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Abstract

In this paper we test the persistence of involuntary part-time employment, making use of large historical series for the US and UK. To evaluate the robustness of our results a comprehensive macro-econometric approach, a battery of panel and time series unit root/stationarity tests were performed, also allowing for flexible specifications as fractional integration and structural breaks in the series. Our results confirm that underemployment in both countries has not returned to its pre-recession levels providing robust evidence about the existence of a long memory process in the involuntary part-time employment and a structural break in the mean of the series in the Great Recession surroundings. Importantly, the two phenomena, identified by a sudden deterministic break in the levels of the models employed and by a unit root process of order one or higher, coexist an interact together.

- **Keywords:** Involuntary part-time, underemployment, long-memory hysteresis, persistence, structural breaks.
- **JEL:** J21,E24,C22.

1. Introduction

During the Great Recession we assisted to an unprecedented increase in involuntary part-time employment that seemed to persist at high levels years after, being documented in many technical reports (e.g. Cajner et al. (2014); Valletta and Bengali (2013); Valletta and der List (2015); Walling and Clancy (2010)). In contrast to unemployment, which turned back relatively fast to pre-recessionary levels, the involuntary part-time work took several years to revert in the US and the UK (if so) (Kudlyak et al. (2019); Bell and Blanchflower (2011), Bell and Blanchflower (2013), Bell and Blanchflower (2018)). Nevertheless, after the financial crisis, this type of underemployment[1] have played a major role in most developed economies, bringing about the necessity of taking into account a wider perspective of labor slack even in situations seemingly or very close to full employment (Bell and Blanchflower (2021)). May that as it may, any of these situations entail a waste of labor resources, leading to inefficiencies in the labor market besides the potentially harmful consequences for the workers' welfare.

Therefore, persistent levels of involuntary part-time employment (IPT hereafter) might be hiding that proportion of labor slack that is not captured by common unemployment measures, i.e., the slack in the intensive margin. Consequently, since they have similar policy implications, we consider that IPT behavior should be further analyzed as unemployment often is. In this sense, the research question this study assesses is whether the IPT responses to shocks are indeed of a persistent nature, i.e. whether a shock may have long-lasting effects in IPT levels.

We focus on two specific cases, the US and UK, making use of large historical series of involuntary part-time, compiled by Borowczyk-Martins and Lalé (2020) from the monthly information contained in the US Current Population Survey and taken from the Office for National Statistics in the case of the UK.

These countries are suitable case studies at least for the following reasons: i) because, although their unemployment rates have returned to pre-recession levels in several countries, underemployment has not (Bell and Blanchflower (2021)); ii) in these countries unemployment is at historic low records that are compatible with high and persistent rates of underemployment and low wage growth rates, in a context marked by the development of the non-standard forms of employment, including different forms of so called 'gig economy' working, and a loss of bargaining power for workers.

Although the progressive loss of bargaining power by workers due to the diminishing influence of unions, the emergence of the informal economy and the gig sector were inertial from before the Great Recession, the latter crisis only accelerated these structural changes. The intensification of this new relationship between job openings and underemployment must be at the root of the labour shortage and new phenomena such as the Great Resignation or the Great Reshuffle. At this point, the main question is whether it is just a temporary mismatch or a persistent situation, possibly accelerated by the Great Recession.

One can hypothesize that the labour shortage cannot be considered as a general phenomenon, as it does not affect certain groups of highly skilled professionals or activities. However, it seems reasonable to think that it is associated with the structural changes that have occurred in certain types of jobs, which are now developed under different labour relations, based on tasks or projects. It is precisely in the latter type of jobs, those associated with employment that does not require special skills and in which labour is abundant and on-demand, that the chronification of underemployment and the persistence of its effects may be behind.

As is standard in empirical literature, we choose to equate hysteresis with the presence of a unit root in the time series. Therefore, we test the long memory structure of IPT through a battery of panel and time series unit root and stationarity tests, including the possibility of fractional integration and

[1] This term is often used to refer to any employment status that, in contrast to unemployment, involves working, albeit not at a full capacity. This implies that an unmet need or, in other words, an unsatisfied demand of work (e.g. mismatch in qualification, skills, hours of work, etc.). Throughout this document, it will be used interchangeably with 'involuntary part-time'.

structural breaks in the series, to present a robust and comprehensive analysis of the IPT's long-run properties. Our main contribution confirms the persistence of the involuntary part-time phenomenon in the US and UK and endogenously detects mean breakpoints surrounding the Great Recession. These results support the initial hypothesis of hysteresis in involuntary part-time employment.

By considering a null hypothesis of unit root coexisting together with a break in the level of the analysed series, our findings show that the hysteresis hypothesis would interact together with a sudden, exogenous change in the data generating process of the series. Following the literature on unit root testing with instabilities, we model such evidence as a deterministic change in both the null hypothesis of hysteresis and its stationary alternative, confirming that the long memory process embodied in the series holds even when a discrete change is taken into account. This ultimately points at the role of the crisis as a mean of transmission of permanent changes in the level of IPT rather than one of the causes of the persistence of the series.

The rest of the paper is organized as follows: section 2 includes a contextualization into related literature; section 3 presents the concepts and data we will be analysing together with some stylized facts; section 4 comprises a technical explanation of the econometric tests and methods we use; section 5 shows and explains the results; and finally, the conclusion and discussion are dropped into section 6.

