Does the Deregulation of the Labour Market Reduce Employment Hysteresis?
An Analysis in a Low Interest Rate Environment

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Abstract

This paper analysis the effects of deregulation of the employment in an environment of low interest rates and economic uncertainty. For this purpose, we estimate a switching employment equation based on the play model of hysteresis. As a novel feature, the estimation allows for a possible change in the value of the switching parameter after the application of labour market reforms. We use Portuguese monthly data spanning from January 2000 to October 2016. Portugal provides a good case study since it is a country where significant measures towards the deregulation of the labour market were applied after the recent financial crises. The results show that these measures reduced the hysteresis effects in the dynamics of aggregate employment except in the period where uncertainty increased substantially.

JEL Classification E24; J23.
Keywords: employment, hysteresis, uncertainty, employment protection legislation

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1. **Introduction**

The Great Recession that followed the recent global financial crisis, and the present slow and weak recovery in many developed countries, have provided new evidence that recessions leave long lasting effects on the economy that may operate through hysteresis mechanisms (see, *e.g.*, Jaimovich and Siu, 2012, Ball 2014, Summers, 2014, Abraham *et al*., 2016, and Yagan, 2017).

In the presence of hysteresis there is no unique long-run equilibrium determined solely by the supply side of the economy, and independent of the history of past shocks, including those caused by monetary and fiscal policies (see, *e.g.*, Cross *et al*., 2005, Setterfield, 2009, Cross, 2014, Göcke and Matulaityte, 2015, and Bassi and Lang, 2016). Indeed, the economy can stay after a financial crisis that cause a recession, for a long time in a position of equilibrium with low employment/high unemployment due to insufficient demand.

Hysteresis may results from institutional characteristics of labour markets, like the employment protection legislation that generate non-convex hiring and firing costs. This kind of adjustment costs often creates a wedge between the marginal revenue of the employment adjustment and the corresponding cost, entailing the presence of separate employment demand triggers for upward and downward adjustment. The difference between these two triggers is called the employment band of inaction, which determines that no adjustment of the number of employees may be the firms’ optimal response to small shocks (see Bertola, 1990, Dixit, 1991, Cross, 1994 and Belke and Göcke 1999).

It is also established in the literature that uncertainty (of economic, financial and regulatory kind) interacts with the non-convex employment adjustment costs, widening the employment band of inaction and reinforcing the hysteresis effects (see, *e.g.*, Dixit, 1989, Dixit and Pindyck, 1994 and Belke and Göcke, 1999).

Furthermore, the relative importance of non-convex adjustment costs and uncertainty for the width of the employment band of inaction varies with the interest rates.

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4 Although hysteresis has been used in economics in different assertions (see, *e.g.*, Phelps, 1972, Layard *et al*., 1991, and Blanchard and Summers, 1996), here we follow the original concept issued from the physics of magnetism, which is characterised by the properties of non-linearity, *remanence* and selective memory, and that have been applied to describe the dynamics of employment and unemployment since Amable *et al*., (1993) and Cross (1994).

5 See, *e.g.*, Pindyck (1991), Hamermesh and Pfann (1996), and Folta (2006) for an extensive list of employment and physical capital adjustment costs.
The lower the interest rates the higher the importance of uncertainty, and the smaller the importance of non-convex employment hiring and firing costs to generate hysteresis effects (see Belke and Göcke, 2003; 2006 and Mota et al., 2015).

This implies that when interest rates are low, as in the current situation in the Eurozone, hysteresis can be quite strong even if the government applies measures towards the deregulation of the labour market due to the stronger role of uncertainty.

The main contribution of this paper is to analyse the effect of the deregulation of the labour market on the presence of hysteresis in aggregate employment, along with its relationship with uncertainty and the dynamics of interest rates. This is very important for the Eurozone, and especially for its peripheral countries, given the austerity measures and the structural reforms that were undertaken in the labour market in the context of the financial assistance provided by the IMF/ ECB/ European Commission, to promote employment and to foster economic growth.

For that purpose, we estimate a switching employment equation from a computational implementation of the linear play model of hysteresis (also known as the friction-backlash model\(^6\)). This equation describes the behaviour of which for small changes of labour demand there is a weak reaction of employment (due to the presence of adjustment costs), whereas for large changes there is a strong reaction.

As a novel feature, we estimate the model allowing for a possible change in the value of the switching parameter after the application of major labour market reforms, some of them applied in a context of high uncertainty and very low interest rates.

We use Portuguese monthly industrial data spanning from January 2000 to October 2016. Portugal provides a good case to study this issue since significant measures towards the deregulation of the labour market were recently applied.

The remainder of the paper is organised as follows. Section 2 presents a model of employment adjustment under uncertainty at the firm level and the aggregation procedure up to the macro level. Section 3 describes the main changes in employment protection legislation since the beginning of the euro. Section 4 describes the details of the empirical strategy and the data set. Section 5 presents the estimation results, and Section 6 concludes.

