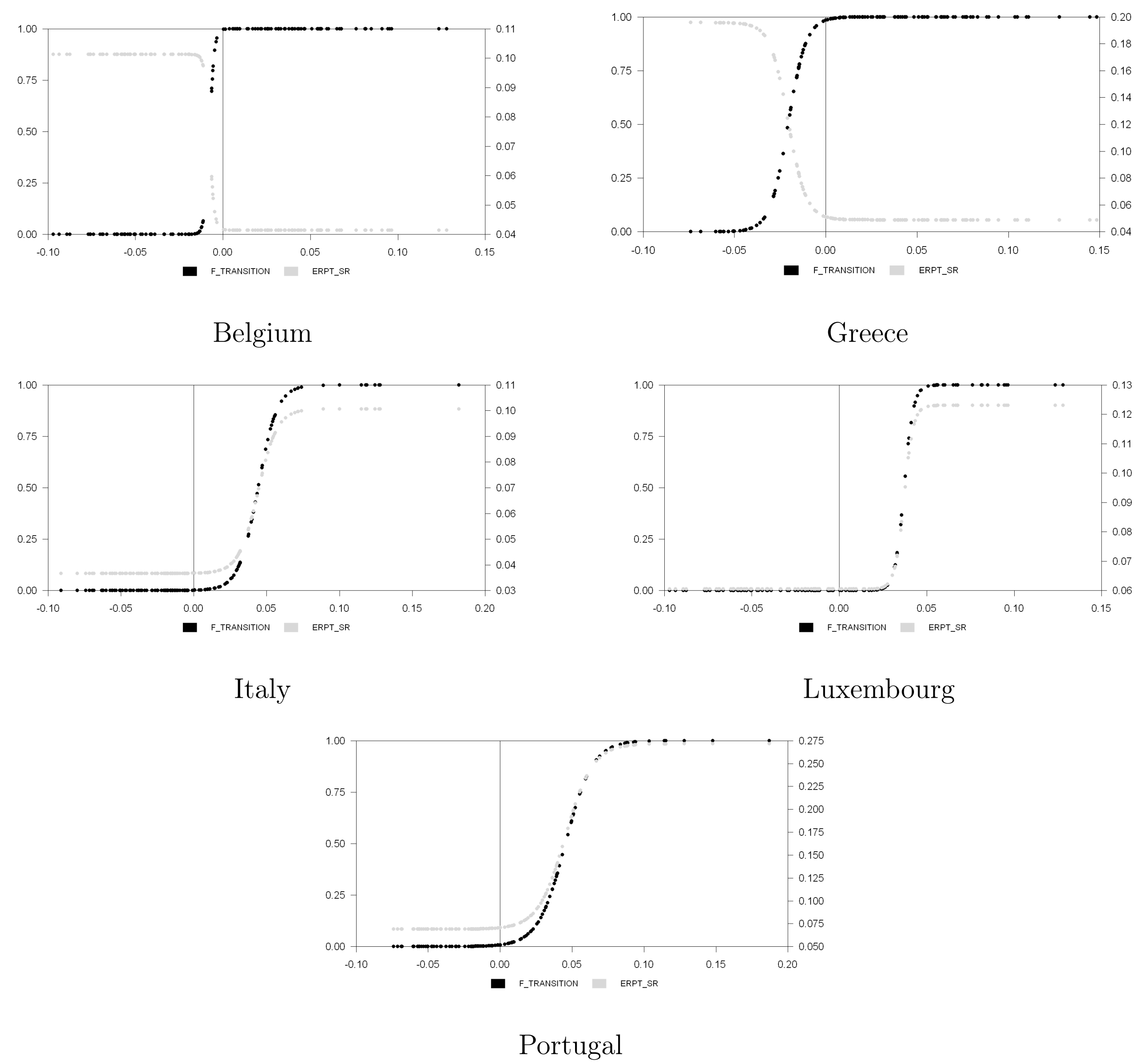
Table 5: Estimated ERPT elasticities from the LSTR model with $s_t = \Delta e_{t-i}$)

	Belgium	**Greece**	**Italy**	**Luxembourg**	**Portugal**
Transition variable (s_t)	Δe_{t-4}	Δe_{t-4}	Δe_{t-2}	Δe_{t-1}	Δe_{t-1}
Threshold (c)	0,004	-0,021	0,044	0,037	0,045
	(0,050)	(0,000)	(0,000)	(0,000)	(0,000)
Speed of transition (γ)	60,750	9,675	7,513	18,530	5,317
	(0,555)	(0,262)	(0,095)	(0,379)	(0,029)
Linear Part : $G = 0$					
SR ERPT	0,101	0,196	0,036	0,060	0,069
	(0,000)	(0,033)	(0,030)	(0,000)	(0,131)
LR ERPT	0,285	0,518	0,433	0,176	0,101
	(0,000)	(0,256)	(0,000)	(0,000)	(0,564)
Non-linear part : $G = 1$					
SR ERPT	0,041	0,049	0,101	0,123	0,272
	(0,016)	(0,081)	(0,106)	(0,001)	(0,000)
LR ERPT	0,151	0,442	-0,107	0,201	2,029
	(0,006)	(0,299)	(0,780)	(0,052)	(0,000)
R^2	0,723	0,904	0,911	0,751	0,805
SSR_{ratio}	0,828	0,634	0,803	0,778	0,694
AIC	-8,047	-6,531	-7,648	-8,059	-5,976
pJB	0,718	0,000	0,000	0,026	0,001
$pLM_{AR(4)}$	0,436	0,094	0,977	0,876	0,315
$pLM_{ARCH(4)}$	0,625	0,440	0,008	0,867	0,005
pLM_C	0,165	0,303	0,020	0,137	0,012
pLM_{NLR}	0,069	0,154	0,548	0,416	0,168

Note: Table reports elasticities of exchange rate pass-through into CPI inflation from LSTR models. Numbers in parentheses are p-values of estimates. R^2 denotes the coefficient of determination, SSR_{ratio} is the ratio of sum of squared residuals between LSTR model and the linear specification, and AIC is the Akaike Information Criterion. The following rows corresponds to the misspecification tests: pJB is the p-values of Jarque-Bera normality test, $pLM_{AR(4)}$ is the p-values of the LM test of no error autocorrelation up to forth order, $pLM_{ARCH(4)}$ is the p-values of the LM test of no ARCH effects up to forth order, pLM_C is the p-values of the LM test of parameter constancy and pLM_{RNL} is the p-values of the LM test of no remaining nonlinearity.

Overall, our findings corroborate with previous empirical studies which provide also no clear-cut evidence on the direction of asymmetry in ERPT. For a set of European industries, Gil-Pareja (2000) found that the direction of the asymmetry varied across industries and countries. Coughlin & Pollard (2004) confirm the same results in their study on 30 U.S. industries. Moreover, Coughlin & Pollard (2004) argued that this contrasting direction of the results reveals the importance of measuring pass-through at the industry level. If the direction of asymmetry varies across industries then aggregation may hide asymmetry that is present at the industry level. This may explain why in our work we find only 5 EA countries exhibiting asymmetric pass-through in terms of exchange rate change direction.

Figure 7: Estimated logistic transition functions and short-run ERPT as a function of past exchange rate depreciations



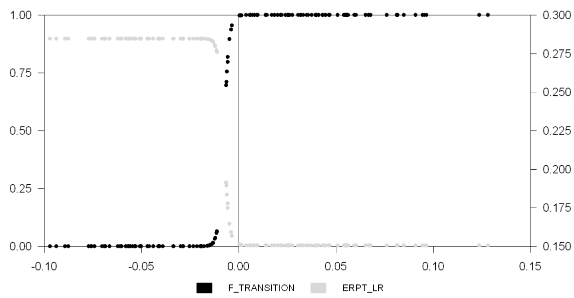
Note: Estimated transition functions and long-run ERPT as function of past exchange rate depreciations. Results are from LSTR model with $s_t = \Delta e_{t-i}$.

Finally, we visualize the time-variation of pass-through elasticity in Figure 9 and 10. The interesting results concern the period of launching the euro area. It is well-known that the EA countries - except Greece which join the monetary union in 2002 - have experienced an ongoing depreciation of the euro between the end of 1998 until the last quarter of 2001[28]. In contrast, since the mid-2002, the euro has started a steady appreciation until the end of 2004. As argued

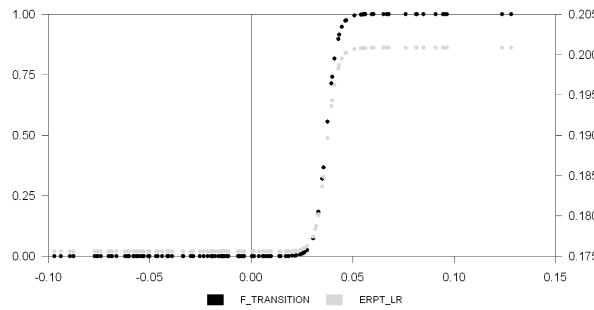
[28]During this period, the euro has depreciated by nearly 20% in nominal effective terms.

by Bussière (2007), such dramatic changes in the value of european currency may give rise to asymmetric pass-through. For Italy, luxembourg and Portugal, it is clear from the visualization of Figure 9 and 10 that ERPT was higher following the introduction of the euro. When the depreciation of the euro surpass some limit, the exchange rate transmission becomes higher for these countries.

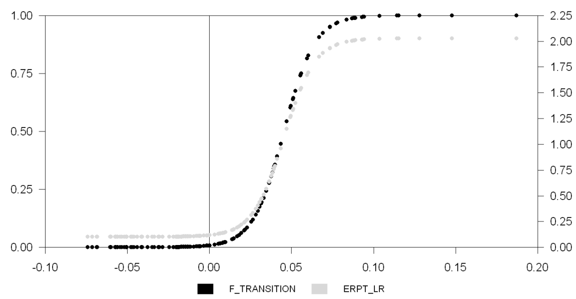
Figure 8: Estimated logistic transition functions and long-run ERPT as a function of past exchange rate depreciations



Belgium



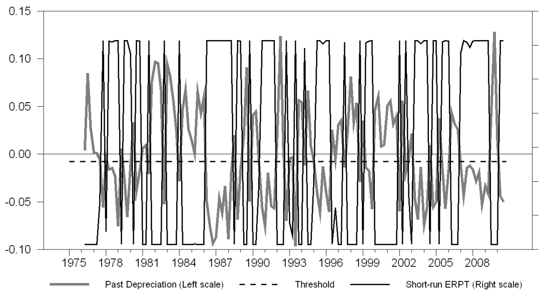
Luxembourg



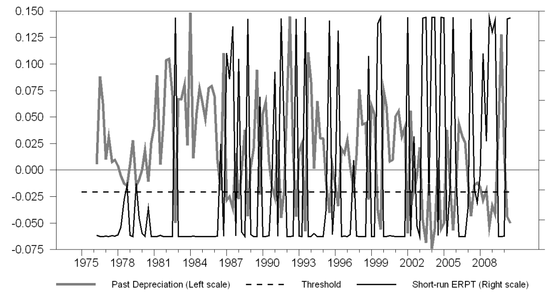
Portugal

Note: Estimated transition functions and long-run ERPT as function of past exchange rate depreciations. Results are from LSTR model with $s_t = \Delta e_{t-i}$.