2. Related literature

This paper contributes to the involuntary part-time employment literature and also relates to the empirical literature on the persistence of labor market series. Overall, the literature on involuntary part-time employment has generally focused on seeking the determinants that can explain its behaviour and existence through both micro and macro approaches. However, its macro-dynamics have often been ignored or not fully explored. On the other hand, while empirical literature on persistence in labour market series is abundant –particularly for unemployment–, we could not find any previous empirical work on persistence in IPT. The following paragraphs include an overview of these literature strands.

Involuntary part-time employment Specific literature on IPT dynamics is yet scarce regarding other labor market measurements. Previous studies seem to agree on the counter cyclical pattern of IPT. However, structural and market determinants are less clear. In this regard, shifts in industry shares to service-dominated economies and the growth of on-demand services have been remarked as structural drivers of IPT in recent years (Leppel and Clain (1988); Valletta et al. (2020); Bell and Blanchflower (2021); Henley (2021)), together with technological change and automation (van Doorn and van Vliet (2022)). Nonetheless, the growth in female labour participation and the shifting preferences from part-time to full-time work –especially women's– may have also played a role in the past (Cohen and Stier (2006); Euwals and Hogerbrugge (2006)). Recently, Kang et al. (2020) have relied on exogenous increases of part-time labour supply to explain the persistently high level of part-time employment –either voluntary or not– after the Great Recession. Although all these factors may explain the hysteresis of IPT, this phenomenon has not yet been proved so far. This is where our contribution to this strand of the literature ultimately lies. Borowczyk-Martins and Lalé (2019, 2020) further explored part-time and IPT dynamics in the US and the UK through labour aggregates of stocks and flows, finding that, in contrast to unemployment –which is driven by job creation and destruction–, IPT mainly reflects changes within firm's labour utilization. Nonetheless, its hysteresis remains yet unexplored. Lastly, we need to mention that some micro-level studies characterized IPT workers with cross-country data and country-specific data, generally finding low qualified workers, women, youngsters and elders to be more likely to work involuntary part time jobs (Cam (2012); Denia and Guillú (2019); Green and Livanos (2017); Kauhanen (2008); Pech et al. (2021)).

Persistence in labor market series The empirical study of persistence in labour market series originally comes from the classical and well-known unemployment hysteresis hypothesis in economic theory. In contrast with Friedman‘s unemployment natural rate hypothesis that affirmed the existence of a post-recessionary mean-reverting tendency in unemployment rates (Friedman (1968); Phelps (1967)), the unemployment hysteresis hypothesis argues that recessions may have long-lasting effects on unemployment rates (Blanchard and Summers (1986)).

So far, an extensive list of empirical papers have addressed this specific question following different standard macro-econometric approaches: from univariate linear unit root tests in the 90s (Brunello (1990); Mitchell (1993); Neudorfer et al. (1990); Røed (1996)), to panel integration methods (Bolat et al. (2014); Camarero et al. (2006); Camarero and Tamarit (2004); León-Ledesma (2002); Smyth (2003); Song and Wu (1998)), and finally non-linear/structural break extensions to classical unit root testing (Camarero et al. (2005); Chang (2011); Furuoka (2014); Lee et al. (2010, 2009)). We can also mention fractional integration methods for analysing unemployment (Caporale and Gil-Alana (2007, 2008); Caporale et al. (2022); Cuestas and Gil-Alana (2011)). These empirical methods to test persistence have also been extended and applied to other labour market topics as self-employment (Congregado et al. (2012); Gil-Alana and Payne (2015); Lopez-Perez et al. (2020)).

To the best of our knowledge, there is no empirical evidence for the involuntary part-time employment long-run dynamics in this regard. Therefore, this paper contributes to filling this gap, testing the persistence of the involuntary part-time employment by using canonical methods previously applied in this empirical literature for other labour market series. Our contribution in time series studies related to the topic is thus twofold: on one hand, we add to the parallel literature on unemployment and its natural level in a pair of countries with a large record of labour and unemployment related studies by exploiting long and high-frequency series of IPT; on the other hand, we present and follow a simple algorithm of analysis which allows us to evaluate the hysteresis phenomenon at a progressively less aggregated and more specification-dependent level.

3. Data and stylized facts

Typically, part-time employment has been classified in voluntary and involuntary. While the former refers to a desired situation in which workers are refusing to work more hours for any non-economic reason (e.g., childcare, education, preferences, etc.), the IPT may be revealing frictions and slack in the labour market, assessing somehow the labour under-utilization in the intensive margin. An operational and widely used definition to identify IPT is to refer to part-time workers - typically those who work less than 35 hours a week - who (i) may usually work full or part-time but are working fewer hours than usual because of economic slack or (ii) those who work part-time because they cannot find full-time work. This definition of IPT is commonly used by institutions such as the OECD and the US Bureau of Labour Statistics (BLS).

The data on involuntary part-time employment in the US has been sourced from the work of Borowczyk-Martins and Lalé (2020), who constructed a large monthly series of IPT based on the US Current Population Survey. The data range from 1976m1 to 2019m12 and is displayed in figure 1. The UK data instead was retrieved from the UK Office for National Statistics. We had thus access to monthly series from 1992m4 to 2022m1. The data is displayed in figure 2. In both countries, we will be conducting an analogous analysis, using IPT in thousands of people and IPT rate over total employment to consider an alternative standardized measure of IPT.

A first glimpse at the data reveals the counter cyclical pattern of the IPT and its rate that was previously suggested in the literature, similar for both countries. The data also highlights the above-mentioned unprecedented increase in IPT during the Great Recession, reaching around a 5% of the employed in its peak for both cases. Such behavior appears to suggest the post-recessionary persistent patterns we aim to test.

Figure 1: Involuntary part-time employment in the US, seasonally adjusted.
Source: Borowczyk-Martins and Lalé (2020), based on CPS.