\(^6\) Linear play models, although not standard in the economic literature, are well suited to describe the aggregate dynamics of economic variables that show characteristics of hysteresis (see, e.g., Belke and Göcke, 1999; 2001, Göcke, 2002 and Mota et al, 2012; 2015).
2. **THE MODEL**

2.1. Hysteresis at the Firm Level

Following the standard sunk-costs hysteresis approach to investment (see Dixit 1989; Dixit and Pindyck 1994), and to employment adjustment (see Amable et al., 1993, Cross, 1994 and Belke and Göcke, 2001), we start by describing a non-ideal relay-type hysteresis model for individual firms that implies discontinuous employment adjustment due to the presence of non-convex employment adjustment costs.

Let us assume a competitive market where each price taker active firm, $j, j = 1, \ldots, J$, employs one unit of employment, $n_{j,t}$, at the unit wage cost $w_j$, to produce $y_{j,t} = n_{j,t} = 1$ units of output, which it sells at a unit price $P_t$.\(^7\) If inactive, the firm produces no output and employs zero units of employment. Furthermore, every individual firm must pay a fixed and constant cost in time to enter (hire a worker and to acquire firm specific physical assets), $H_j$, or to leave the market (fire its single worker), $F_j$. We consider a profit maximising problem of the individual firm, with discrete time and an infinite plan horizon. The discount factor is $\delta = \frac{1}{1+i}$, where $i$ is the risk free interest rate.\(^8\)

In this setting, a previously inactive firm will only enter the market if hiring costs are recovered. Hence the entry (hiring) trigger price, $P_{\text{entry},j}$, exceeds the wage, $w_j$, by $\frac{1}{1+i} H_j$. Conversely, a previously active firm will exit the market if losses exceed firing costs. Hence exit (contracting) trigger price, $P_{\text{exit},j}$, is below $w_j$ by $\frac{1}{1+i} F_j$.\(^9\)

Note that the decision to enter the market is akin to the hiring decision, and the decision to exit is akin to the firing decision. This simplification does not restricts the application of the model as we can consider a firm divided into single production units, with every unit represented individually (Belke and Göcke, 1999), or view the firms as potential units of labour with the set of all potential units of labour representing all the jobs that can potentially be created in the economy (Lang and Peretti, 2009).

\(^7\) We are assuming that all firms face a common demand schedule ($P_{j,t} = P_t$) and that the wage is constant over time, but not necessarily across firms ($w_{j,t} = w_j$).

\(^8\) See Göcke (2002) and Mota *et al.* (2012) for a complete description of the model.

\(^9\) See Göcke (2002).
Thus, the employment demand function of firm \(j\), may be represented by the non-ideal relay hysteresis operator (also known as hysteron):

\[
n_{j,t} = R_{p_{\text{exit},j}p_{\text{entry},j}}(t_0, n_{j,t_0}, t)[P_t] = \begin{cases} 
1, & \text{if } n_{j,t-1} = 0 \text{ and } P_t \geq w_j + \frac{i}{i+1}H_j \\
 & \text{or } n_{j,t-1} = 1 \text{ and } P_t > w_j - \frac{i}{i+1}F_j \\
0, & \text{if } n_{j,t-1} = 0 \text{ and } P_t < w_j + \frac{i}{i+1}H_j \\
 & \text{or } n_{j,t-1} = 1 \text{ and } P_t \leq w_j - \frac{i}{i+1}F_j 
\end{cases}
\]  

(1)

Where \(n_{j,t}\) denotes the employment of firm \(j\) in period \(t\), \(P_{\text{exit},j} = w_j - \frac{i}{i+1}F_j\) and \(P_{\text{entry},j} = w_j + \frac{i}{i+1}H_j\). \(P_{\text{exit},j}\) is the threshold value for exit and entry. \(P_t\) \((t \geq t_0)\) is the price level, and \(n_{j,t_0}\) is the initial state that can take the values of 1 or 0. The values of the operator are defined for \(n_{j,t_0} = 0\) if \(P_{t_0} < P_{\text{exit},j}\), for \(n_{j,t_0} = 1\) if \(P_{t_0} > P_{\text{entry},j}\), and both for \(n_{j,t_0} = 0\) and \(n_{j,t_0} = 1\) if \(P_{\text{entry},j} < P_{t_0} < P_{\text{exit},j}\).

The first branch of Equation (1) refers to a situation where firm \(j\) enters or stays active while the second one specifies the situation where firm \(j\) stays inactive or exits. Since \(P_{\text{entry},j}\) is greater than \(P_{\text{exit},j}\) the difference between these two trigger points, \(\frac{i}{i+1}(H_j + F_j)\), creates an employment band of inaction (see Bertola, 1990; Dixit, 1992 and Belke and Göcke, 2001). Each firm requires an aggregate positive demand shock \(P_t > P_{\text{entry},j}\) to enter (hire its workforce), and an aggregate negative demand shock \(P_t < P_{\text{exit},j}\) to exit (fire). Demand shocks within the range \(P_{\text{exit},j} < P_t < P_{\text{entry},j}\) do not cause any change in employment.