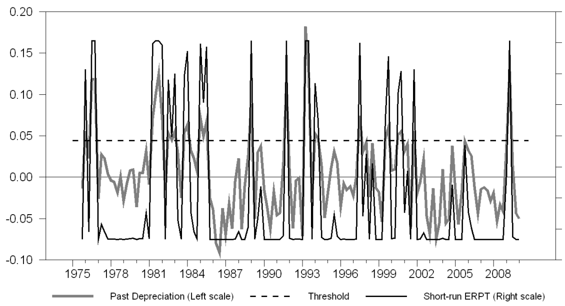
Figure 9: Time-varying short-run ERPT and past currency depreciations during 1975-2010 (LSTR model)



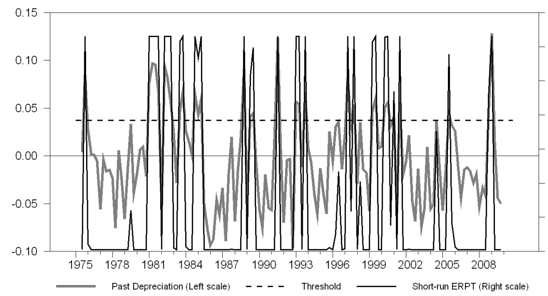
Belgium



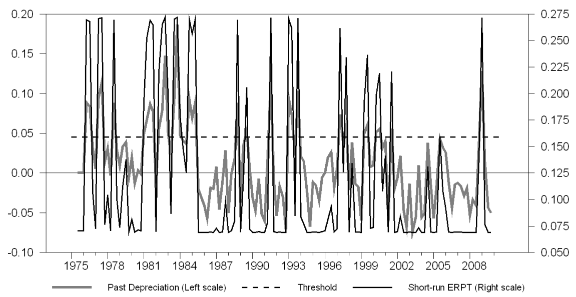
Greece



Italy



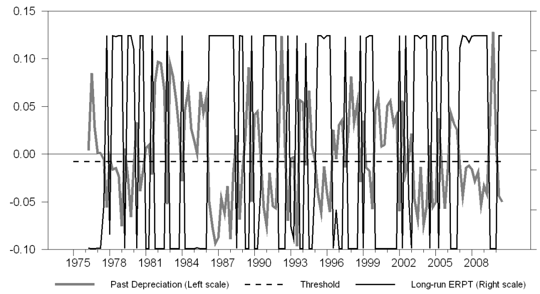
Luxembourg



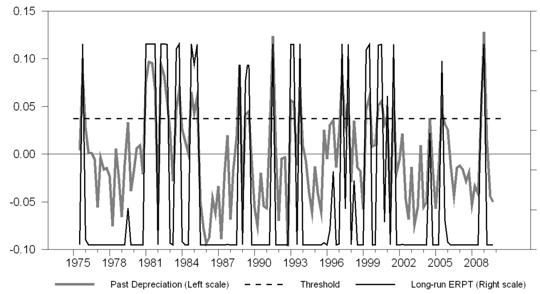
Portugal

Note: Time-varying short-run ERPT and past currency depreciations during 1975-2010. Results are from LSTR model with $s_t = \Delta e_{t-i}$.

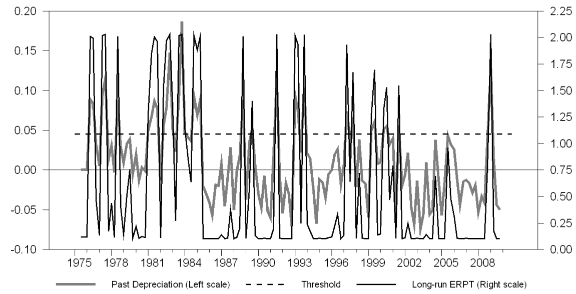
Figure 10: Time-varying long-run ERPT and past currency depreciations during 1975-2010 (LSTR model)



Belgium



Luxembourg



Portugal

Note: Time-varying long-run ERPT and past currency depreciations during 1975-2010. Results are from LSTR model with $s_t = \Delta e_{t-i}$.

Results from ESTR model The second type of possible linearity is related to the magnitude of exchange rate change. Then, the extent of pass-through may respond asymmetrically to the size of currency fluctuations, in the sens that there is differential effect of large versus small exchange rate shocks. As discussed above, an ESTR specification would be more appropriate to capture this kind of asymmetric behavior. As explained above, ESTR model allow for symmetric dynamics with respect to negative and positive deviations of exchange rate Δe_{t-i} from the threshold level c. What matters here is the size exchange rate movements, i.e. whether Δe_{t-i} is close or far away from the threshold.

In Table 6, we report only countries with significant pass-through elasticity. As we can see, most of EA countries (except Austria and Portugal) exhibit a significant non-linear response of CPI inflation to exchange rate movements. Especially in the short-run, there is nine EA countries with an evidence of positive correlation between pass-through and the magnitude of currency change. In Spain, the short-run ERPT coefficient is not statistically significantly different from zero when exchange rate variation is small - when Δe_{t-i} is close to the threshold of $c = 0.006$. But when for large currency movements, i.e. when Δe_{t-i} is far away from the threshold level, the Spanish short-run pass-through corresponds to 0.12%.

Figure 11 and 12 give a supportive evidence of the presence of asymmetries arising from the size of exchange rate shocks. That is, large exchange rate changes elicit greater ERPT. This result is consistent with the menu cost assumption. If foreign firms perceive that price changes are costly, a small currency change can be accommodated within the mark-up. But, if exchange rate changes exceed some threshold, firms are tempted to change their prices in the currency of importing country. Empirically, Nogueira Jr. & Leon-Ledesma (2008) has put forth the role of menu costs in explaining non-linearities in ERPT. To the best of our knowledge, it is the only work using ESTR model in this context. The results of Nogueira Jr. & Leon-Ledesma (2008) suggest that only two out of six countries (Mexico and UK) provide an evidence of non-linear ERPT with respect to the size of exchange rate changes.

Concerning the evolution of ERPT over time, plots are reported in Figure 13 and 14. One curious result is that during the European Monetary System (EMS) crisis (1992-1993) the extent of pass-through was higher for most of EA countries. It is known that for countries members of EMS, currencies were allowed to fluctuate within pre-specified bands - a system known as the Exchange Rate Mechanism (ERM). During the crisis period, a wave of devaluations has occurred for major EMS countries, especially for Italy that was forced to withdraw the ERM in September 1992[29]. Consequently, due to the excessive variability of the European currencies (conjugated with the confidence crisis), it is expected that foreign firms tend to modify pricing strategy, i.e. from LCP to PCP. As a result, the degree of pass-through would be higher during this episode.

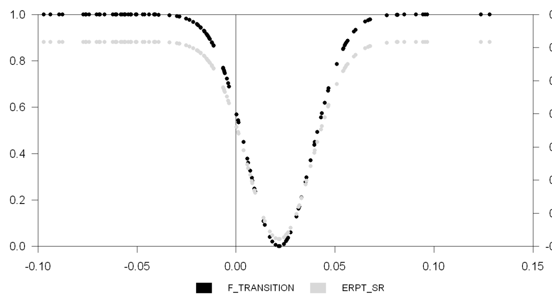
[29] Austria, Finland and Greece were not member of the ERM at that time.

Table 6: Estimated ERPT elasticities from the ESTR model with $s_t = \Delta e_{t-i}$

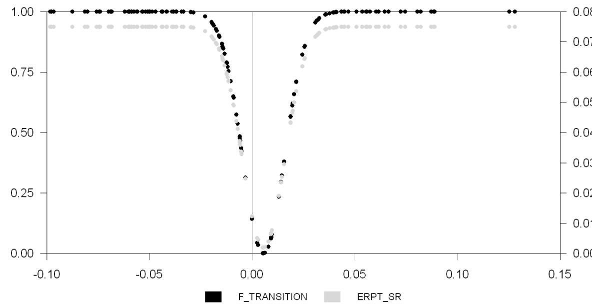
	Belgique	**Allemagne**	**Espagne**	**Finlande**	**France**	**Grèce**	**Irlande**	**Italie**	**Luxembourg**	**Pays-Bas**
Transition variable (s_t)	Δe_{t-4}	Δe_{t-1}	Δe_{t-4}	Δe_{t-2}	Δe_{t-3}	Δe_{t-3}	Δe_{t-2}	Δe_{t-1}	Δe_{t-3}	Δe_{t-4}
Threshold (c)	0,022	0,006	0,035	0,021	-0,022	0,030	0,043	0,016	0,010	0,033
	0,059	0,037	0,004	0,000	0,000	0,000	0,000	0,000	0,016	0,000
Speed of transition (γ)	4,381	11,092	4,322	11,347	2,487	33,264	1,274	9,112	4,041	1,128
	0,000	0,062	0,110	0,004	0,064	0,053	0,025	0,105	0,057	0,058
Linear part : $G = 0$										
SR ERPT	-0,016	0,002	0,019	-0,071	-0,019	-0,291	0,065	0,009	0,055	-0,018
	0,681	0,972	0,814	0,183	0,485	0,073	0,256	0,886	0,062	0,476
LR ERPT	-0,107	-0,478	-0,286	-0,129	0,036	0,414	0,125	-0,211	0,090	0,030
	0,648	0,516	0,582	0,327	0,807	0,441	0,164	0,844	0,228	0,908
Non-linear part: $G = 1$										
SR ERPT	0,103	0,075	0,121	0,050	0,077	0,104	-0,010	0,070	0,090	0,104
	0,000	0,000	0,000	0,004	0,000	0,000	0,750	0,000	0,000	0,000
LR ERPT	0,573	0,435	0,671	0,122	0,374	-0,237	0,215	0,465	0,265	1,192
	0,044	0,488	0,176	0,003	0,042	0,378	0,008	0,239	0,007	0,572
R^2	0,660	0,573	0,787	0,796	0,884	0,882	0,802	0,902	0,742	0,737
SSR	0,826	1,147	1,020	0,768	0,962	0,781	0,685	0,886	0,807	0,827
AIC	-8,050	-7,969	-6,674	-7,639	-8,167	-6,412	-6,779	-7,519	-8,023	-8,221
pJB	0,229		0,000	0,035		0,450	0,000	0,000	0,132	0,464
$pLM_{AR(4)}$	0,454	0,000	0,582	0,043	0,000	0,000	0,123	0,147	0,834	0,850
$pLM_{ARCH(4)}$	0,340	0,801	0,521	0,010	0,640	0,000	0,154	0,389	0,224	0,293
pLM_C	0,070	0,605	0,137	0,131	0,166	0,450	0,456	0,037	0,253	0,207
pLM_{NLR}	0,113	0,199	0,370	0,368	0,572	0,659	0,107	0,328	0,220	0,253

Note: Table reports elasticities of exchange rate pass-through into CPI inflation from LSTR models. Numbers in parentheses are p-values of estimates. R^2 denotes the coefficient of determination, SSR_{ratio} is the ratio of sum of squared residuals between LSTR model and the linear specification, and AIC is the Akaike Information Criterion. The following rows corresponds to the misspecification tests: pJB is the p-values of Jarque-Bera normality test, $pLM_{AR(4)}$ is the p-values of the LM test of no error autocorrelation up to forth order, $pLM_{ARCH(4)}$ is the p-values of the LM test of no ARCH effects up to forth order, pLM_C is the p-values of the LM test of parameter constancy and pLM_{RNL} is the p-values of the LM test of no remaining nonlinearity.

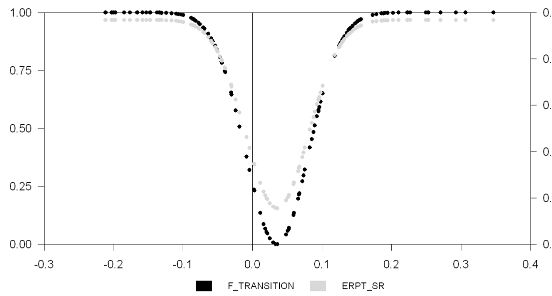
Figure 11: Estimated exponential functions and short-run ERPT as a function past exchange rate depreciations