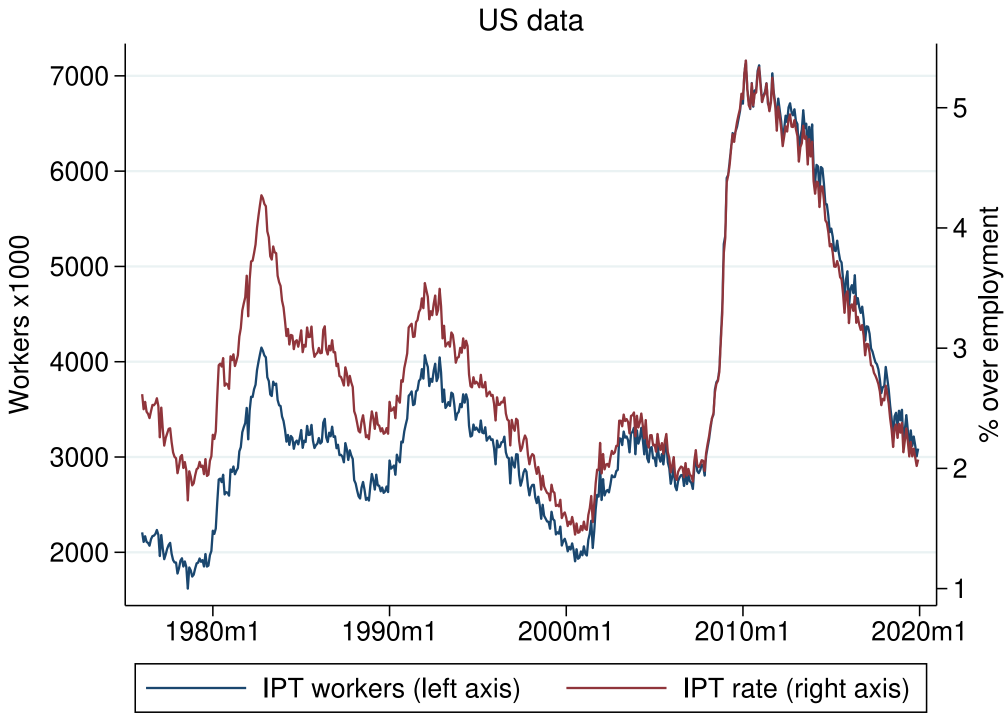
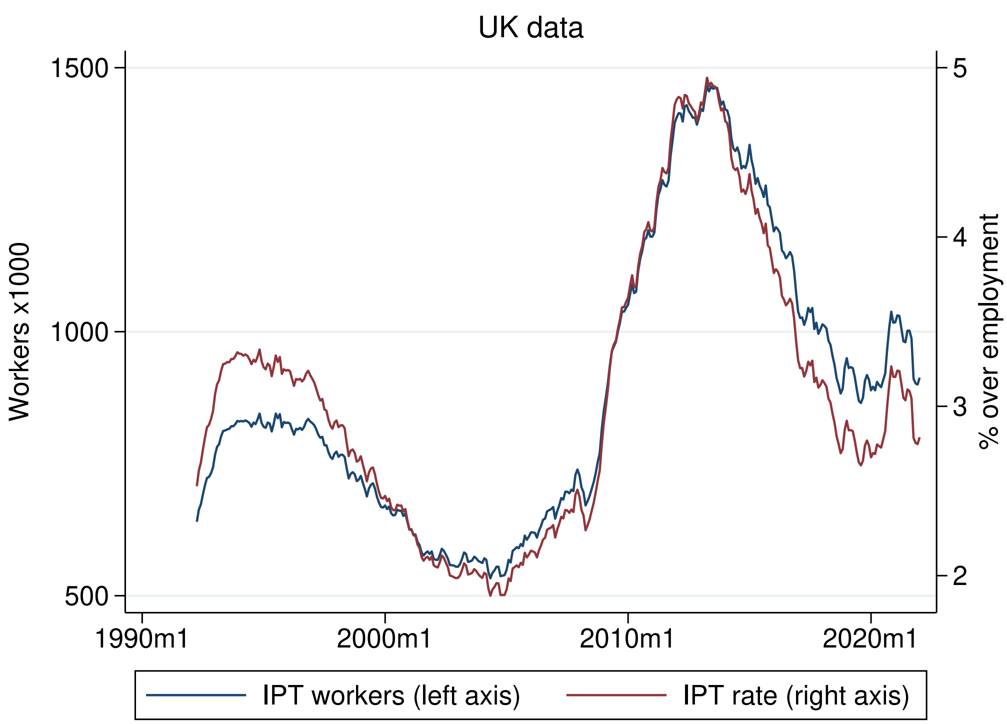


Figure 2: Involuntary part-time employment in the UK, seasonally adjusted.
Source: UK Office for National Statistics.