This result matches to the observation that employment adjustments are made relatively infrequently and in large amounts, rather than responding more or less continuously to small changes of firms’ product demand (see, e.g., Varejão and Portugal, 2007 and Mota et al., 2012).

Moreover, \(P_t\) is not sufficient to determine the firm’s state of employment. The whole history of \(P_t\) \(\{P_t, \tau \in (0, \tau)\} \subseteq \mathbb{R}\), must be taken into account. Therefore there is no single-valued mapping from \(\mathbb{R}\) into \(\mathbb{R}\) that associates each value of \(n_{j,t}\), with the
current level of $P_t$. Instead the system is characterised by path dependence and ‘multibranch non-linearity’.

In order to illustrate the effect of uncertainty we consider an expected future stochastic one-time shock in the price level that generates revenue uncertainty, in line with Belke and Göcke (1999). As our objective is the aggregation up to the macro level, we model uncertainty in a simple way by assuming a nonrecurring single stochastic change in the output price, which can be either positive, $+\varepsilon$, or negative, $-\varepsilon$. We consider that both realizations of the shock have the same probability of 0.5. In this case, $P_{t+1} = P_t \pm \varepsilon \Rightarrow E(P_{t+1}) = P_t$, and from period $t + 2$ on the firm will decide under certainty again.

With uncertainty, a previously inactive/active firm has three possible strategies: i) stay inactive/active; ii) enter/exit the market; iii) wait and make a decision after the realization of the stochastic shock. If the firm has the possibility of delaying its entry decision, it faces a trade-off: waiting can have a positive value since it brings more information about the evolution of the price level, but it also has the cost of foregoing the profits earned, if entry had occurred. Thus, uncertainty introduces an additional cost of entering (opportunity cost) that is the value of the option to wait (see Dixit, 1991; 1989 and Dixit and Pindyck, 1994).

In this case, the employment demand function of the individual firm can be described as a non-linear hysteretic transformation of a stochastic input, $P_t$:

$$
n_{j,t} = R_{p_{exit,j}}^{v_{exit,j}} R_{p_{entry,j}}^{v_{entry,j}}(t_0, n_{j,t_0})[P_t] =
\begin{cases}
1, & \text{if } n_{j,t-1} = 0 \text{ and } P_t \geq w_j + \frac{i}{i+1} H_j + \frac{1}{1+2i} \varepsilon \text{ [entry]} \\
\text{or } n_{j,t-1} = 1 \text{ and } P_t > w_j - \frac{i}{i+1} F_j \text{ [stay active]} \\
\text{or } n_{j,t-1} = 1 \text{ and } w_j - \frac{i}{i+1} F_j - \frac{1}{1+2i} \varepsilon < P_t \leq w_j - \frac{i}{i+1} F_j \text{ [wait in activity]} \\
0, & \text{if } n_{j,t-1} = 0 \text{ and } P_t < w_j + \frac{i}{i+1} H_j \text{ [stay inactive]} \\
\text{or } n_{j,t-1} = 0 \text{ and } w_j + \frac{i}{i+1} H_j \leq P_t < w_j + \frac{i}{i+1} H_j + \frac{1}{1+2i} \varepsilon \text{ [wait in activity]} \\
\text{or } n_{j,t-1} = 1 \text{ and } P_t < w_j - \frac{i}{i+1} F_j - \frac{1}{1+2i} \varepsilon \text{ [exit]} 
\end{cases}
$$

10 See Belke and Göcke (1999) for more detail.
Combining both triggers under uncertainty, the width of the band of inaction, $BI$, is determined by the interest costs of hiring and firing, and by uncertainty:\textsuperscript{11}

$$BI = \frac{P_{entry,j}^{U} - P_{exit,j}^{U}}{2\epsilon} = \frac{P_{entry,j} - P_{exit,j} + \frac{2\epsilon}{1+2i}}{i+1} = \frac{\epsilon}{i} (H_j + F_j) + \frac{2\epsilon}{1+2i} \quad (3)$$

Where $P_{entry,j}^{U}$ and $P_{exit,j}^{U}$ are the entry and the exit triggers under uncertainty respectively. Thus, uncertainty widens the employment band of inaction. The option value of waiting effect raises the optimal entry threshold, increasing the probability of a firm to stay inactive even if current product demand increases; similarly on the opposite sense, the waiting effect lowers the optimal exit threshold, increasing the probability of a firm staying active when product demand decreases (see Dixit, 1992 and Belke and Göcke, 1999). Therefore, hysteresis effects are amplified.