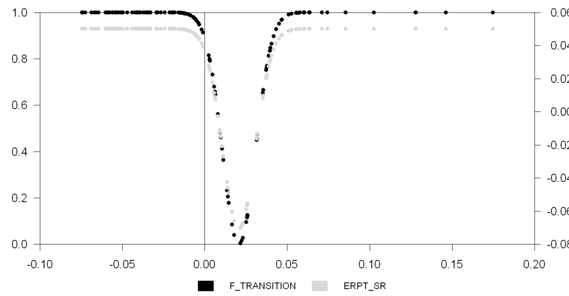
Belgique



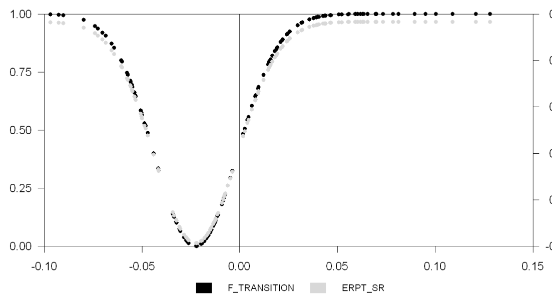
Germany



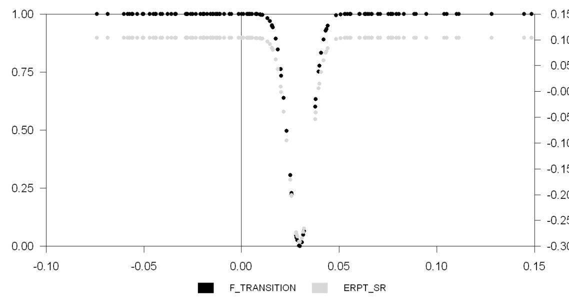
Spain



Finland

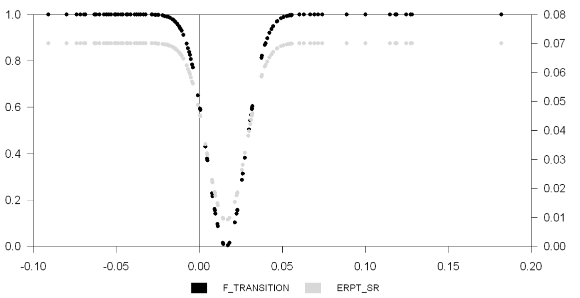


France

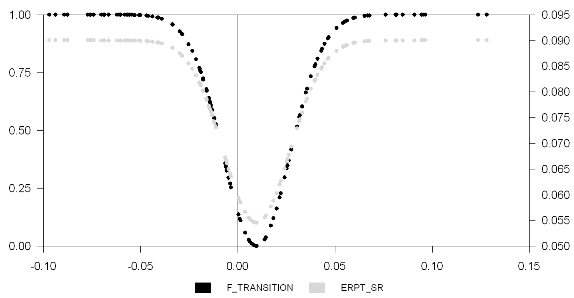


Greece

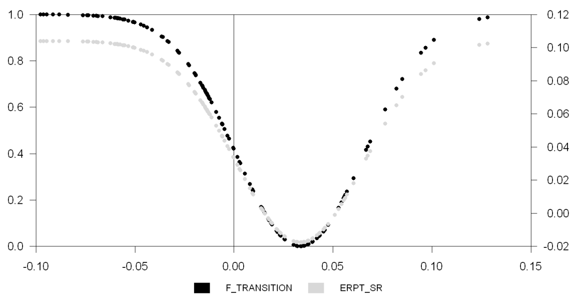
Continued



Italy



Luxembourg

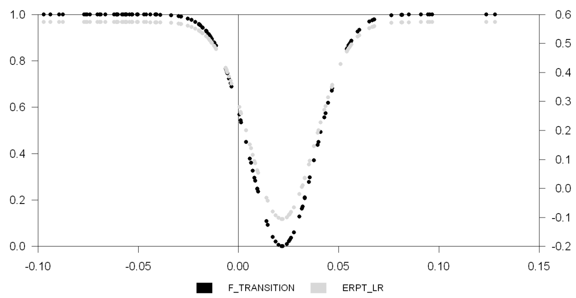


Netherlands

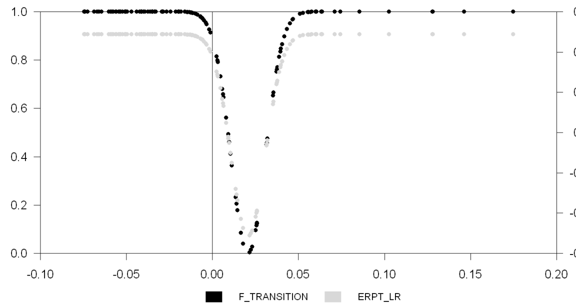
Note: Estimated exponential transition functions and short-run ERPT as a function past exchange rate depreciations. Results are from ESTR specification with $s_t = \Delta e_{t-i}$.

In all, one might say that the EMS crisis could be an illustration of asymmetric mechanisms of ERPT with regard to exchange rate change magnitude. When exchange rate changes surpass some limit, the exchange rate transmission becomes larger. Similarly, pass-through of exchange rate to consumer prices was higher at the beginning of the creation the euro area which is common for most of EA countries. The large depreciation of the European currency during the three first year, nearly by 20%, seems to be the main factor for leading to higher rate of pass-through. One again, the dramatic change of the euro during this period gives a support to the presence of asymmetry in ERPT.

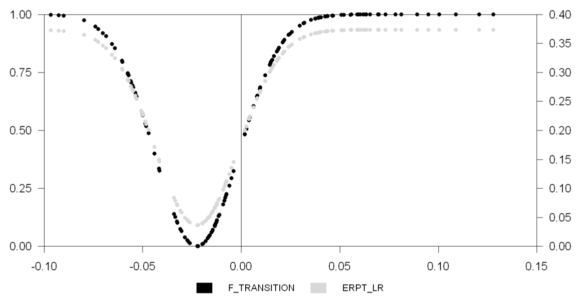
Figure 12: Estimated exponential transition functions and long-run ERPT as a function past exchange rate depreciation



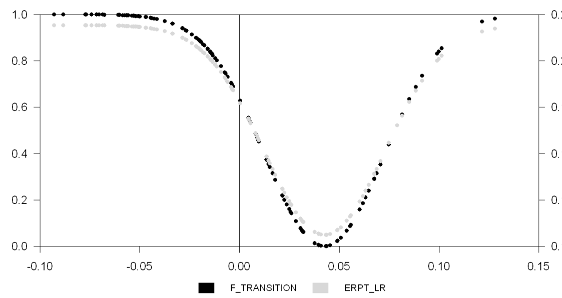
Belgium



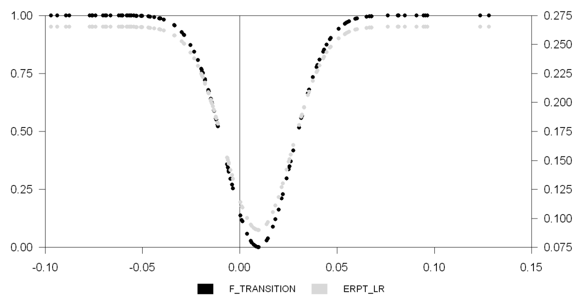
Finland



France



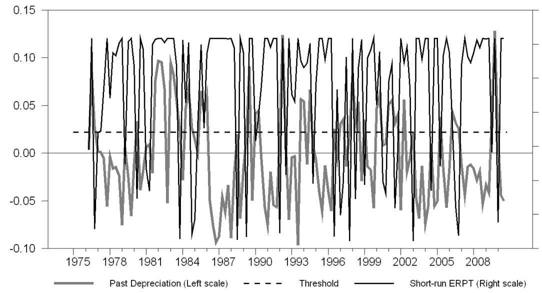
Ireland



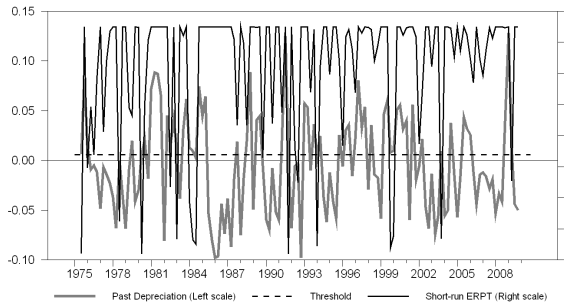
Luxembourg

Note: Estimated exponential transition functions and long-run ERPT as a function past exchange rate depreciations. Results are from ESTR specification with $s_t = \Delta e_{t-i}$.

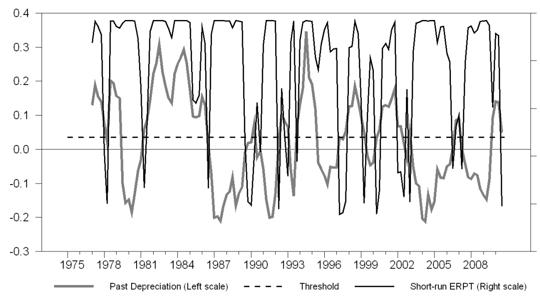
Figure 13: Time-varying short-run ERPT and past exchange rates depreciations (ESTR model)



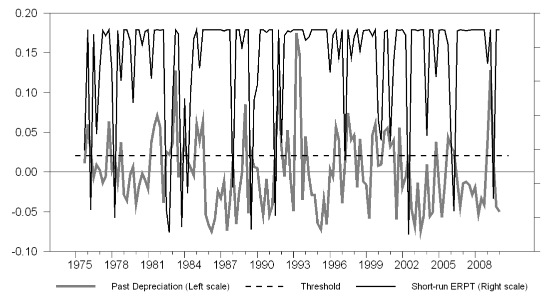
Belgium



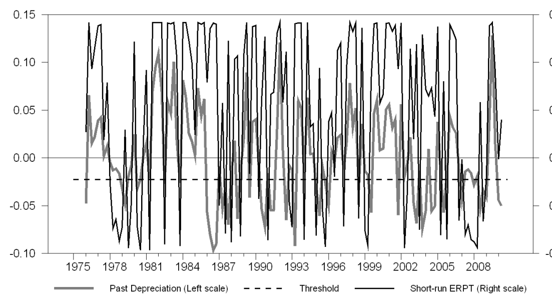
Germany



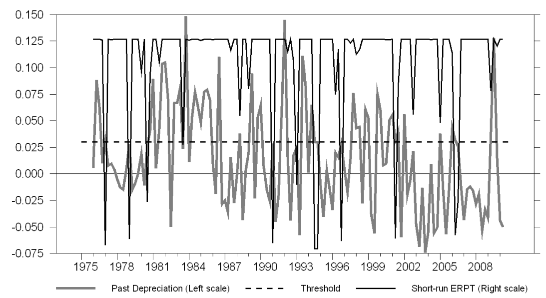
Spain



Finland

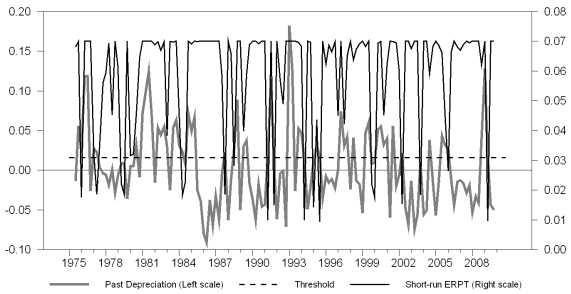


France

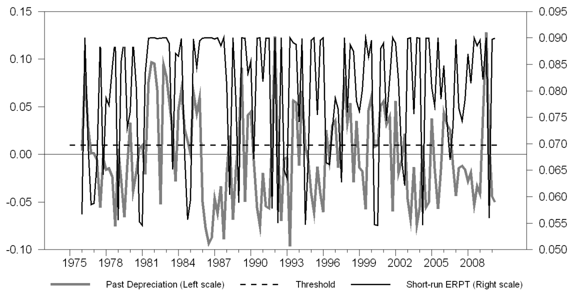


Greece

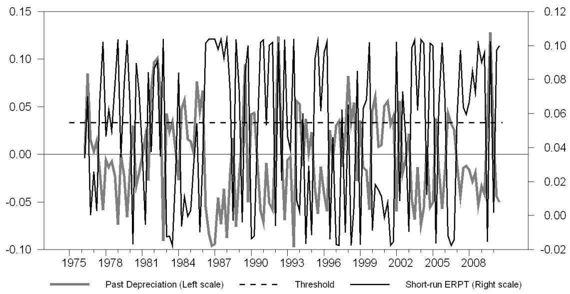
Continued



Italy



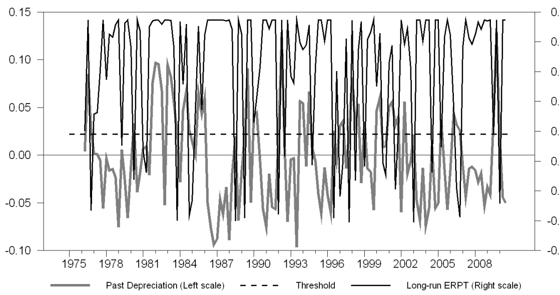
Luxembourg



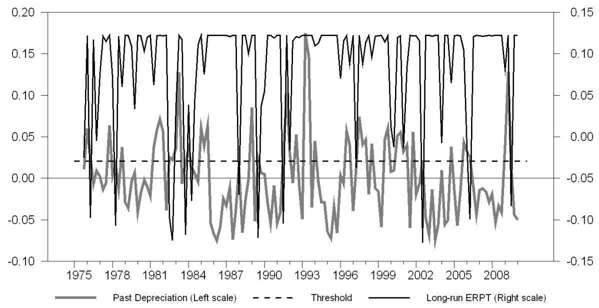
Netherlands

Note: Time-varying short-run ERPT and past exchange rate depreciations. Results are from ESTR specification with $s_t = \Delta e_{t-i}$.

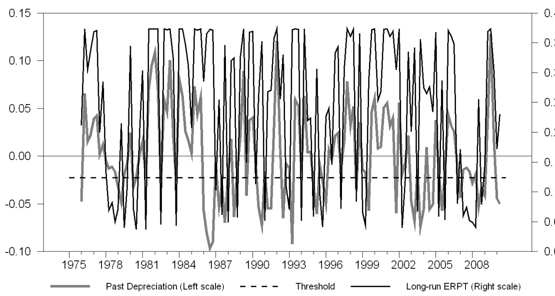
Figure 14: Time-varying short-run ERPT and past exchange rates depreciations (ESTR model)



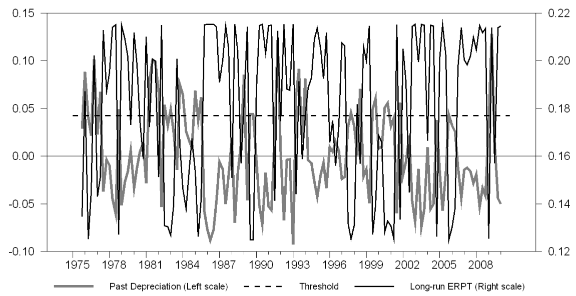
Belgium



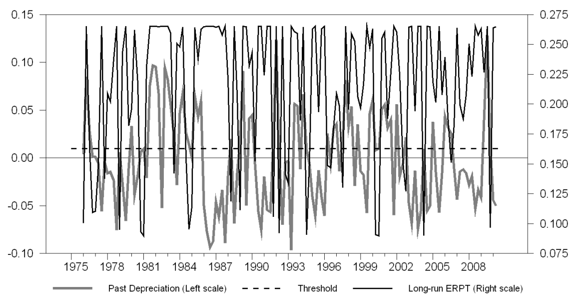
Finland



France



Ireland



Luxembourg

Note: Time-varying long-run ERPT and past exchange rate depreciations. Results are from ESTR specification with $s_t = \Delta e_{t-i}$.