4. Empirical approach

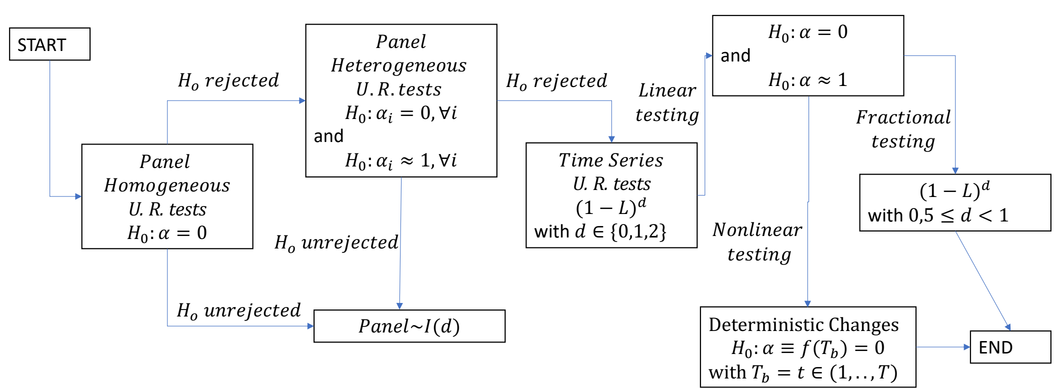
Our analysis follows an algorithm aimed at analyzing the time series properties of the data both at the panel and at the national level. We initially test for the presence of an homogeneous unit root panel. Upon rejection of the null hypothesis, we move to heterogeneous testing, allowing for the autoregressive coefficients in our test equations to be independently estimated at the cross sectional level. In such second step, the heterogeneous stationary alternative hypothesis is compared to a heterogeneous non-stationary alternative hypothesis in an auxiliary test.

If, by any chance, the null of homogeneous non-stationarity is rejected, we then resort to linear time series testing. Following the canonical literature approach, we compare the results of a linear unit root test equation together with the results of a stationarity test to gather some decisive evidence on the order of integration of each series.

To address the potential for a level break in the alternative hypothesis and to account for the realistic possibility of a deterministic break in both the null and alternative hypotheses, we conducted a battery of tests capable of capturing the interaction between a non-stationary, random walk component and an estimated break. The break date was determined endogenously through recursive estimation within a predetermined regression window. This step would allow us to make inference on both the presence of a unit root and a deterministic break in the data generating process of the series, representing a decisive robustness test aimed at pushing to its limits the rejection rate of the unit root/hysteresis hypothesis.

As a final step, depending on whether the order of integration might differ and range between 2 and 1 across the analyzed countries and series, we add a fractional analysis of the memory processes. This offers additional evidence on the persistence hypothesis as well as a more detailed description of the stochastic properties of the series across time.

The general algorithm of the analysis is explained in the figure below. In the next subsections we will offer a more insightful explanation on the methods employed and how they operate.



4.1. Panel unit root analysis

The persistence analysis contained in this paper exploits a top-down approach to analyze both the order of integration of the involuntary party time series for the US and the UK. In order to gather hints on possible external validity of the hysteresis phenomenon, we initially resort to a panel with an homogeneous stationary alternative, an extension of the Augmented Dickey Fuller test by Levin et al. (2002) (LLC test, hereafter) where, following a quasi-canonical test equation, residual auto-correlation is controlled for with a number of additional lagged differences and eventual cross sectional correlation is (partially) limited by augmenting the model with the time-wise, cross-sectional averages of each of our two panels:

$$\Delta y_{it} = \alpha y_{it-1} + z'_{it}\gamma_i + \sum_{j=1}^{p} \beta_{ij} \Delta y_{it-1} + u_{it} \tag{1}$$

Upon rejection of the null hypothesis of level non-stationarity, the procedure would end, leading us to consider stationarity as a panel-related concept, regardless of any possible differences in the results at the national level. If non-rejection of the null hypothesis of unit root for the level variables happens instead, the procedure continues with a test accounting for a heterogeneous alternative. That would entail that the auto-regressive term for the benchmark equation, $(1-\alpha) = \rho$, is left free to vary across panels, $\rho_i = (1-\alpha_i)$. In such eventuality, two different tests would be required, one with an alternative heterogeneous stationary hypothesis, and one with an alternative heterogeneous unit root hypothesis. In the first scenario, where a unit root null is assumed, the Im et al. (2003) test (IPS test, hereafter) allows us to relax the assumption of a common auto-regressive parameter and allows, as the LLC test, to introduce panel specific components $(z'_{it}\gamma_i)$, such as averages of the cross sections, to account for any unobserved, cross-sectional-related heterogeneity and eventual spatial spillovers across panels:

$$\Delta y_{it} = \alpha_i y_{it-1} + z'_{it}\gamma_i + \sum_{j=1}^{p} \beta_{ij} \Delta y_{it-1} + u_{it} \tag{2}$$

As before, the above equation is eventually augmented with lags of the first-differenced series $(\sum_{j=1}^{p} \beta_{ij} \Delta y_{it-1})$ to account for eventual time-patterns left in the residual term. As for the second scenario, where a stationarity null is assumed, we resort to the well-known Hadri (2000) test. Given a series composed of a panel specific random walk p_{it} and a deterministic, panel specific trend γ_{it}:

$$\begin{gathered} y_{it} = p_{it} + \gamma_{it} + u_{it}, \\ \text{with } p_{it} = p_{it-1} + e_{it} \end{gathered} \tag{3}$$

If the variance of the error term e_{it} is 0, then the random walk component p_{it} reduces to a constant across time. If that is true, then the original process y_{it} is just trend-stationary. In order to check for such possibility, the Hadri test considers a null hypothesis such that $\frac{\sigma_u^2}{\sigma_e^2} = 0$ against the alternative that such ratio is higher than 1.

Upon non-rejection of the unit root null against heterogeneous stationarity in the IPS test and rejection of the null of stationarity against heterogeneous non-stationarity with the Hadri test, we are then free to evaluate separately the time property of each of the analyzed series for the two separate Anglo-Saxon countries which form part of our analysis. This step would allow us to confirm the validity of the Panel result as well as allowing us to check for both the intensity of the persistence phenomenon and its linearity across time.