The width of the employment band of inaction, $BI$, described in equation (3) depends positively on the fixed adjustment costs, $\frac{\partial BI}{\partial (H_j + F_j)} = \frac{i}{i+1} > 0$ (with $i > 0$), and on the degree of uncertainty, $\frac{\partial BI}{\partial \epsilon} = \frac{2}{1+2i} > 0$. However, the effect of interest rates change on the band of inaction depends on how the level of uncertainty compares with the magnitude of the fixed hiring and firing costs.

Furthermore, the lower the interest rate the higher the importance of uncertainty for the width of the band of inaction, and the lower the importance of the fixed adjustment costs: when $i = 0$, $BI = 2\epsilon$; when $i \to \infty$, $BI \to (H_j + F_j)$.

In fact, in a low interest rate environment, as it is the present situation in many advanced economies, fixed employment adjustment costs are not as relevant as uncertainty to generate hysteresis effects. Indeed, hysteresis can be quite strong even for small values of the fixed hiring and firing costs (see Dixit, 1989).

2.2. Hysteresis at the Aggregate level

We now consider an aggregation approach base on the Preisach model of hysteresis.\textsuperscript{12}

\textsuperscript{11} See Belke and Göcke (1999) for more detail.
\textsuperscript{12} The Preisach model is a procedure for aggregating non-ideal relays of the type described by Equation (2) developed in general terms by Krasnosel’skii and Pokrovskii (1989) and Mayergoyz (1986), and introduced to economics by Amable et al. (1993) and Cross (1994).
The aggregate economy is represented as a set of the potential number of active heterogeneous \( J \) firms (or units of labour), \( J \in T \), each one acting according to Equation (2), whereby entry and exit trigger prices are assumed to be firm specific. The set \( T \) (named the Preisach triangle) is a two-dimensional half-plan:

\[
T = \{(p_{exit,j}^U, p_{entry,j}^U): p_{entry,j}^U \geq p_{exit,j}^U \text{ and } p_{exit,j}^U \geq p_{exit,min}^U \\
\text{ and } p_{entry,j}^U \leq p_{entry,max}^U \}
\]

Where \( p_{exit,min}^U \) is the exiting threshold for the less demanding firm, and \( p_{entry,max}^U \) is the entering threshold of the most demanding firm. Given that the level of employment of every active firm is one, the aggregate employment at time \( t \), \( N_t \), is fully described by sum of the active firms in the market:

\[
N_t = N_t[t_0, N_{t_0}] = \int_T u(p_{exit,j}^U, p_{entry,j}^U) \mathcal{R}_{p_{exit,j}^U, p_{entry,j}^U}[t_0, n_j, t_0] P_t dP_{exit,j}^U dP_{entry,j}^U
\]

where \( u(p_{exit,j}^U, p_{entry,j}^U) \) is the weight (density) function of the individual firms in \( T \) (also known as the Preisach Function), such that the pairs \((p_{exit,j}^U, p_{entry,j}^U)\) are distributed with some integral density:

\[
\int_T g(p_{exit,j}^U, p_{entry,j}^U) dP_{exit,j}^U dP_{entry,j}^U = 1
\]

and \( \mathcal{R}_{p_{exit,j}^U, p_{entry,j}^U}[t_0, n_j, t_0] \) represents the employment demand of individual firms described by Equation (2).

The main result is that for cycles of variation in aggregate demand there is a continuous macroeconomic hysteresis loop for aggregate employment (see Figure 2 in

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13 For a complete explanation of the Preisach model of hysteresis see Mayergoyz (2003) and Mota and Vasconcelos (2012).

14 Empirical evidence on firms entry and exit triggers is difficult to obtain because of issues of commercial confidence. In the empirical work is common to assume that \( p_{exit,min}^U \) is equal to the minimum of the input series, and that \( p_{entry,max}^U \) is equal to the maximum of the input series (see, e.g., Cross et al., 2005 and Lang and Peretti, 2009). We also assume a uniform weight function. In fact, the results are not very sensitive to the specification of the Preisach function, a property that is usually referred to as the statistical stability of the Preisach Model (see Cross et al., 2005).

15 Note that The distance of the relays, \( \mathcal{R}_{p_{exit,j}^U, p_{entry,j}^U} \), from the origin in \( T \) is determined by the variable cost, \( w_j \), and the orthogonal distance of the relays from the 45°-line is a positive function of the non-convex employment adjustment costs, and uncertainty.
Mota and Vasconcelos, 2012, p. 99). Differently from the employment dynamics at the firm level,\textsuperscript{16} at the aggregate level every reversal of the direction of $P_t$ leads to a structural break in the employment-aggregate demand relationship represented by a continuous transition between different curves (branches). After a reversal of the path followed by $N_t$ there is a weak response of employment that will evolve into a strong one, once the entry or exit thresholds of many firms are passed. Whenever direction of the aggregate demand changes, a continuous branch-to-branch transition occurs, implying that transitory changes in $P_t$ can lead to permanent variations in $N_t$.