6.2.3 Output growth as transition variable

In the last part of our analysis, we raise the question whether the degree of ERPT is affected by the business cycle in a non-linear way. The sparse empirical evidence on this issue has put forth a positive relationship between economic activity and the transmission of exchange rate. The intuition behind this is that mark-ups and profit margins are pro-cyclical. Thus, prices would move in the same direction with the business cycle, increasing during the expansion and decreasing during economic slowdown (Small (1997)). Moreover, the power of wage negotiations is more important during recovery periods, which may leading to price increases. Thereby, exporters are more willing to pass currency changes through prices when the economy is booming than in periods of slowdown.

The asymmetric reaction of ERPT over the business cycle was confirmed by Goldfajn & Werlang (2000) in a panel of 71 countries. The authors have found that depreciations have a higher pass-through to prices during prosperity periods. In a Phillips curve threshold framework, Correa & Minella (2006) and Przystupa & Wróbel (2011) suggest that when the output gap is above a certain threshold, ERPT becomes higher[30]. More interestingly, García & Restrepo (2001) explained that the lower ERPT in Chile in the 1990s is due to the positive dependence of pass-through to economic activity. The negative output gap during this period has offset the inflationary impact of exchange rate depreciation by reducing margins.

To our knowledge, only the study of Nogueira Jr. & Leon-Ledesma (2008) which uses STR model to capture non-linearity in ERPT with respect to the business cycle. In our analysis, we follow their approach by using LSTR specification which can describe an asymmetric behaviour depending on whether the transition variable is below or above the threshold. As a proxy for the business cycle we use the real GDP growth[31]. The choice of the adequate lagged output growth as a transition variable by means of linearity tests is reported in Table 3. According to the results, there is no evidence of non-linearities for France, Ireland and Luxembourg. Estimated short- and long-run ERPT from LSTR model are summarized in Table 7. From statistical point of view, the model performs well in terms of the goodness of fit and according to misspecification tests. We see that the threshold level of GDP growth varies significantly across countries, ranging from 0.3% in Belgium to 4% in Austria.

[30]The former study deals with the Brazilian case, while the second concern the polish economy.

[31]As explained by Nogueira Jr. & Leon-Ledesma (2008), the use of an ad hoc detrending processes like the output gap might eliminate valuable information from the data.

Table 7: Estimated ERPT elasticities from the LSTR model with $s_t = \Delta y_{t-i}$

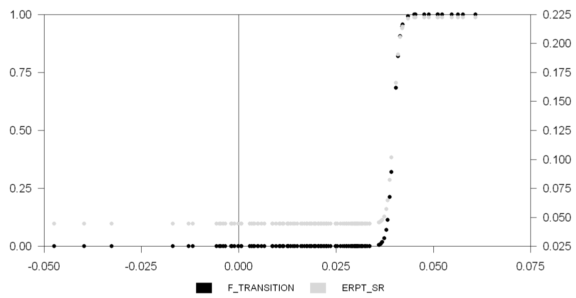
	Autriche	**Belgique**	**Allemagne**	**Espagne**	**Finlande**	**Grèce**	**Italie**	**Pays-Bas**	**Portugal**
Transition variable (s_t)	Δy_{t-1}	Δy_{t-3}	Δy_{t-4}	Δy_{t-3}	Δy_{t-2}	Δy_{t-2}	Δy_{t-1}	Δy_{t-4}	Δy_{t-3}
Threshold (c)	0,040	0,003	0,010	0,006	0,029	0,021	0,017	0,007	0,013
	0,000	0,000	0,079	0,509	0,000	0,009	0,000	0,000	0,000
Speed of transition (γ)	24,444	20,760	3,304	26,210	3,740	4,585	3,944	8,959	26,378
	0,651	0,168	0,162	0,000	0,193	0,202	0,003	0,265	0,311
Linear part : $G = 0$									
SR ERPT	0,044	0,105	0,024	0,049	0,010	0,112	0,044	0,043	0,093
	0,001	0,000	0,269	0,129	0,708	0,001	0,000	0,025	0,021
LR ERPT	0,191	0,328	0,088	0,198	0,148	0,581	0,328	0,208	0,707
	0,015	0,000	0,135	0,400	0,121	0,001	0,000	0,000	0,000
Non-linear part: $G = 1$									
SR ERPT	0,222	0,071	0,136	0,163	0,080	0,006	0,073	0,032	0,126
	0,012	0,000	0,005	0,000	0,007	0,936	0,736	0,075	0,162
LR ERPT	0,337	0,197	0,180	1,061	0,471	0,279	-1,358	0,156	1,619
	0,250	0,000	0,163	0,116	0,009	0,443	0,332	0,014	0,042
R^2	0,735	0,772	0,695	0,845	0,790	0,870	0,954	0,737	0,793
SSR_{ratio}	0,812	0,681	0,818	0,729	0,790	0,859	0,413	0,826	0,736
AIC	-8,087	-8,158	-8,247	-6,979	-7,610	-6,317	-8,311	-8,221	-5,857
pJB	0,466	0,364	0,081	0,000	0,108	0,005	0,000	0,462	0,000
$pLM_{AR(4)}$	0.1898	0,968	0,429	0,393	0,015	0,057	0,543	0,691	0,121
$pLM_{ARCH(4)}$	0,446	0,996	0,058	0,093	0,228	0,316	0,000	0,917	0,019
pLM_C	0,193	0,176	0,625	0,010	0,642	0,088	0,539	0,660	0,241
pLM_{RNL}	0,410	0,851	0,943	0,618	0,787	0,164	0,572	0,506	0,730

Note: Table reports elasticities of exchange rate pass-through into CPI inflation from LSTR models. Numbers in parentheses are p-values of estimates. R^2 denotes the coefficient of determination, SSR_{ratio} is the ratio of sum of squared residuals between LSTR model and the linear specification, and AIC is the Akaike Information Criterion. The following rows corresponds to the misspecification tests: pJB is the p-values of Jarque-Bera normality test, $pLM_{AR(4)}$ is the p-values of the LM test of no error autocorrelation up to forth order, $pLM_{ARCH(4)}$ is the p-values of the LM test of no ARCH effects up to forth order, pLM_C is the p-values of the LM test of parameter constancy and pLM_{RNL} is the p-values of the LM test of no remaining nonlinearity.

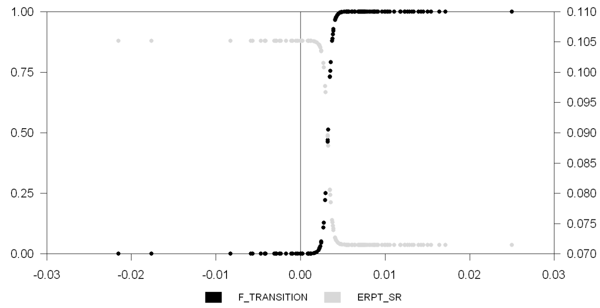
In the short-run, there are 6 out of 12 EA countries showing non-linear significant ERPT with respect to business cycle. For these six countries, our results point that pass-through depend positively on economic activity, except for Belgium and Netherlands. The exchange rate transmission to CPI inflation is significantly greater when output growth is above some threshold. For Germany, the pass-through coefficient is 0.02% not significnatly different from zero when GDP growth is below 1%, i.e. during economic slowdown. But when german economy is growing faster - above the threshold - pass-through elasticity increase to about 0.13%. In the long run, we obtain almost the same result, i.e. when economy is booming, ERPT becomes larger. We can say that these findings seems to be line with the empirical literature cited above. In their LSTR model, Nogueira Jr. & Leon-Ledesma (2008) rather found a positive link between pass-through and economic activity. This is true for the half of their country sample.

When we inspect Figure 15 and 16, it must be noted that for Belgium and Netherlands there is a significant negative link between ERPT and output growth in both short- and long-run. In fact, this result is not surprising if low or negative output growth are considered as a period of crisis or macroeconomic instability. Consequently, if foreign producers expect less stable conditions, they will be more willing to shift away from local-currency pricing which is leading to a higher degree of ERPT.

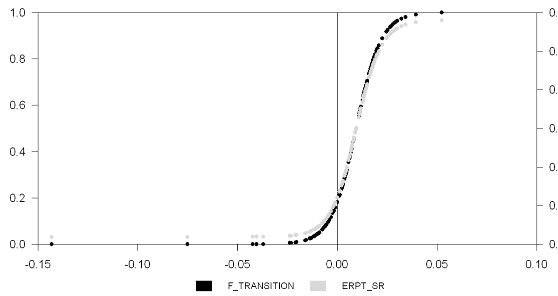
Figure 15: Estimated transition functions and short-run ERPT as a function of past output growth



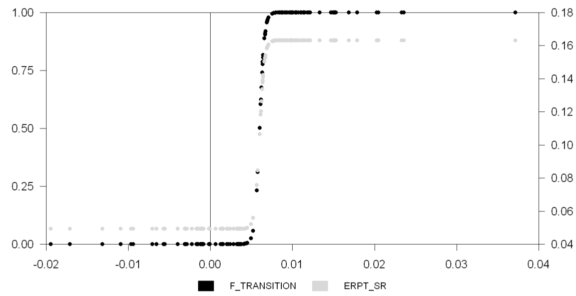
Austria



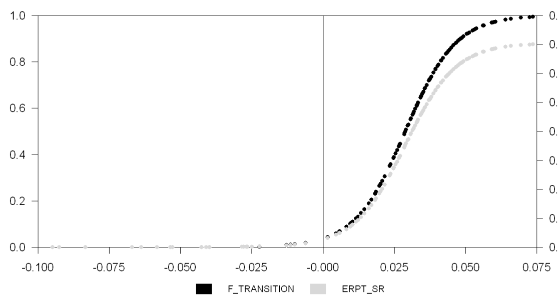
Belgium



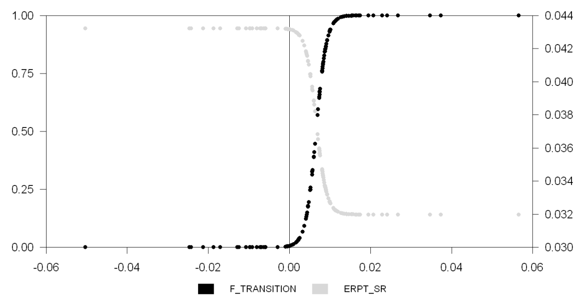
Germany



Spain



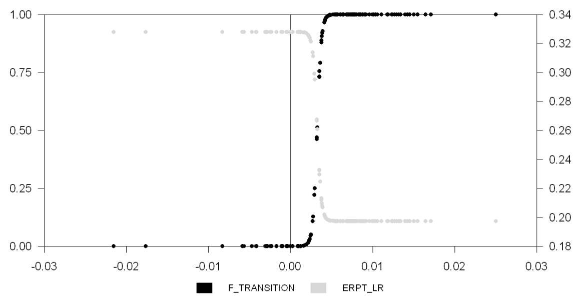
Finland



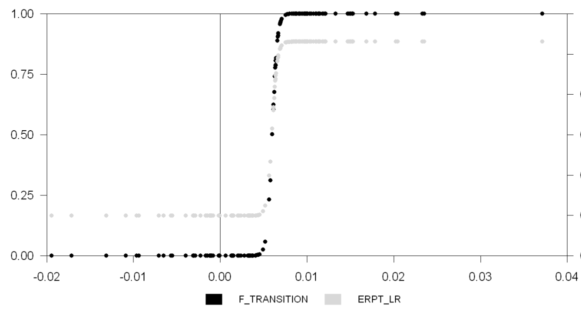
Netherlands

Note: Estimated transition functions and short-run ERPT as a function of past output growth. Results are from LSTR model with $s_t = \Delta y_{t-i}$.