4.2. Time Series unit root analysis

In order to test for the possibility of a unit root within the analyzed countries, we choose the Augmented Dickey Fuller test (ADF test) as the benchmark for our persistence analysis:

$$\Delta y_t = g(t) + \alpha y_{t-1} + \sum_{j=1}^{p} \beta_j \Delta y_{t-1} + \varepsilon_t \tag{4}$$

Where, in the canonical re-parametrized test model expressed above:

$$\begin{aligned} \alpha &= 1 - \rho \\ y_t &= \alpha + \rho y_{t-1} + \epsilon_t \end{aligned} \tag{5}$$

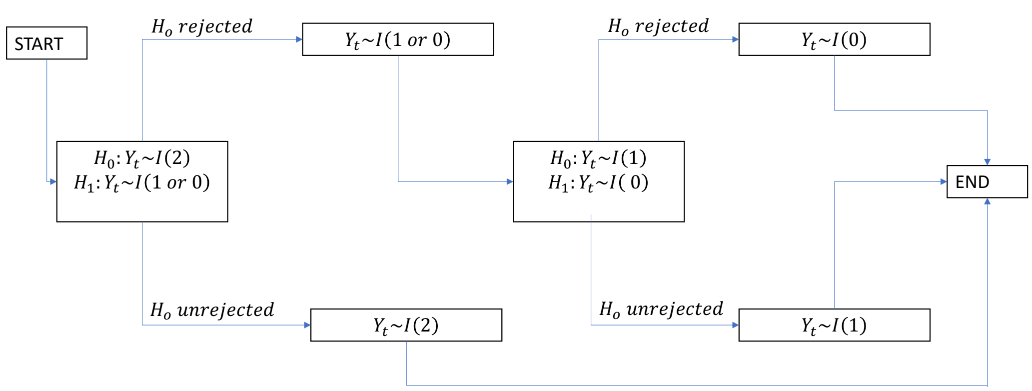
The model, according to the analysis of the first differences variables and their levels, can thus be expressed considering as a standard non-stationary alternative either a random walk without drift, one with drift or an unrestricted one which leaves the deterministic component choice to their statistical significance as expressed by the results of the OLS regression. Eventual time patterns in the residuals are then addressed parametrically, selecting a maximum lag length following the empyrical rule by Schwert (1987, 2002) and selecting the most parametrized model based on the significance of the last lag introduced in the specification:

$$p_{max} = integer\left[12 \times \left(\frac{100}{T}\right)^{\frac{1}{4}}\right] \tag{6}$$

Following Dickey and Pantula (1987), and considering the nowadays common economic evidence that sees real variables generally be I(1) and nominal values generally containing at most two unit roots, our application of the augmented Dickey fuller method also follows a specific, two-step top-down algorithm: in the first phase, the I(2) null hypothesis is evaluated against either the probability of the series containing one or no unit roots at all. Upon rejection of such hypothesis, the procedure would continue with a final test, evaluating the I(1) hypothesis against a stationary alternative. The first phase test equation would as such be:

$$\Delta^2 y_t = g(t) + \alpha \Delta y_{t-1} + \sum_{j=1}^{p} \beta_j \Delta^2 y_{t-1} + \varepsilon_t \tag{7}$$

In general, upon non-rejection of any null at any step, the procedure stops and is followed by a statistical decision of the order of integration of the series. The algorithm is reported below:



After careful analysis of the series, we choose to adopt a deterministic specification with $g(t) = \mu$, as none of the series in their first differences present any source of time variation that would appear to trend either upwards or downwards across time, suggesting us that the residual attractor value of the series could be a fixed average instead of a trend.

Similarly to the Panel section, checking for a test where the unit root is nested into the alternative hypothesis instead of being part of the null led us to corroborate the results of the ADF test using the trend stationarity test by Kwiatkowski et al. (1992) (KPSS test, hereafter). This could be, without loss of generality intended as the time series equivalent of the Hadri test. Given:

$$\begin{aligned} y_t &= \xi_t + p_t + \theta_t, \\ \text{and } p_t &= p_{t-1} + \phi_t \end{aligned} \tag{8}$$

And considering $\phi_t \sim iid(0, \sigma^2_\phi)$, the test once more is based on the fact that when the variance of the random walk p_t is equal to zero, then the walk is just a constant. That implies that the series is stationary around a given trend (ideally nonzero, but possibly equivalent to it with $\xi = 0$. The authors consider that case as well). The relevant Lagrangean Multiplier test statistic, as with Hadri, will thus be based on the hypothesis $\sigma^2_\phi = 0$.

4.3. Time Series unit root break analysis

Since the seminal work of Philippe Perron on the Great crisis (Perron (1989)) and its first attempts at devising a unit root with an exogenous (identified a-priori) break-in-mean nested in the alternative hypothesis (Perron (1990)), literature on hysteresis has grown acquainted with the idea that linear alternatives to the unit root null tested through a random walk benchmark might be biased toward a non-rejection of a unit root process when indeed such process might not exist as it could be approximated by a change in the deterministic components of a stationary or even totally deterministic series. Using the Zivot and Andrews (2002) test (ZA test, hereafter) in its additive outlier specification, we aim at distinguishing for such hypothesis considering an alternative containing a sudden deterministic change in the level of the variables (their intercept), endogenously retrieved through a recursive OLS estimation of the trimmed series. Upon finding a period where the value of the break impulse dummy stands the most standard errors away from zero, that specific OLS test regression is taken as the one determining the value of the ADF t-test.