3. THE DYNAMICS OF EMPLOYMENT PROTECTION LEGISLATION AND UNCERTAINTY

Portuguese labour law, traditionally based on legal provisions and on collective agreements between the employers’ associations and trade unions, was until recently placed among the most rigid across OECD countries. This is particularly the case of the protection of regular employment.\textsuperscript{17}

In the time span of our data set, and especially in the aftermath of the recent financial and economic crisis, successive reforms of the labour market have been applied.\textsuperscript{18}

A first major labour market reform was undertaken in 2003 with the first Labour Code approved by the Law no. 99/2003, of August 2003.\textsuperscript{19} The Labour Code introduced significant changes to labour regulation and collective bargaining. In particularly, it eliminated the principle that collective agreements could only establish more favourable conditions than those set by the general law, and more favourable than what was previously agreed. These reforms created, also, the possibility of expiration, after a certain period of time, of collective agreements that had not been renegotiated. This led to an important fall in collective bargaining.\textsuperscript{20} The 2003 new Labour Code also introduced

\textsuperscript{16} At the firm level there are only two branches, and the transition between those branches only occurs when $P_t$ increases above $P^H_{\text{entry, } j}$ or decreases below $P^H_{\text{exit, } j}$.

\textsuperscript{17} We are relying in the Employment Protection Legislation for Regular Contracts Indicator (version 2) built by OECD.

\textsuperscript{18} See Ramalho (2013) and Távora and González (2014) for a comprehensive analysis of labour markets reforms in Portugal in the last two decades, with particular incidence in the period after the recent financial crisis.

\textsuperscript{19} And regulated by the Law no. 35/2004 of 29 July 2004.

\textsuperscript{20} Note, however, that the 2003 Labour Code was revised by the Law no. 9/2006, of March 2006, and later by the new Labour Code of 2009 (Law no. 7/2009, of 12 February 2009) that partially reinstated the former provisions, allowing collective agreements to be extended under certain conditions and for certain periods of time.
more working time flexibility, and loosened the rules for the use of fixed-term contracts and temporary employment agencies.

After the crisis, a first major reform of the Labour Code was implemented in 2009. Concerning employment protection, the main changes were: i) the simplification of the administrative procedures associated to individual and collective dismissals; ii) the reduction of the notice period for the short-duration workers (and the increase in this notice period for the long-duration workers); iii) the decrease of the compensation paid to workers and the right to reinstatement whenever the dismissal is judged irregular for processual reasons; iv) the decrease of the period that workers have to denounce the dismissal from one year to 60 days.

Other major reforms were implemented in the context of the conditionality measures associated to the financial assistant programme signed with IMF/ECB/European Commission in 2011. The reforms covered four areas: i) employment protection; ii) working time arrangements; iii) wage setting and collective bargaining; and iv) unemployment benefits.

Regarding employment protection legislation of regular employment, the main revisions of the Labour Code introduced in 14 of October 2011 reduce the severance pay of non-fixed term contracts from 30 to 20 days salary for each year of service, with an upper limit of 12 months, for new contracts, and creates an employer fund to finance these payments.

The revised Code reduces even further severance payment to 12 days per year of service in the case of collective dismissals, and creates a transitory regime for reducing the severance pay in the case of individual dismissals.

About temporary contracts, an extraordinary regime of two renewals (which may not exceed 18 months) for fixed-term employment contracts that reach their maximum duration by 30 June 2013 was introduced.

The revision of the Labour Code also turned easier the definition of fair dismissals. Under the new law, individual dismissals based on unsuitability are possible through the extinction of the work position (as before), but now without the justification based on the

22 See Portugal: Memorandum of understanding on Specific Economic Policy Conditionality, p. 19.
23 Law no. 53/2011.
24 Law no. 23/2012.
25 Law no. 23/2012.
introduction of new technology. Moreover, the employer, under the new law, does not need to follow a tenure rule to dismiss based on the extinction of the working post.

The labour market reforms mentioned above are reflected in the dynamics of the employment protection legislation index for regular contracts built by OECD (EPRC V2) and displayed in Figure 1. There is a decrease of this index in 2004 reflecting the reforms introduced by the Labour code of 2003. After the crisis, measures towards the relaxation of the protection against individual dismissals and the reduction of severance pay are reflected in a decrease of the index of employment protection for regular contracts in four steps – the first in 2008, the second in 2010, the third in 2012, and the last one in 2013 (see Figure 1).