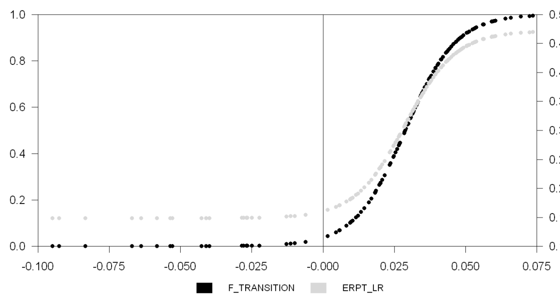
Figure 16: Estimated transition functions and long-run ERPT as a function of past output growth



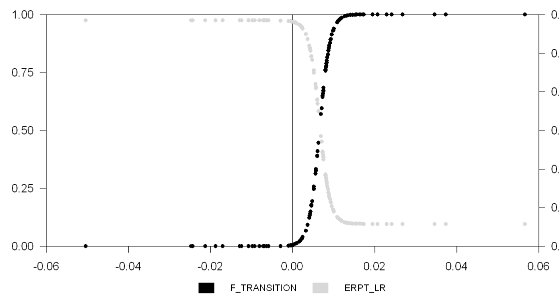
Belgium



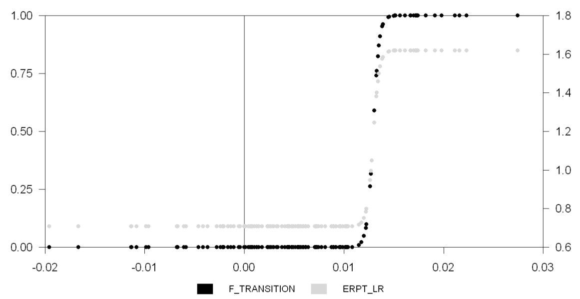
Spain



Finland



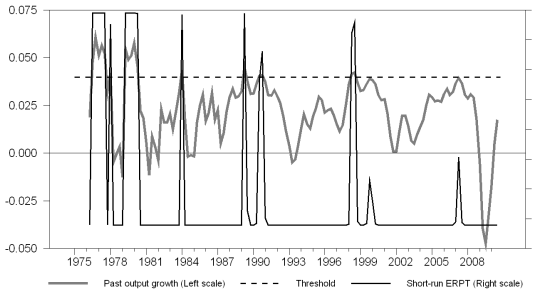
Netherlands



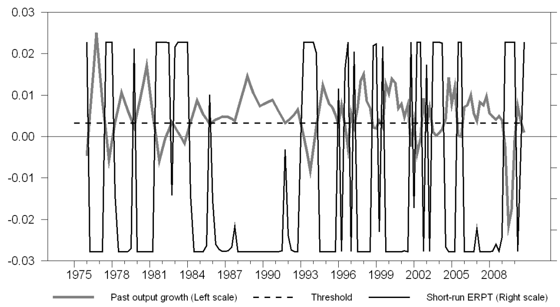
Portugal

Note: Estimated transition functions and long-run ERPT as a function of past output growth. Results are from LSTR model with $s_t = \Delta y_{t-i}$.

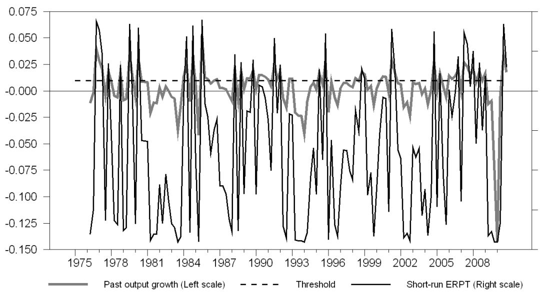
Figure 17: Time-varying short-run ERPT and past output growth between 1975-2010



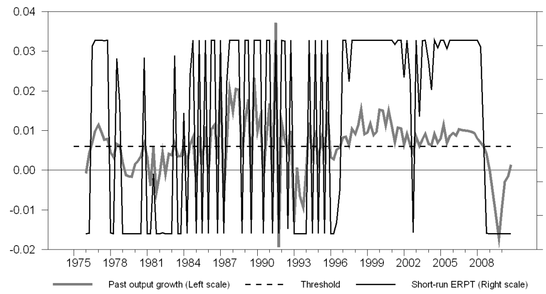
Austria



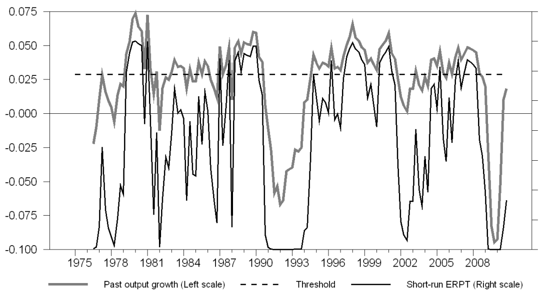
Belgium



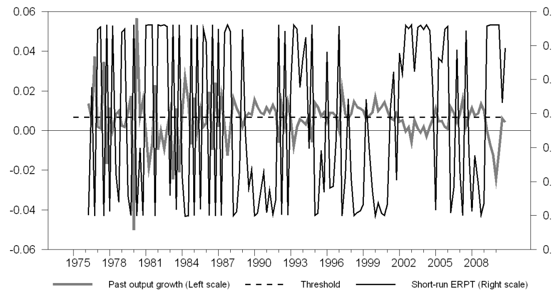
Germany



Spain



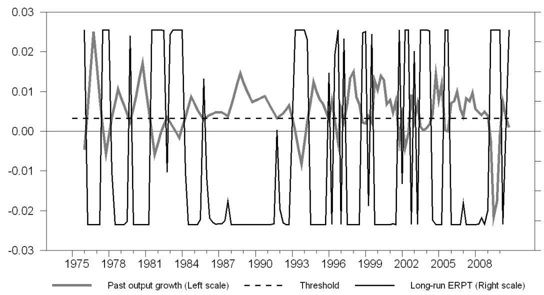
Finland



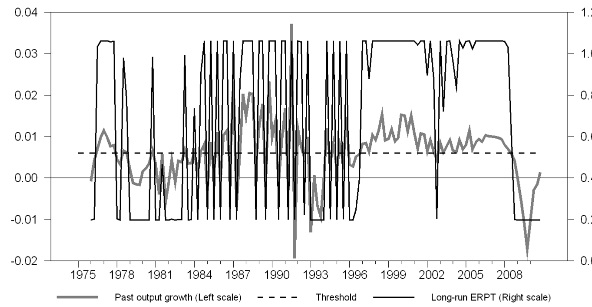
Netherlands

Note: Time-varying short-run ERPT and past output growth between 1975-2010. Results are from LSTR model with $s_t = \Delta y_{t-i}$.

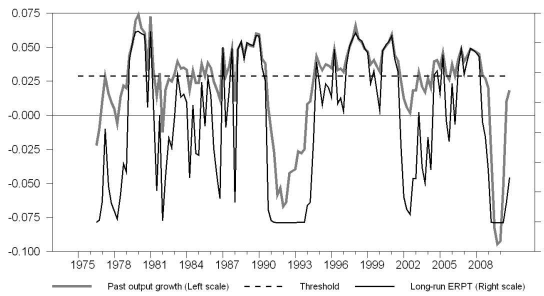
Figure 18: Time-varying long-run ERPT and past output growth between 1975-2010



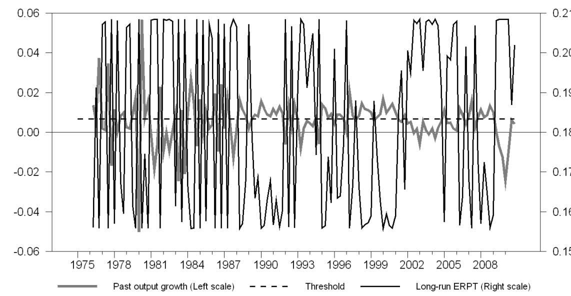
Belgium



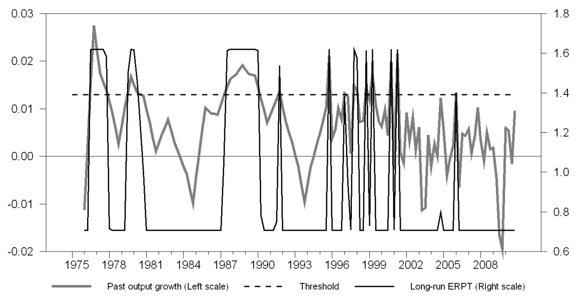
Spain



Finland



Netherlands



Portugal

Note: Time-varying long-run ERPT and past output growth between 1975-2010. Results are from LSTR model with $s_t = \Delta y_{t-i}$.

7 Conclusion

In this study, we investigate for possible non-linear mechanisms in the exchange rate pass-through (ERPT) to consumer prices for 12 euro area (EA) countries. This exercise is conducted using the family of smooth transition regression models as tool. Mainly, we explore the existence of non-linearities with respect to three macroeconomic determinants of ERPT, namely inflation environment, exchange rate fluctuations and business cycle.

Using quarterly data spanning from 1975 to 2010, we find a strong evidence that pass-through respond non-linearly to inflation level. The transmission of exchange rate is higher when inflation rate surpass some threshold. Results are more striking in the long run with 8 out of 12 EA countries reveal of positive relationship between ERPT-Inflation. We give a supportive evidence to the TaylorŠs view that pass-through is decreasing in a lower and more stable inflation environment. Furthermore, plots of time-varying pass-through coefficients suggest that prices sensibility to exchange rate changes has declined over time in response to a shift to a low-inflation regime.

When considering exchange rate movements as a potential source of non-linearities, we focus on asymmetries arising from both direction and magnitude of exchange rate. First, we provide a support of asymmetrical ERPT to appreciations and depreciations, but there is no clear-cut about the direction of asymmetry. In other words, for some countries pass-through is found to be greater when exchange rate is depreciating than when it is appreciating. This finding is consistent with the so-called *quantity constraint* theory. Nevertheless, we find the opposite result for the rest of EA countries, i.e. ERPT is higher during importer's currency appreciation than during a period of depreciation. This latter result is line with the *market share* explanation. It is important to note that similar mixed result was pointed out by a number of empirical studies (Gil-Pareja (2000) and Olivei (2002) and Coughlin & Pollard (2004)). Next, we check the asymmetry of pass-through with respect exchange rate magnitude. We find that CPI inflation reaction is found to be higher for large exchange rate changes than for small ones. This can be interpreted as an evidence of the presence of *menu costs*, where large currency movements are promptly transmitted to prices. A careful inspection of time-varying pass-through elasticitiy reveals that CPI inflation responsiveness to exchange rate variation was relatively higher during the EMS Crisis and at the launch of the euro.

The last source of non-linearities considered in our study is relative to business cycle. We report that pass-through depends positively on economic activity; that is, when real GDP is growing above some threshold, the extent of ERPT becomes higher. As a future step of research, other sources of non-linearities can be tested by means of STR models such as exchange rate volatility (Correa & Minella (2006)) or measures of macroeconomic instability (Nogueira Jr. & Leon-Ledesma (2008)).

References

Bailliu, J. & Fujii, E. [2004]. "Exchange Rate Pass-Through and the Inflation Environment in Industrialized Countries: An Empirical Investigation". *Bank of Canada Working Paper No. 2004-21.*

Bussière, M. [2007]. "Exchange Rate Pass-Through to Trade Prices: The Role of Nonlinearities and Asymmetries". *European Central Bank Working Paper no. 822.*

Choudhri, E. & Hakura, D. [2006]. "Exchange Rate Pass Through to Domestic Prices: Does the Inflationary Environment Matter?" *Journal of International Money and Finance*, 25, pp. 614–639.

Correa, A. & Minella, A. [2006]. "Nonlinear mechanisms of exchange rate passthrough: a Phillips curve model with threshold for Brazil". *Working Paper 122*, Central Bank of Brazil.

Coughlin, C. C. & Pollard, P. S. [2004]. "Size Matters: Asymmetric Exchange Rate Pass-Through at the Industrial Level". *Federal Reserve Bank of St. Louis, Working Paper No. 2003-029C.*

de Bandt, O., Banerjee, A. & Kozluk, T. [2007]. "Measuring long run exchange rate pass-through". *Banque de France, Notes d'Etudes et de Recherche No. 173.*

Eitrheim, Ø. & Terasvirta, T. [1996]. "Testing the adequacy of smooth transition autoregressive models". *Journal of Econometrics*, 74, pp. 59–76.

Engle, R. & Granger, C. [1987]. "Cointegration and error correction: Representation, estimation, and testing". *Econometrica*, 55, p. 251?27.

Gagnon, J. & Ihrig, J. [2004]. "Monetary Policy and Exchange Rate Pass-Through". *International Journal of Finance and Economics*, 9 (4), pp. 315–38.

García, J., C. & Restrepo, E., J. [2001]. "Price inflation and Exchange rate pass-through in Chile". *Central bank of chile, working paper nř 128.*

Gil-Pareja, S. [2000]. "Exchange Rates and European Countries' Export Prices: An Empirical Test for Asymmetries in Pricing to Market Behavior". *Weltwirtschaftliches Archiv*, 136(1), pp. 1–23.