The recursive[2] pseudo t-test procedure will thus be a single step regression based on the following test equation:

$$y_t = \mu + \theta DU_t(\hat{\lambda}) + \hat{\beta} t + \alpha y_{t-1} + \sum_{j=1}^{k} \hat{c}_j \Delta y_{t-j} + \hat{e}_t \tag{9}$$

which contains an intercept, μ, a level break dummy function of the proportion of the series which have been trimmed away, θDU_t, the auto-regressive coefficient on which the t-ratio of the test is calculated, α, and some additional lags to control for eventual non-spherical disturbances. The hats, citing the authors, emphasize the fact that the parameters correspond to the estimated value of the break fraction. It would be worth remembering that the null hypothesis for the Andrews and Zivot (1992) and all the test based on it, such as the Lumsdaine and Papell (1997), are all based on the simple null of unit root. The null hypothesis as such would always be:

[2] Any endogenous ADF-type test requires a trimming procedure, aimed at creating a regression window to estimate recursively the test equation including each possible break-date from the start to the end of the window. Much has been said on such topic, but following Banerjee et al. (1992), Andrews (1993), Perron and Vogelsang (1992a) and Perron and Vogelsang (1992b), we decided to set the trimming window to $\lambda = [0.15, 0.85]$. This appears to be, according to the very first authors, a convenient choice that would account for both the necessity of keeping the regressions minimum length high enough to affirm a Gaussian approximation of the estimates and to possibly capture break points even at an early or late stage of the time series.

$$y_t = \mu + y_{t-1} + e_t \tag{10}$$

It is however necessary to point out that such over-simplification does not take into account the possibility that an intercept break might be present in the null hypothesis, interacting with the non-stationary component of the series and creating some variation in the resulting stochastic trend. According to Lee and Strazicich (2003), considering a break in the alternative hypothesis when such hypothesis is true effectively augments the rejection rate of the null hypothesis, in the spirit of Perron (1989). However, the null hypothesis needs also to be realistic, and take into consideration the eventuality that a break in the deterministic levels of the series might coexist with a unit root.

To take into account such last eventuality, we resort to the Perron and Vogelsang (1992a) endogenous unit root test with one level shift.[3] In such test, the null hypothesis thus entails a unit root break with a single mean shift, against a totally deterministic alternative:

$$H_0 : y_t = \delta D(TB)_t + y_{t-1} + w_t \tag{11}$$

$$H_1 : y_t = c + \delta DU_t + v_t \tag{12}$$

Where $dD(T_b)_t = 1$ the period exactly after the break, 0 otherwise, and $DU_t = 1$ from the period exactly after the break and on-wards till the end of the time series. The null will thus nest an impulse break propagating in time through the random walk, while, intuitively, the alternative will just present a shift dummy that will add a given differential to the original average of the series.

The recursive pseudo t-test procedure will thus be a two step estimation based on a first step regression aimed at subtracting the deterministic component from the series

$$y_t = \mu + \delta DU_t + \tilde{y}_t \tag{13}$$

and a second step aimed at obtaining the relevant test statistic using the residuals from the first step de-trending equation, $\tilde{y}_t$:

$$\tilde{y}_t = \sum_{i=0}^{k} \omega_i D(TB)_{t-i} + \alpha \tilde{y}_{t-1} + \sum_{j=1}^{k} c_j \Delta \tilde{y}_{t-j} + e_t \tag{14}$$

4.4. Time Series fractional integration analysis

In traditional integration models, time series are either variance-stationary, since they are integrated of order I(0), or non-stationary, thus integrated of an order $d \in Z : [1, N]$. However, given the limitation proposed by these methods that simply consider integer degrees of differentiation, this paper makes use of fractional tools to draw more conclusive inference on the approximated, decimal degree of integration of the data. To add some additional degree of robustness to the results of the traditional approach, we analyse the order of fractional integration of IPT and IPT rate individually with the semi-parametric log-periodogram regression proposed by Geweke and Porter-Hudak (1983) (GPH, hereafter) and modified and further developed by Robinson (1995). The GPH procedure entails maximum likelihood estimation of the following log-linearly approximated model:

[3]Endogenous tests have gone a long way in the past years. Some extensions to the aforementioned Perron and Vogelsang (1992a) tests are well represented by the two shift in mean test by Clemente et al. (1998) and, most recently, by the Lagrangean Multiplier test of Lee and Strazicich (2003). In recent years, a relatively innovative test by Narayan and Popp (2010) has been built based on maximizing the statistical significance of the break-point rather than the absolute value of the t-statistic for the break-date. All such tests offer a significant contribution in terms of statistical improvement of the analysis but are not free from the data mining critique, where break over-parametrization leads to over-fitting of the model.

$$lnI(\omega_k) = \alpha_0 + \alpha_1 ln \left[2\sin\left(\frac{2\omega_k}{2}\right)\right]^2 \tag{15}$$

Where $I(\omega)$ represents the loglinearized periodogram of the series with ω_k frequencies, while α_0 and α_1 represent the stable and slope components of the loglinearized periodogram. Estimation and reparametrization of the slope coefficients gives us the Hurst Coefficient, $H = 1 - \alpha_1/2$, and ultimately the order of fractional integration d, as $-d = \alpha_1$.