Nonetheless, at the same time uncertainty increased substantially. In Figure 1, we display, together with the employment protection index, the Sovereign Systemic Stress Composite Indicator for Portugal (CISS), which is an indicator of the contemporaneous instability or “stress” in the financial system. The CISS indicator that emphasises the systemic nature of existing stress in the financial system increased markedly after August 2007, and especially after the failure of Lehman Brothers in 2008.26

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26 See, for more detail, Holló et al. (2012).
The index of employment protection of regular contracts is the weighted sum of sub-indicators concerning the regulations for individual dismissals and additional provisions for collective dismissals. The indicators of employment protection take values between 0 and 6. Higher values indicate more rigid regulation. The Sovereign Systemic Stress Composite Indicator comprises five segments of the financial system: i) the bank sector; ii) the non-bank financial institutions sector; iii) money markets; iv) securities markets; and v) foreign exchange markets. The current level of stress in each of these segments is measured on the basis of three indicators capturing agents’ uncertainty, investor disagreement and information asymmetries. Higher values indicate more stress.

The recent contrasting dynamics of employment protection legislation and uncertainty have opposite effects on the employment band of inaction, and consequently on the flexibility of the labour market. Thus, which effect predominates is ultimately an empirical question.

4. **EMPIRICAL STRATEGY AND DATA**

4.1. Empirical Implementation

In the empirical work, we apply the linear play model of hysteresis that can be viewed as a piecewise-linear approximation of the Preisach hysteresis loop, where the slope of the linear functions change at extrema (see Figure 2).\textsuperscript{27}

\[\text{See Kranosel’skii and Pokrovskii (1989) and Visitin (1994) for a general description of the model. See also Göcke (2001) and Mota et al. (2012; 2015), for an application to the dynamics of aggregate employment.}\]
The Linear Play Operator, \( Pr \), is characterised by horizontal reversible inner branches of the same length (the play segment) and upward sloping linear limiting branches (the spurt segments) that form counter-clockwise oriented loops as shown in Figure 2. The slope of a linear section changes when a local extremum of \( P_t \) is reached – every change in the direction of \( P_t \) implies that the system starts with traversing a *play interval*, and only after this interval is passed, a strong reaction results.

There are similarities between concepts of employment band of inaction at the firm level and the play interval, *PLAY*, that is its counterpart at the aggregate level.

In this model the memory effect is captured by the difference in slopes between two adjacent lines (the play line and the spurt lines - see Figure 2). If \( \beta_1 \) denotes the slope of the flatter line - the play, then \( \beta_1 + \beta_2 \) is the slope of the steeper one - the spurt, and \( \beta_2 \) is the memory or remanence parameter (Göcke, 2001):

\[
\frac{dN_t}{dN_t} = \beta_1 + D \beta_2, \text{ with } D = \begin{cases} 0, & \text{on the play lines} \\ 1, & \text{on the spurt lines} \end{cases}
\]

As the slope of limiting branches is fixed, the play operator is characterised by a single parameter - its input threshold value or the magnitude of the play segment. The value of this parameter increases with the magnitude of employment non-convex adjustment costs and uncertainty. The initial value of the operator state, the pair \( \left( P_{t_0}, P_{t_0} \right) \), together with the future values of the input, \( P_t \), determine the value of the employment.

This model has two testable implications. Firstly, after the reversal of the direction of the price level we expect to observe a weak reaction of the employment to changes in \( P_t \). Secondly, a switch to a strong reaction of aggregate employment to changes in price (i.e., a structural break) do occur for large changes in \( P_t \).

The linearized play dynamics is illustrated in Figure 2. Assume \( P_t = P_{t_0} \) (the system starts at point A). An increase in the price level up to \( P_{t_1} \) causes, initially, a weak response of the aggregate employment (along a *play line*) until a threshold value \( P_B \) is passed (the system is at point B). This is due to the existence of non-convex costs of employment adjustment and uncertainty. When the price change becomes sufficiently large (i.e., when the threshold value \( P_B \) is surpassed), the employment responds strongly, increasing along an *upward spurt line* (the level of employment follows the sequence

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28 The term is used due to its analogy to play in mechanics.
ABC). A subsequent return of the price to $P_{t_0}$ leads again to a weak response of the aggregate employment. The transitory positive shock leaves a permanent effect on the level of aggregate employment (remanence). Thus, to restore the original state of equilibrium it is not enough to revert the input variable to the original value. If the price continues to decrease to $P_{t_3}$, employment continues to decrease weakly until reaching a threshold at $P_B$ (the system is at point D). After this threshold value is surpassed, employment starts to decrease markedly along the downward spurt line (the level of employment follows the sequence CDE). A further reversion of the aggregate demand to $P_{t_3}$ leads again to a weak employment reaction along a play line, which is vertically shifted downward (the level of employment follows the sequence EF).

To illustrate the effect of uncertainty, consider that when aggregate demand starts to decrease from $P_{t_1}$ there is an increase in uncertainty. In this case, the downward spurt line is displaced to the left, and a reduction of aggregate demand to $P_{t_2}$ has only a weak impact on the level of employment due to the increase of the play interval. The system ends up at point D'.

**Figure 2: Play Hysteresis Loop**

29. This can be the result of an exogenous shock or endogenously caused by the decrease of demand. In fact, of a lack of aggregate demand and increasing unemployment can be viewed as the result of the malfunctioning of the economy and thus affects business confidence.