Goldfajn, I. & Werlang, S.R.C. [2000]. "The Pass-through from Depreciation to Inflation: A Panel Study". *Banco Central Do Brasil Working Paper, vol. 5.*

Gregory, W., A. & Hansen, E., B. [1996]. "Residual-based tests for cointegration in models with regime shifts". *Journal of Econometrics*, vol. 70, no 1, pp. 99–126.

Herzberg, V., Kapetanios, G. & Price, S. [2003]. "Import prices and exchange rate pass-through: Theory and evidence from the United Kingdom." *Working Paper 182*, Bank of England.

Kilian, L. & Taylor, M. P. [2003]. "Why is it so difficult to beat the random walk forecast of exchange rates?" *Journal of International Economics*, 60, pp. 85–107.

Knetter, M. [1994]. "Is Export Price Adjustment Asymmetric? Evaluating the Market Share and Marketing Bottlenecks Hypotheses". *Journal of International Money and Finance*, 13(1), pp. 55–70.

Lumsdaine, R. L. & Papell, D. H. [1997]. "Multiple Trend Breaks and the Unit Root Hypothesis". *Review of Economics and Statistics*, 79 (2), pp. 212–218.

Luukkonen, R., Saikkonen, P. & Terasvirta, T. [1988]. "Testing Linearity against Smooth Transition AutoRegressive Models". *Biometrika*, 75, pp. 491–499.

Marazzi, N. Sheets, M., Vigfusson, R., J. Faust, J. Marquez R. Martin T. Reeve, J. Gagnon & Rogers, John [2005]. "Exchange Rate Pass-through to U.S. Import Prices: some New Evidence". *Board of Governors of the Federal Reserve System, International Finance Discussion Paper, No. 832*.

Marston, R. [1990]. "Pricing to Market in Japanese Manufacturing". *Journal of International Economics*, 29, p. 217Ũ36.

Michael, P., Nobay, A. & Peel, D. A. [1997]. "Transaction costs and non-linear adjustments in real exchange rates: an empirical investigation ." *Journal of Political Economy*, 105, pp. 862–79.

Nogueira Jr., R. P. & Leon-Ledesma, M. [2008]. "Exchange Rate Pass-Through Into Inflation: The Role of Asymmetries and NonLinearities". *Working paper*, Studies in Economics 0801, Department of Economics, University of Kent.

Nogueira Jr., R. P. & Leon-Ledesma, M. [2011]. "Does exchange rate pass-through respond to mesures of macroecomic instabiltity?" *Journal of Applied Economics*, XIV, No. 1, pp. 167–180.

Olivei, G. P. [2002]. "Exchange Rates and the Prices of Manufacturing Products Imported into the United States". *New England Economic Review*, First Quarter, pp. 3–18.

Przystupa, J. & Wróbel, E. [2011]. “Asymmetry of the Exchange Rate Pass-Through: An Exercise on Polish Data”. *Eastern European Economics*, 49 (1), pp. 30–51.

Shintani, M., A., Terada-Hagiwara & Y., Tomoyoshi [2009]. “Exchange Rate Pass-Through and Inflation: A Nonlinear Time Series Analysis”. *Working Paper, Department of Economics, Vanderbilt University.*

Small, I. [1997]. “The Cyclicality of Mark-ups and Profit Margins: Some Evidence for Manufacturing Services”. *Working paper of the bank of england.*

Taylor, J. [2000]. “Low Inflation, Pass-Through and the Pricing Power of Firms”. *European Economic Review*, 44, pp. 1389–1408.

Taylor, M. P. & Peel, D. A. [2000]. “Nonlinear adjustment, long-run equilibrium and exchange rate fundamentals”. *Journal of International Money and Finance*, 19, pp. 33–53.

Taylor, M. P., Peel, D. A. & Sarno, L. [2001]. “Nonlinear mean-reversion in real exchange rates: Toward a solution to the purchasing power parity puzzles”. *International Economic Review*, 42, pp. 1015–1042.

Teräsvirta, T. [1994]. “Specification, estimation and evaluation of smooth transition autoregressive models”. *Journal of the American Statistical Association*, 89, pp. 208–218.

Teräsvirta, T. [1998]. “Modelling Economic Relationship with Smooth Transition Regressions”. In *Handbook of Applied Economic Statistics* (D.E.A. Giles and Ullah, A. (eds), Marcel Dekker, New York.).

Teräsvirta, T. [2004]. “Smooth transition regression modelling”. In *Applied time series econometrics* (H. Lutkepohl and M. Kratzig, eds., Cambridge, Cambridge University Press.).

van Dijk, D., T., Teräsvirta & P., Franses [2002]. “Smooth Transition Autoregressive Models: A Survey of Recent Developments”. *Econometric Reviews*, 21, pp. 1–47.

Yang, J. [2007]. “Is Exchange Rate Pass-through Symmetric? Evidence from US Imports”. *Applied Economics*, 39, pp. 169–178.

Zivot, E. & Andrews, K. [1992]. “Further Evidence On The Great Crash, The Oil Price Shock, and The Unit Root Hypothesis”. *Journal of Business and Economic Statistics*, 10 (10), pp. 251–70.

Appendices

A Stationary Tests

Table 8: Unit Root Tests for π_t

	Austria	Belgium	Germany	Spain	Finland	France
ADF test	-2,49941*	-3,1285**	-2,3269 *	-2,3443*	-2,2732*	-1,3871
Zivot & Andrews (1992)	-4,626*	-5,42664**	-3,28748	-5,20309**	-4,14169*	-4,89641*
Lumsdaine & Papell (1997)	-5,4525*	-5,7938*	-3,8357	-6,6154*	-4,6757	-4,7807
	Greece	**Ireland**	**Italy**	**Luxembourg**	**Netherlands**	**Portugal**
ADF test	-1,0933	-2,4113	-1,5206	-3,1449**	-3,5305**	-1,7559
Zivot & Andrews (1992)	-4,32156*	-4,87005*	-4,71944*	-4,74024**	-4,73330*	-4,94901**
Lumsdaine & Papell (1997)	-4,5474	-5,3954	-6,0446*	-5,0647	-5,8354*	-5,9477*

Key: **,* the null hypothesis of unit root is rejected at 5% and 10% respectively. Zivot & Andrews (1992) test allow for one single break under the alternative hypothesis. Lumsdaine & Papell (1997) allow for two structural breaks under the alternative hypothesis. Specifications for Zivot & Andrews (1992) and Lumsdaine & Papell (1997) tests include both a constant and a time trend. Lag selection: Akaike (AIC). Maximum lags number = 8.

Table 9: Unit Root Tests for Δe_t

	Austria	Belgium	Germany	Spain	Finland	France
ADF test	-7,07806**	-8,1554 **	-8,4405**	-8,1891**	-8,5382**	-8,1272
Zivot & Andrews (1992)	-8,78526**	-8,64366**	-8,77998**	-8,87720**	-8,98770**	-8,83657**
Lumsdaine & Papell (1997)	-9,8235**	-9,6429**	-9,8282**	-9,7165**	-9,6528**	-9,7718**
	Greece	**Ireland**	**Italy**	**Luxembourg**	**Netherlands**	**Portugal**
ADF test	-8,7663	-8,3102	-8,1064**	-8,1554**	-8,4879**	-7,5155**
Zivot & Andrews (1992)	-4,59649*	-8,87136**	-8,81869**	-8,64366**	-8,88402**	-9,07966**
Lumsdaine & Papell (1997)	-5,7138*	-9,6448**	-9,4803**	-9,6429**	-9,9132**	-9,8650**

Key: **,* the null hypothesis of unit root is rejected at 5% and 10% respectively. Zivot & Andrews (1992) test allow for one single break under the alternative hypothesis. Lumsdaine & Papell (1997) allow for two structural breaks under the alternative hypothesis. Specifications for Zivot & Andrews (1992) and Lumsdaine & Papell (1997) tests include both a constant and a time trend. Lag selection: Akaike (AIC). Maximum lags number = 8.

Table 10: Unit Root Tests for Δw_t^*

	Austria	Belgium	Germany	Spain	Finland	France
ADF test	-6,12781**	-8,2643 **	-8,2643**	-8,2643**	-8,2643**	-8,2643
Zivot & Andrews (1992)	-8,80324**	-8,80324**	-8,80324**	-8,80324**	-8,80324**	-8,80324**
Lumsdaine & Papell (1997)	-9,3322**	-9,3322**	-9,3322**	-9,3322**	-9,3322**	-9,3322**
	Greece	**Ireland**	**Italy**	**Luxembourg**	**Netherlands**	**Portugal**
ADF test	-8,2643**	-8,2643 **	-8,2643**	-8,2643**	-8,2643**	-8,2643
Zivot & Andrews (1992)	-8,80324**	-8,80324**	-8,80324**	-8,80324**	-8,80324**	-8,80324**
Lumsdaine & Papell (1997)	-9,3322**	-9,3322**	-9,3322**	-9,3322**	-9,3322**	-9,3322**

Key: **,* the null hypothesis of unit root is rejected at 5% and 10% respectively. Zivot & Andrews (1992) test allow for one single break under the alternative hypothesis. Lumsdaine & Papell (1997) allow for two structural breaks under the alternative hypothesis. Specifications for Zivot & Andrews (1992) and Lumsdaine & Papell (1997) tests include both a constant and a time trend. Lag selection: Akaike (AIC). Maximum lags number = 8.

Table 11: Unit Root Tests for Δy_t

	Austria	**Belgium**	**Germany**	**Spain**	**Finland**	**France**
ADF test	-11,4573**	-6,5366 **	-8,3907**	-3,2332*	-4,2874**	-5,0841**
Zivot & Andrews (1992)	-11,8537**	-7,47145**	-8,50138**	-3,61602	-5,04799*	-5,77605**
Lumsdaine & Papell (1997)	-12,2914**	-7,9376**	-8,7710**	-4,3821	-5,2084	-6,4820*
	Greece	**Ireland**	**Italy**	**Luxembourg**	**Netherlands**	**Portugal**
ADF test	-4,1562**	-3,5561**	-6,4883**	-11,2848**	-14,2895**	-4,1707
Zivot & Andrews (1992)	-4,59308*	-4,40607*	-7,51558**	-3,58642	-14,9294**	-5,32930**
Lumsdaine & Papell (1997)	-5,2146	-5,4084	-7,8473**	-4,3088	-15,5851**	-6,1936*

Key: **,* the null hypothesis of unit root is rejected at 5% and 10% respectively. Zivot & Andrews (1992) test allow for one single break under the alternative hypothesis. Lumsdaine & Papell (1997) allow for two structural breaks under the alternative hypothesis. Specifications for Zivot & Andrews (1992) and Lumsdaine & Papell (1997) tests include both a constant and a time trend. Lag selection: Akaike (AIC). Maximum lags number = 8.

Table 12: Cointegration Tests

	Austria	**Belgium**	**Germany**	**Spain**	**Finland**	**France**
Engle & Granger (1987)	-2,018	-2,724	-2,858	-2,927	-2,039	-2,556
Gregory & Hansen (1996)						
Break in constant	-4,407	-4,438	-4,042	-5,021	-4,479	-4,421
Break in constant and slope	-4,883	-5,002	-5,308	-5,768	-6,703*	-5,419
	Greece	**Ireland**	**Italy**	**Luxembourg**	**Netherlands**	**Portugal**
Engle & Granger (1987)	-2,601	-3,337*	-3,414**	-3,257*	-3,313*	-2,786
Gregory & Hansen (1996)						
Break in constant	-4,476	-5,191*	-5,439*	-4,806	-5,496*	-4,180
Break in constant and slope	-5,442	-5,454	-5,232	-6,655*	-5,63	-5,704

Key: **,* the null hypothesis of unit root in the residuals (no cointegration) is rejected at 5% and 10% respectively. Specifications for Gregory & Hansen (1996) tests include both a constant and a time trend. Lag selection: Akaike (AIC). Maximum lags number = 8.