As a rule of thumb, if $0 < d < 0.5$, our series is stationary and mean-reverting, that is, the effect of the shocks disappear after a few periods; if $0.5 \leq d < 1$, the series is non-stationary but it is still mean-reverting, while $d \geq 1$, consistently with canonical wisdom on unit root behavior, means non-stationarity and non-mean-reversion. This last piece of information is thus crucial for our exercise: adding to the canonical inference on shocks when a unit root is present, the fractional study depicts three possibilities: stationary mean reversion of the process, long memory, with a slow but nevertheless decaying process reaching the mean (in other words, series with a high order of autocorrelation that nevertheless reach 0 after a non negligible number of periods) and finally long memory with a persistent behavior typical of integrated processes. In our exercise, the fractional parameter d for each univariate series is estimated and presented in results using three different bandwidths, $m = T^{0.4}, m = T^{0.5}, m = T^{0.6}$; so, we calculate three values of d for each series, respectively. To calculate these values, we work with the first difference (second if needed), since this test requires that the results are limited to the interval $[-0.5, 0.5]$, adding the whole part of the integration order (either 1 or 2) to obtain the proper estimation of d.

5. Results

This section contains the main results of each of the analyses we previously described, using the same structure we employed in the methodology section, hence, going from panel integration to classical time series unit root analysis and finally introducing flexibility with structural breaks and fractional integration methods. We remind the reader that the objective is to test persistence in IPT series and the detection of structural breaks consistent with the economic theory. For convenience, along this section we will use the acronym IPT to specifically refer to the Involuntary part-time employment absolute series, while IPT rate to precisely refer to its rate over total employment, both preceded by US or UK according to the corresponding country when needed.

5.1. Panel unit root results

Let us start first with the aggregate, panel case. Table 1 reports the results for the LLC, IPS and Hadri tests both in the first-differenced version of the ADF-type test equation (I(2) vs. I(1 or 0)) and the level version (I(1) vs I(0)). The panel was balanced including all the available periods shared by the series, thus 1992m4-2019m12. The homogeneous null of unit root for the LLC test is generally never rejected against an homogeneous stationary alternative[4]. Failure to rejected the null of a homogeneous unit root also appears to hold in every general specification when making use of the IPS test in order to account for possible local stationarity of some of the panels. Out of any possible deterministic specification and of all the information criteria used, we could never reject the null. Table 1 reports,

[4]When the Schwarz-Bayesian and Hann-Quinn criteria are employed for lag selection, regardless of any deterministic specification. When the far less conservative Akaike criteria is employed, the null is unrejected for the non-trending test and strongly rejected when a trend is nested in the test equation. Judging by the time pattern of the series in its level and differences, the most realistic test model equation should contain an intercept only (although accounting for it does not generally change the results). The slightly offsetting result of the test for the LLC test with the over-parameterized suggestion made by the AIC however, would tell us that, even if cross sectional spillover has been accounted for, some additional investigation at the national level would be needed. All tests contain contemporaneous cross sectional averages as added regressors. We also attempted a top-down t-test procedure, and it can be made available upon request.

as for the LLC test, the most parametrically parsimonious and realistic (in terms of its deterministics) specification of the IPS.

Let us countercheck our results with the Hadri test for stationarity. We can, as we expected, comfortably reject the null of homogeneous stationarity. Note that the Hadri test, contrary to the other ADF type test equations, is not augmented parametrically to account for spherical disturbances but implies a correction of the long-run variance/covariance matrix. As we are not considering an estimate of the long run variance for each panel series since that would require the choice of a specific lag length, results of the Hadri test perhaps overestimate the degree of non-stationarity of the series to the point that the null for the series in first differences can be rejected, leading to the possible conclusion that either of the two might be integrated of order two[5].

Our overall results indicate that the memory process represented in the two series could suggest the presence of a single unit root in both countries, as suggested by the Hadri test results, or that one of them might even have an integration order of two. However, given some potential ambiguity stemming from the over-parameterization imposed by the Akaike information criteria and its tendency to point at model structures which end up being more sensitive to the deterministic choices made, we reckon that some different lag order structure (a different medium/long memory process) might be affecting dis-homogeneously the two series. That is why the following time series application will help us shed some light on any potential additional heterogeneity that the panel application could not help us detect.

Table 1: Panel integration analysis. Variables: Involuntary part-time (Ipt) and Involuntary part-time rate (IptRate). Panel obs.: N = 2 (US and UK); T = 333 (1992m4-2019m12).

Series (I)	Test (II)	H_0 (III)	H_1 (IV)	Lags (V)	Stat (VI)	Decision (VII)
Ipt	ΔLLC	Hom I(2)	Hom I(1 or 0)	0	-36.924*	not I(2)
	LLC	Hom I(1)	Hom I(0)	6	-0.028	Hom. I(1)
	ΔIPS	Hom I(2)	Het I(1 or 0)	0	-32.030*	not I(2)
	IPS	Hom I(1)	Het I(0)	6	0.200*	Hom. I(1)
	ΔHadri	Hom I(1 or 0)	Het I(2)	0	2.057*	US or UK possibly I(2)
IptRate	ΔLLC	Hom I(2)	Hom I(1 or 0)	0	-26.570*	not I(2)
	LLC	Hom I(1)	Hom I(0)	0	-1.119	Hom I(1)
	ΔIPS	Hom I(2)	Het I(1 or 0)	0	-23.545*	not I(2)
	IPS	Hom I(1)	Het I(0)	0	1.058	Hom I(1)
	ΔHadri	Hom I(1 or 0)	Het I(2)	0	2.168*	US or UK possibly I(2)

* Null rejection at 5% level. All test equations are augmented with their cross-sectional averages and include a nonzero intercept as the unique deterministic component. (I) Tested time series; (II) Performed tests: Levin, Lin and Chu -LLC-, Im, Pesaran and Shin -IPS- and Hadri, run in first differences -Δ- and, where appropriate, levels to follow the Dickey and Pantula (1987) suggestion; (III-IV) Null and alternative hypothesis; (V) Most parsimonious lag structure suggested by the AIC, BIC and HQIC criteria; (VI-VII) Test statistic and decision under the null.