30. A similar effect is caused by an increase of the flexibility of adjusting the number of hours of work per employee (see Mota et al. 2012).
The linear play model is implemented empirically via a linear switching employment equation with an unknown splitting factor - the PLAY – to capture the non-linear play hysteresis effects.

Following Belke and Göcke (2001), and Mota et al. (2015), we describe the change in aggregate employment, $N_t$, induced by a change in the price, $P_t$, as divided between a weak reaction along a play line and a strong reaction along a spurt line, when $P_t$ changes sufficiently, and we estimate the following equation:\(^{31}\)

$$N_t = \beta_0 + \beta_1 Y_t + \beta_2 SPURT_t + \beta_3 W_t + \beta_4 t + \epsilon_t$$ \hspace{1cm} (7)

Where $SPURT_t$ is a hysteresis transformed input variable results from the $P_t$ series with all small changes ($\Delta P_t < PLAY_t$) filtered out. In this framework $\beta_1$ gives the reaction of aggregate employment, $N_t$, along the play line, while $\beta_2$ is the difference of the reaction of $N_t$ along the spurt line and the play line caused by price changes.

In the estimation we use real production in industry, $Y_t$, as a proxy for the aggregate demand represented in the theoretical model by $P_t$. We also include in the equation as non-hysteretic regressors, the real wage, $W_t$, and a time trend, $t$, due to the secular decline of employment in industry caused by technological change (all the variables are in logarithms).\(^{32}\)

The strategy is to test whether the non-linear model, which includes hysteresis, provides better results than the linear one, by looking to the significance of the transformed real production variable. The presence of hysteresis is corroborated if $\beta_2$ is significantly greater than zero.

Following the algorithm described in Belke and Göcke (2001) and Mota et al. (2015), a MATLAB program to generate the hysteresis transformed real production variable, $SPURT_t$, was developed and implemented, which in turn requires the estimation of the width of the PLAY interval – the employment band of inaction at the macro level. The innovation here is that the program allows for different splitting factors (different PLAY values) caused by the application of major reforms towards the increase of the flexibility of the Portuguese labour market.

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\(^{31}\) The details of the empirical implementation of the play model can be found in Belke and Göcke (2001) and in Mota et al. (2012, 2015).

\(^{32}\) $\epsilon_t$ is a random disturbance term.
In line with the changes of the employment protection indicator displayed in Figure 1, which result from the implementation of labour reforms, the algorithm allows for structural breaks in the splitting factor of the employment equation in 2008:01; 2010:01 and 2012:01. This originates four possibly different switching parameters. The algorithm estimates the $R^2$ of the employment equation associated to each combination of those fours play values. Finally, the program selects the combination that maximises the $R^2$ of the employment equation.

4.2. Data

In the estimation we use industrial monthly data from the EUROSTAT – General Statistics, Industry Commerce and Services. Aggregate employment, $N_t$, is measured by the index of the number of employees in industry. We use as the proxy of aggregate demand the real production in industry adjusted by the number of working days, $Y_t$. Real wages, $W_t$, are measured by the index of gross wages in industry deflated by the general consumer price index. All the series are seasonally adjusted. The data covers the period from January 2000 to October 2016.

5. Estimation Results

We start by analysing the stationarity of the series by applying the augmented Dickey-Fuller units root test to the series in levels and to their first differences (see Table 1). For all the variables in levels the augmented Dickey-Fuller test statistic is larger than the 5% critical value (-2.875) indicating that we do not reject the hypothesis of the existence of a unit root. For the first difference of the series we reject the hypothesis of the existence of a unit root (in this case, the test statistic is smaller than the 5% critical value for all the variables). Thus, the variables included in the regression are integrated of order one, I(1).
Table 1: Augmented Dickey-Fuller Test Statistics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Level</th>
<th>1st Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>$N_t$</td>
<td>-2.242</td>
<td>-3.989</td>
</tr>
<tr>
<td>$Y_t$</td>
<td>-1.070</td>
<td>-10.035</td>
</tr>
<tr>
<td>$W_t$</td>
<td>-2.006</td>
<td>-3.686</td>
</tr>
<tr>
<td>$SPURT_t$</td>
<td>-1.020</td>
<td>-8.320</td>
</tr>
</tbody>
</table>

(5% critical value: -2.875)

To verify the existence of a true equilibrium relationship between the variables, we test for cointegration using the Johansen Test Procedure.\(^{33}\) Based on this test, we do not reject the hypothesis of a single cointegrating vector relating the variables. In the two models considered (the standard employment equation and the switching employment equation), the trace test statistic is greater than the 5 per cent critical value (see Table 2).

However, because the series are non-stationary, to obtain asymptotically unbiased estimates of the parameters, we estimate the cointegrating regression (Equation 7) using Fully Modified Least Squares (FM-OLS), which is an asymptotically efficient estimator of long-run economic relationships, and leads to conventional chi-squared criteria for inferential purposes with respect to coefficients (fully modified Wald tests).