B Results from linear models

Table 13: Estimated ERPT elasticities from linear model

	Austria	Belgium	Germany	Spain	Finland	France
Constant	0,003	0,004	0,004	0,001	0,002	0,000
	(0,006)	(0,000)	(0,000)	(0,399)	(0,106)	(0,980)
π_{t-1}			0,172			0,355
			(0,011)			(0,000)
π_{t-2}	0,174			0,392		
	(0,011)			(0,000)		
π_{t-3}			0,231			
			(0,002)			
π_{t-4}	0,514	0,487	0,353	0,458	0,652	0,253
	(0,000)	(0,000)	(0,000)	(0,000)	(0,000)	(0,003)
Δe_t	0,040	0,080	0,052	0,124	0,040	0,028
	(0,003)	(0,000)	(0,000)	(0,000)	(0,011)	(0,016)
Δe_{t-1}	0,034		0,023		0,046	0,018
	(0,012)		(0,001)		(0,004)	(0,147)
Δe_{t-2}		0,042		0,014		
		(0,001)		(0,358)		
Δe_{t-3}		0,017				0,010
		(0,035				(0,157
Δe_{t-4}			-0,019	-0,051	0,005	
			(0,008	(0,026	(0,616	
Δw^*_t	0,075	0,151	0,093	0,202	0,055	0,064
	(0,000)	(0,000)	(0,000)	(0,000)	(0,034)	(0,001)
Δw^*_{t-1}	0,069	0,007			0,108	0,028
	(0,002	(0,622)			(0,000)	(0,145)
Δw^*_{t-2}		0,086		-0,061		0,001
		(0,000)		(0,101)		(0,015)
Δw^*_{t-3}						
Δw^*_{t-4}						
Δy_t	-0,023	-0,100		0,113	0,079	
	(0,597)	(0,181)		(0,209)	(0,050)	
Δy_{t-1}			0,043			
			(0,005)			
Δy_{t-2}	0,068					
	(0,129)					
Δy_{t-3}			-0,026			
			(0,133)			
Δy_{t-4}			0,035			
			(0,074)			
LR ERPT	0,235	0,272	0,115	0,142	0,264	0,142
	(0,000)	(0,000)	(0,019)	(0,003)	(0,000)	(0,003)
R^2	0,674	0,666	0,715	0,788	0,734	0,879
SSR	0,002	0,002	0,001	0,007	0,003	0,002
$SE\ of\ Residuals$	0,004	0,004	0,003	0,007	0,005	0,003
AIC	-8,087	-8,068	-8,539	-6,872	-7,570	-8,322
pJB	0,000	0,399	0,000	0,001	0,032	0,000
$pLM_{AR(4)}$	0,819	0,244	0,845	0,209	0,000	0,112
$pLM_{ARCH(4)}$	0,710	0,511	0,869	0,004	0,020	0,860
$pRESET$	0,051	0,544	0,744	0,657	0,000	0,000

Key: Table reports estimates of linear pass-through equation. Numbers in parentheses are p-values.

Continued

	Greece	**Ireland**	**Italy**	**Luxembourg**	**Netherlands**	**Portugal**
Constant	-0,011	-0,001	0,002	0,003	0,000	0,008
	(0,000)	(0,497)	(0,208)	(0,003)	(0,657)	(0,014)
π_{t-1}	0,348		0,250			0,138
	(0,000)		(0,006)			(0,080)
π_{t-2}		0,284	0,196	0,249	0,129	0,194
		(0,000)	(0,024)	(0,000)	(0,078)	(0,014)
π_{t-3}	0,157	0,221	0,222			
	(0,034)	(0,003)	(0,011)			
π_{t-4}	0,373	0,221	0,205	0,358	0,488	0,252
	(0,000)	(0,001)	(0,013)	(0,000)	(0,000)	(0,002)
Δe_t	0,072	0,031	0,060	0,077	0,042	0,104
	(0,006)	(0,234)	(0,000)	(0,000)	(0,001)	(0,009)
Δe_{t-1}	0,038	0,120	0,024	0,041		0,076
	(0,151)	(0,000)	(0,151)	(0,002)		(0,058)
Δe_{t-2}						
Δe_{t-3}					0,044	
					(0,000)	
Δe_{t-4}			-0,037			0,093
			(0,019)			(0,013)
Δw^*_t	0,118	0,079	0,110	0,145	0,077	0,168
	(0,003	(0,057	(0,000	(0,000)	(0,000)	(0,006)
Δw^*_{t-1}	0,063	0,211	0,036	0,044		0,077
	(0,118)	(0,000)	(0,213)	(0,045)		(0,226)
Δw^*_{t-2}						
Δw^*_{t-3}					0,069	
					(0,000)	
Δw^*_{t-4}			-0,049			0,073
			(0,086)			(0,254)
Δy_t				-0,024	-0,056	
				(0,372)	(0,090)	
Δy_{t-1}	0,056		0,182		0,063	
	(0,113)		(0,011)		(0,042)	
Δy_{t-2}					0,079	
					(0,008)	
Δy_{t-3}	0,040					
	(0,274)					
Δy_{t-4}	0,088	0,138	0,050		0,043	0,266
	(0,010)	(0,030)	(0,517)		(0,150)	(0,075)
LR ERPT	0,903	0,551	0,447	0,413	0,224	0,657
	(0,012)	(0,000)	(0,000)	(0,000)	(0,000)	(0,000)
R^2	0,879	0,712	0,884	0,680	0,682	0,719
SSR	0,011	0,009	0,003	0,002	0,002	0,019
$SE\ of\ Residuals$	0,008	0,008	0,005	0,004	0,004	0,012
AIC	-6,541	-6,641	-7,572	-8,003	-8,270	-5,791
pJB	0,000	0,000	0,000	0,000	0,269	0,000
$pLM_{AR(4)}$	0,560	0,312	0,841	0,491	0,687	0,699
$pLM_{ARCH(4)}$	0,220	0,001	0,009	0,992	0,938	0,000
$pRESET$	0,012	0,014	0,063	0,202	0,393	0,000

Key: Table reports estimates of linear pass-through equation. Numbers in parentheses are p-values.

C Results from STR pass-through models

Table 14: Estimation results from LSTR model with $s_t = \pi_{t-i}$

	Austria	**Belgium**	**Germany**	**Spain**	**Finland**	**France**
s_t	π_{t-4}	π_{t-1}	π_{t-1}	π_{t-4}	π_{t-3}	π_{t-2}
c	0,033	0,030	0,013	0,022	0,027	0,011
	(0,000)	(0,000)	(0,000)	(0,000)	(0,000)	(0,000)
γ	22,013	17,566	9,390	12,702	13,291	6,134
	(0,547)	(0,312)	(0,208)	(0,437)	(0,531)	(0,067)
Linear Part: $G = 0$						
Constant	0,000	0,007	0,005	0,001	0,001	0,003
	(0,866)	(0,000)	(0,000)	(0,753)	(0,485)	(0,021)
π_{t-1}			0,195			0,174
			(0,058)			(0,262)
π_{t-2}	0,160					
	(0,077)					
π_{t-3}				-0,115		
				(0,287)		
π_{t-4}	0,534	0,068	0,438	0,863	0,782	0,257
	(0,534)	(0,638)	(0,000)	(0,000)	(0,000)	(0,053)
Δe_t	0,043	0,091	0,063	0,085	0,044	0,066
	(0,042)	(0,000)	(0,000)	(0,009)	(0,005)	(0,001)
Δe_{t-1}	0,004	0,042			0,048	-0,013
	(0,821)	(0,033)			(0,002)	(0,535)
Δe_{t-2}				0,015		
				(0,626)		
Δe_{t-3}		-0,002				-0,004
		(0,845)				(0,680)
Δe_{t-4}			-0,021	0,010	-0,003	
			(0,116)	(0,567)	(0,785)	
Δw^*_t	0,078	0,140	0,091	0,171	0,058	0,111
	(0,024)	(0,000)	(0,000)	(0,003)	(0,020)	(0,002)
Δw^*_{t-1}	0,047	0,004			0,098	-0,012
	(0,213)	(0,844)			(0,000)	(0,723)
Δw^*_{t-2}		0,087	-0,001	0,040		
		(0,011)	(0,956)	(0,482)		
Δw^*_{t-3}						
Δw^*_{t-4}			-0,006			
			(0,788)			
Δy_t	0,117	-0,293		0,065	0,142	0,000
	(0,206)	(0,004)		(0,534)	(0,000)	(0,517)
Δy_{t-1}			0,026			
			(0,148)			
Δy_{t-2}	0,036					
	(0,708)					
Δy_{t-3}			-0,036			
			(0,085)			
Δy_{t-4}			0,063			
			(0,013			
Non-linear Part: $G = 1$						
Δe_t	-0,018	-0,017	-0,060	0,082	-0,024	-0,071
	(0,516)	(0,529)	(0,489)	(0,063)	(0,753)	(0,015)
Δe_{t-1}	0,071				-0,016	0,080
	(0,014)				(0,762)	(0,004)
Δe_{t-2}		-0,014		-0,097		
		(0,595)		(0,026)		
Δe_{t-3}		0,044				0,046
		(0,011)				(0,014)
Δe_{t-4}			0,110	0,057	0,120	
			(0,245)	(0,078)	(0,079)	

Key: Table reports estimates of STR pass-through equation. Numbers in parentheses are p-values.

Continued

	Greece	Ireland	Italy	Luxembourg	Netherlands	Portugal
s_t	π_{t-3}	π_{t-2}	π_{t-2}	π_{t-4}	π_{t-3}	π_{t-1}
c	0,022	0,034	0,031	0,015	0,008	0,088
	(0,024)	(0,000)	(0,000)	(0,000)	(0,000)	(0,000)
γ	2,358	8,456	2,449	4,909	9,361	4,061
	(0,120)	(0,003)	(0,002)	(0,056)	(0,333)	(0,053)
Linear Part: $G = 0$						
Constant	-0,014	-0,001	0,002	0,002	-0,002	0,002
	(0,346)	(0,551)	(0,106)	(0,048)	(0,161)	(0,716)
π_{t-1}			0,552			0,013
			(0,000)			(0,965)
π_{t-2}		0,453		0,249	0,064	0,216
		(0,000)		(0,007)	(0,571)	(0,443)
π_{t-3}		0,092	-0,067			-0,119
		(0,250)	(0,635)			(0,702)
π_{t-4}	0,645	0,189	0,220	0,541	0,490	
	(0,000)	(0,015)	(0,096)	(0,000)	(0,000)	
Δe_t	0,105	0,043	0,032	0,053	0,049	0,040
	(0,134)	(0,097)	(0,050)	(0,002)	(0,009)	(0,547)
Δe_{t-1}	-0,046	0,074	0,021	0,039		0,001
	(0,541)	(0,003)	(0,221)	(0,012)		(0,993)
Δe_{t-2}						
Δe_{t-3}					0,010	
					(0,327)	
Δe_{t-4}						0,012
						(0,765)
Δw^*_t	0,187	0,113	0,074	0,098	0,058	0,099
	(0,036)	(0,005)	(0,007)	(0,001)	(0,072)	(0,300)
Δw^*_{t-1}	-0,029	0,139	0,025	0,059		0,011
	(0,765)	(0,000)	(0,429)	(0,020)		(0,910)
Δw^*_{t-2}						
Δw^*_{t-3}					0,001	
					(0,944)	
Δw^*_{t-4}						
Δy_t	-0,037			-0,007	-0,028	
	(0,728			(0,808)	(0,679)	
Δy_{t-1}			0,038		0,043	
			(0,616)		(0,501)	
Δy_{t-2}					0,115	
					(0,020)	
Δy_{t-3}		0,052	0,027			
		(0,298)	(0,755)			
Δy_{t-4}	-0,068	0,127			0,099	0,056
	(0,544)	(0,019)			(0,099)	(0,787)
Non-linear Part: $G = 1$						
Δe_t	-0,049	1,871	0,134	0,106	-0,013	0,045
	(0,595)	(0,001)	(0,013)	(0,008)	(0,647)	(0,609)
Δe_{t-1}	0,191	-1,355	0,078	0,023		0,165
	(0,062)	(0,018)	(0,191)	(0,531)		(0,076
Δe_{t-2}						
Δe_{t-3}					0,034	
					(0,062)	
Δe_{t-4}						0,175
						(0,005)

Key: Table reports estimates of STR pass-through equation. Numbers in parentheses are p-values.