The method modifies least squares with semiparametric corrections that account for serial correlation effects and for endogeneity in the regressors that result from the existence of cointegrating relationships (see Phillips and Hansen, 1990, and Phillips, 1995).

Through the process of four-dimensional grid search described above, the estimated values obtained for the play are 0.12 for the period until 2007:12, 0.04 for the period between 2008:01 and 2009:12, 0.2 for the period between 2010:01 and 2011:12, and 0.20 for the period after 2012:01 (see Figure 3 b) and Table 2).

These results are consistent with the presence of an employment band of inaction that depends positively on the magnitude of employment adjustment costs, but which is also found to be wider when uncertainty is high. Thus, the measures towards the

\(^{33}\) We apply the Trace Test performed with four lags in the VAR representation and with an intercept and time trend in the cointegrating equation. We report the results of testing the null hypothesis of no cointegration ($r = 0$) against the existence of at least one cointegrating vector ($r$).
deregulation of the labour market applied after the crises decreased the employment band of inaction except in the period where uncertainty is very high. In this case the effect of uncertainty more than compensates the reduction of the employment adjustment costs.

The original aggregate employment series is plotted in Figure 3 \(a\) and the industrial production series along with its transformation according to the model of hysteresis (the spurt variable) are displayed in Figure 3 \(c\).
Figure 3: Original Series, the Spurt and the Play Variables

a) Employment ($N_t$)

b) Band of Inaction ($PLAY_t$)

c) Industrial Production ($Y_t$) and the Hysteresis Transformed Variable ($SPURT_t$)
In Table 2 we present the results of the estimation of the switching employment equation (7). Table 2 shows that using fully-modified Wald tests, the coefficient that captures the reaction along the play, $\beta_1$, is not significantly different from zero, while the coefficient that captures the difference of the reaction along the spurt and the play, $\beta_2$, is 0.747 (significant at 1%). This shows that the reaction along the play is weaker (non-existent in this case) than the reaction along the spurt, implying that employment change requires sufficiently large demand shocks.

**Table 2: Employment Switching Equation Estimation Results**

<table>
<thead>
<tr>
<th>Variables</th>
<th>Estimates</th>
</tr>
</thead>
<tbody>
<tr>
<td>$PLAY_t$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Until 2007:12: 0.12</td>
</tr>
<tr>
<td></td>
<td>- From 2008:01 to 2009:12: 0.04</td>
</tr>
<tr>
<td></td>
<td>- From 2010:01 to 2011:12: 0.20</td>
</tr>
<tr>
<td></td>
<td>- After 2012:01: 0.07</td>
</tr>
<tr>
<td>$C$</td>
<td>4.751***</td>
</tr>
<tr>
<td></td>
<td>(6.886)</td>
</tr>
<tr>
<td>$Y_t$</td>
<td>0.133</td>
</tr>
<tr>
<td></td>
<td>(1.415)</td>
</tr>
<tr>
<td>$SPURT_t$</td>
<td>0.747***</td>
</tr>
<tr>
<td></td>
<td>(5.092)</td>
</tr>
<tr>
<td>$W_t$</td>
<td>-0.119</td>
</tr>
<tr>
<td></td>
<td>(-0.869)</td>
</tr>
<tr>
<td>$t$</td>
<td>-0.002***</td>
</tr>
<tr>
<td></td>
<td>(-12.456)</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.964</td>
</tr>
<tr>
<td>Trace Test Stat</td>
<td>82.786</td>
</tr>
<tr>
<td></td>
<td>(Critical Value: 63.876)</td>
</tr>
</tbody>
</table>

$t$-statistics are in parentheses.
***, **, * Significant at 1, 5, and 10 per cent respectively

6. **CONCLUSION**

The theoretical model of hysteresis described in this paper, predicts that in a low interest rate environment, fixed employment adjustment costs are not as relevant as uncertainty in generating hysterical effects. Consequently, hysteresis can be quite strong
even for small values of the fixed hiring and firing costs that may result from the measures to increase the flexibility of the labour market.

At the same time, we document the presence of a contrasting dynamics of employment protection legislation that is a source of adjustment costs and uncertainty after the emergence of the recent financial crisis, in a context a general decrease of interest rates.

We have found that measures towards the deregulation of the labour market reduced the hysteresis effects in the dynamics of aggregate Portuguese employment except in the period where uncertainty increased substantially.

Therefore, when interest rates are low, hysteresis can be quite strong even if the government applies measures towards the deregulation of the labour market, due to uncertainty. Besides, uncertainty can even result from attempts to reduce non-convex adjustment costs, or from austerity measures that depress the economy in the short-run (see Dosi et al., 1917)

These results have important policy implications. Supporting Blanchard (2009): “So what are policymakers to do? First and foremost, reduce uncertainty.”

REFERENCES


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