Table 15: Estimation results from LSTR model with $s_t = \Delta e_{t-i}$

	Belgique	**Grèce**	**Italie**	**Luxembourg**	**Portugal**
s_t	Δe_{t-4}	Δe_{t-4}	Δe_{t-2}	Δe_{t-1}	Δe_{t-1}
c	0,004	-0,021	0,044	0,037	0,045
	(0,050)	(0,000)	(0,000)	(0,000)	(0,000)
γ	60,750	9,675	7,513	18,530	5,317
	(0,555)	(0,262)	(0,095)	(0,379)	(0,029)
Linear part: G=0					
Constant	0,005	-0,008	0,000	0,003	0,002
	(0,001)	(0,331)	(0,925)	(0,009)	(0,622)
π_{t-1}		0,545	0,478		
		(0,090)	(0,000)		
π_{t-2}				0,211	
				(0,006)	
π_{t-3}		-0,187	0,089		
		(0,484)	(0,360)		
π_{t-4}	0,445	0,439	0,227	0,330	0,662
	(0,000)	(0,071)	(0,013)	(0,000)	(0,000)
Δe_t	0,101	0,196	0,037	0,060	0,069
	(0,000)	(0,033)	(0,030)	(0,000)	(0,131)
Δe_{t-1}		-0,091	0,052	0,020	
		(0,249)	(0,008)	(0,275)	
Δe_{t-2}	0,032				
	(0,083)				
Δe_{t-3}	0,024				-0,035
	(0,086)				(0,466)
Δe_{t-4}					
Δw_t^*	0,193	0,255	0,075	0,115	0,087
	(0,000)	(0,014)	(0,005)	(0,000)	(0,240)
Δw_{t-1}^*	0,022	-0,114	0,098	0,049	0,013
	(0,196)	(0,314)	(0,005)	(0,057)	(0,816)
Δw_{t-2}^*	0,080				
	(0,002)				
Δw_{t-3}^*					-0,066
					(0,323)
Δw_{t-4}^*					
Δy_t	-0,167			-0,050	
	(0,129)			(0,075)	
Δy_{t-1}		-0,119	0,321		
		(0,339)	(0,000)		
Δy_{t-2}					
Δy_{t-3}		0,146	0,007		0,201
		(0,163)	(0,931)		(0,334)
Δy_{t-4}		0,118			0,026
		(0,139)			(0,904)
Non-linear part: G=1					
Δe_t	-0,060	-0,147	0,064	0,063	0,203
	(0,029)	(0,131)	(0,330)	(0,109)	(0,010)
Δe_{t-1}		0,132	-0,175	-0,051	
		(0,129)	(0,004)	(0,337)	
Δe_{t-2}	-0,005				
	(0,849)				
Δe_{t-3}	-0,009				0,448
	(0,594)				(0,000)
Δe_{t-4}					

Key: Table reports estimates of STR pass-through equation. Numbers in parentheses are p-values.

Table 16: Estimation results from ESTR model with $s_t = \Delta e_{t-i}$

	Belgium	**Germany**	**Spain**	**Finland**	**France**
s_t	Δe_{t-4}	Δe_{t-1}	Δe_{t-4}	Δe_{t-2}	Δe_{t-3}
c	0,022	0,006	0,035	0,021	-0,022
	(0,059)	(0,037)	(0,004)	(0,000)	(0,000)
γ	4,381	11,092	4,322	11,347	2,487
	(0,000)	(0,062)	(0,110)	(0,004)	(0,064)
Linear Part: G=0					
Constant	0,004	0,005	-0,005	0,007	-0,002
	(0,188)	(0,181)	(0,306)	(0,166	(0,332
π_{t-1}			0,028		
			(0,896)		
π_{t-2}		0,798			
		(0,007)			
π_{t-3}					0,410
					(0,007)
π_{t-4}	0,696		0,748	0,139	0,345
	(0,000)		(0,003)	(0,459)	(0,033)
Δe_t	-0,016	0,002	0,019	-0,071	-0,019
	(0,681)	(0,972)	(0,814)	(0,183)	(0,485)
Δe_{t-1}				-0,046	0,065
				(0,691)	(0,015)
Δe_{t-2}	-0,002		-0,065		
	(0,967)		(0,128)		
Δe_{t-3}	-0,015	-0,099			
	(0,449)	(0,015)			
Δe_{t-4}			-0,019	0,006	-0,038
			(0,611)	(0,864)	(0,027)
Δw^*_t	-0,064	-0,029	0,059	-0,322	0,045
	(0,479)	(0,779)	(0,731)	(0,029)	(0,159)
Δw^*_{t-1}	-0,041		-0,061	0,012	0,112
	(0,370)		(0,449)	(0,932)	(0,005)
Δw^*_{t-2}	0,022	-0,129			
	(0,786)	(0,008)			
Δw^*_{t-3}					
Δw^*_{t-4}		0,009			
		(0,886)			
Δy_t	-0,111		0,012	-0,163	
	(0,585)		(0,951)	(0,475)	
Δy_{t-1}					
Δy_{t-2}		0,165			0,338
		(0,062)			(0,024)
Δy_{t-3}					
Δy_{t-4}		0,100			
		(0,246)			
Non-linear Part: G=1					
Δe_t	0,119	0,073	0,102	0,121	0,095
	(0,006)	(0,200)	(0,253)	(0,040)	(0,008)
Δe_{t-1}				0,101	-0,059
				(0,405)	(0,110)
Δe_{t-2}	0,045		0,054		
	(0,333)		(0,259)		
Δe_{t-3}	0,042	0,112			
	(0,076)	(0,009)			
Δe_{t-4}			0,059	-0,006	0,046
			(0,160)	(0,871)	(0,038)

Key: Table reports estimates of STR pass-through equation. Numbers in parentheses are p-values.

Continued

	Grèce	Irlande	Italie	Luxembourg	Pays-Bas
s_t	Δe_{t-3}	Δe_{t-2}	Δe_{t-1}	Δe_{t-3}	Δe_{t-4}
c	0,030	0,043	0,016	0,010	0,033
	(0,000)	(0,000)	(0,000)	(0,016)	(0,000)
γ	33,264	1,274	9,112	4,041	1,128
	(0,053)	(0,025)	(0,105)	(0,057)	(0,058)
Linear Part: G=0					
Constant	0,002	0,003	0,003	0,009	-0,003
	(0,956)	(0,504)	(0,532)	(0,001)	(0,226)
π_{t-1}	-0,495	0,160	0,812		0,391
	(0,591)	(0,267)	(0,015)		(0,032)
π_{t-2}		-0,169		0,174	
		(0,301)		(0,478)	
π_{t-3}	0,049		-0,429		
	(0,919)		(0,274)		
π_{t-4}	2,068	0,304	0,410	0,290	0,506
	(0,044)	(0,014)	(0,100)	(0,090)	(0,000)
Δe_t	-0,291	0,065	0,009	0,055	-0,018
	(0,073)	(0,256)	(0,886)	(0,062)	(0,476)
Δe_{t-1}	0,034	0,023	0,014	-0,006	0,021
	(0,852)	(0,652)	(0,943)	(0,878)	(0,162)
Δe_{t-2}					
Δe_{t-3}					
Δe_{t-4}			-0,067		
			(0,125)		
Δw_t^*	-0,455	0,062	0,067	0,042	0,017
	(0,006)	(0,594)	(0,426)	(0,393)	(0,727)
Δw_{t-1}^*	0,186	0,176	-0,117	0,016	
	(0,586)	(0,026)	(0,279)	(0,820)	
Δw_{t-2}^*					
Δw_{t-3}^*					0,046
					(0,024)
Δw_{t-4}^*					
Δy_t				-0,174	0,113
				(0,078)	(0,234)
Δy_{t-1}	-0,258		0,047		0,195
	(0,412)		(0,817)		(0,003)
Δy_{t-2}					-0,015
					(0,826)
Δy_{t-3}	0,083	0,037	0,084		
	(0,808)	(0,745)	(0,784)		
Δy_{t-4}	0,578	0,080			0,044
	(0,175)	(0,567)			(0,416)
Non-linear Part: G=1					
Δe_t	0,395	-0,076	0,061	0,035	0,122
	(0,018)	(0,294)	(0,370)	(0,329)	(0,002)
Δe_{t-1}	0,009	0,140	0,022	0,058	-0,002
	(0,961)	(0,042)	(0,912)	(0,234)	(0,920)
Δe_{t-2}					
Δe_{t-3}					
Δe_{t-4}			0,057		
			(0,227)		

Key: Table reports estimates of STR pass-through equation. Numbers in parentheses are p-values.

Table 17: Estimation results from LSTR model with $s_t = \Delta y_{t-i}$

	Autriche	**Belgique**	**Allemagne**	**Espagne**	**Finlande**
s_t	Δy_{t-1}	Δy_{t-3}	Δy_{t-4}	Δy_{t-3}	Δy_{t-2}
c	0,040	0,003	0,010	0,006	0,029
	(0,000)	(0,000)	(0,079)	(0,509)	(0,000)
γ	24,444	20,760	3,304	26,210	3,740
	(0,651)	(0,168)	(0,162)	(0,000)	(0,193)
Linear Part: G=0					
Constant	0,002	0,009	0,007	0,000	0,000
	(0,193)	(0,000)	(0,000)	(0,960)	(0,931)
π_{t-1}			0,352		
			(0,004)		
π_{t-2}	0,197			0,091	
	(0,007)			(0,553)	
π_{t-3}					
π_{t-4}	0,538	0,425	0,167	0,765	0,673
	(0,000)	(0,000)	(0,273)	(0,000)	(0,000)
Δe_t	0,044	0,105	0,024	0,049	0,010
	(0,001	(0,000)	(0,269)	(0,129)	(0,708)
Δe_{t-1}				0,056	0,031
				(0,032)	(0,234)
Δe_{t-2}		0,058		-0,077	
		(0,007)		(0,023)	
Δe_{t-3}		0,025			
		(0,044)			
Δe_{t-4}	0,006		0,019		0,008
	(0,685)		(0,477)		(0,621)
Δw_t^*	0,084	0,168	0,028	0,125	-0,018
	(0,000)	(0,012)	(0,445)	(0,002)	(0,719)
Δw_{t-1}^*	0,016	-0,067			0,102
	(0,256)	(0,090)			(0,014)
Δw_{t-2}^*		0,171	0,039	-0,046	
		(0,000)	(0,154)	(0,376)	
Δw_{t-3}^*					
Δw_{t-4}^*	-0,001		0,051		
	(0,982)		(0,279)		
Δy_t	0,027	-0,389		0,565	-0,013
	(0,642)	(0,016)		(0,001)	(0,864)
Δy_{t-1}			0,006		
			(0,839)		
Δy_{t-2}	0,079				
	(0,085)				
Δy_{t-3}			-0,041		
			(0,145)		
Δy_{t-4}			-0,078		
			(0,328)		
Non-linear Part: G=1					
Δe_t	0,178	0,057	0,112	0,114	0,070
	(0,046)	(0,645)	(0,052)	(0,010)	(0,126)
Δe_{t-1}				-0,060	0,023
				(0,066)	(0,582)
Δe_{t-2}		-0,034		0,069	
		(0,300)		(0,151)	
Δe_{t-3}		-0,029			
		(0,275)			
Δe_{t-4}	-0,139		-0,068		0,012
	(0,042)		(0,232)		(0,685)

Key: Table reports estimates of STR pass-through equation. Numbers in parentheses are p-values.

Continued

	Greece	**Italy**	**Netherlands**	**Portugal**
s_t	Δy_{t-2}	Δy_{t-1}	Δy_{t-4}	Δy_{t-3}
c	0,021	0,017	0,007	0,013
	(0,009)	(0,000)	(0,000)	(0,000)
γ	4,585	3,944	8,959	26,378
	(0,202)	(0,003)	(0,265)	(0,311)
Linear Part: G=0				
Constant	0,001	0,001	-0,001	0,006
	(0,603)	(0,094)	(0,649)	(0,091)
π_{t-1}		0,388		0,151
		(0,000)		(0,076)
π_{t-2}			0,076	0,293
			(0,490)	(0,003)
π_{t-3}		0,233		
		(0,000)		
π_{t-4}	0,728	0,206	0,478	0,308
	(0,000)	(0,001)	(0,000)	(0,000)
Δe_t	0,112	0,044	0,043	0,093
	(0,001)	(0,000)	(0,025)	(0,021)
Δe_{t-1}	0,046	0,013		
	(0,294)	(0,334)		
Δe_{t-2}				0,041
				(0,146)
Δe_{t-3}			0,050	
			(0,014)	
Δe_{t-4}				0,041
				(0,129)
Δw^*_t	0,186	0,103	0,029	0,155
	(0,000)	(0,000)	(0,439)	(0,016)
Δw^*_{t-1}	0,101	0,008		0,000
	(0,100)	(0,729)		(0,995)
Δw^*_{t-2}				
Δw^*_{t-3}			0,086	
			(0,004)	
Δw^*_{t-4}				
Δy_t	-0,025		-0,056	
	(0,605)		(0,232)	
Δy_{t-1}		0,042	0,020	
		(0,528)	(0,688)	
Δy_{t-2}			0,041	
			(0,422)	
Δy_{t-3}		-0,011		0,014
		(0,848)		(0,957)
Δy_{t-4}	0,059		-0,066	0,370
	(0,203)		(0,275)	(0,077)
Non-linear Part: G=1				
Δe_t	-0,105	0,029	-0,011	0,032
	(0,258)	(0,895)	(0,684)	(0,743)
Δe_{t-1}	0,023	-0,321		
	(0,774)	(0,213)		
Δe_{t-2}				0,080
				(0,299)
Δe_{t-3}			-0,012	
			(0,660)	
Δe_{t-4}				0,114
				(0,159)

Key: Table reports estimates of STR pass-through equation. Numbers in parentheses are p-values.