5.2. Time Series unit root results

For this section, as we are working with two independent time series, results are summarized in table 2 which comprise the key results for the stationarity/unit root tests using the US and UK data, with IPT absolute series and its rate over employment. The tests are performed on both the first differences and the original series in levels.[6]

[5] A Bartlett Kernel with 11 lags, given by Schwert maximum length criteria, was also tested. Results for such specification allowed us to not reject the I(1 or 0) null in the first differences specification and reject the I(0) null in levels.

[6] Further test specifications are mentioned below these tables and detailed in the methodology section.

Table 2: Linear tests for integration order. Variable: US and UK involuntary part-time employment in nº of workers (Ipt) and rate over total employment (IptRate).

Series (I)	Test (II)	H_0 (III)	H_1 (IV)	Lags (V)	Stat (VI)	Decision (VII)
US Ipt	ΔADF	I(2)	I(1 or 0)	10	-3.673*	not I(2)
(T=528)	ADF	I(1)	I(0)	11	-2.579	I(1)
	ΔKPSS	I(1)	I(2)	10	0.169	I(1)
	KPSS	I(0)	I(1)	11	1.720*	not I(0)
US IptRate	ΔADF	I(2)	I(1 or 0)	16	-4.076*	not I(2)
(T=528)	ADF	I(1)	I(0)	11	-3.000*	not I(1)
	ΔKPSS	I(1)	I(2)	16	0.099	I(1)
	KPSS	I(0)	I(1)	11	0.581*	not I(0)
UK Ipt	ΔADF	I(2)	I(1 or 0)	11	-3.818*	not I(2)
(T=358)	ADF	I(1)	I(0)	12	-1.274	I(1)
	ΔKPSS	I(1)	I(2)	11	0.249	I(1)
	KPSS	I(0)	I(1)	12	1.300*	not I(0)
UK IptRate	ΔADF	I(2)	I(1 or 0)	11	-4.044*	not I(2)
(T=358)	ADF	I(1)	I(0)	14	-1.667	I(1)
	ΔKPSS	I(1)	I(2)	11	0.229	I(1)
	KPSS	I(0)	I(1)	14	0.620*	not I(0)

* Null rejection at 5% level using the critical values of each distribution. Constant and no trend. (I) Tested time series and total number of periods T; (II) Performed tests: Augmented Dickey-Fuller -ADF- and Kwiatkowski, Phillips, Schmidt and Shin -KPSS-, run in first differences -Δ- and, where appropriate, levels to follow the Dickey and Pantula (1987) suggestion; (III-IV) Null and alternative hypothesis; (V) Lag structure chosen by general-to-specific lag selection method based on Schwarz max length criterion; (VI-VII) Test statistic and decision under the null.

Starting with the US IPT we may see how we can confidently reject the null of a second unit root when performing the ADF test on the first difference, failing to reject the unit root when it is performed over the IPT in level. Equivalently, the results after the null inversion of the KPSS test led us to consider the US IPT to be an I(1) process as well, reinforcing this result. When performing the same tests but now using the US IPT rate, although the ADF results are not conclusive of the integration order of the series, the rest of the analysis seems to indicate again its I(1) nature.

Noticeably, applying the same analysis to the UK IPT and IPT rate leads us to very similar and clear conclusions, being the series well identified as integrated of order one by any test performed. Therefore, we may conclude IPT series present a form of persistent behavior in any analyzed case so far. However, in the next section we will present results based on the nonlinear alternative specifications we illustrated in the methodology section to check the robustness of these results.

5.3. Time Series unit root break results

Let us consider the results of the ZA test first. As we have already mentioned, we test the null of an unbroken unit root process against the possible alternative of a deterministic, mean reverting process with a sudden change in the intercept. As we can observe in Table 3, the test reaches the same conclusion as the linear tests, with the introduction of an endogenously detected structural break in the mean, spotted in December 2007 for the IPT in level. This appears to be historically and theoretically consistent as we find it to be close to the ideal beginning of the financial crisis in the US, exactly at the same month when the peak and following crisis is technically identified by the US Business Cycle Dating Committee[7].

The ZA structural break was detected this time for May 2008 in the UK IPT and its rate. Again,

[7]https://www.nber.org/research/data/us-business-cycle-expansions-and-contractions

this result seems be consistent with the economic theory since the financial crisis took some months to spread to the rest of the economies. Indeed, this business cycle turning point was precisely identified in 2008Q1 by the UK Office for National Statistics[8].

There is however an important caveat to consider: the ZA testing evaluates the possibility of a unit root process acting as a perfect substitute for a mean reverting process, regardless of the presence of any external factor that might have modified the time pattern of the series interacting with its stochastic, integrated root. To gain a precise understanding of whether this is true or if there has been an external, well-defined exogenous source of change that has effectively interacted with the long memory process, further analysis is needed. We thus resort to the PV one break test. The importance of this test is twofold: on one side, it acts as a robust alternative to the ZA test, presenting a strong increase in power as it realistically consider the possibility of a break in both the null and the alternative hypothesis (Narayan and Popp (2010)); on the other side, if the null hypothesis is true and the break dates are statistically significant, it underlines a mean changing event (represented by the break event) that altered the evolution of the series as it became part of the long run memory process contained in the unit root.

In Table 3, our estimates confirm non-stationarity for the US and the UK in both the IPT variable and its rate with respect to total unemployment. For the US, the break-date for the IPT variable remains in the neighbourhood of 2008, with a slightly less coherent estimate for the variable rate, for which a break is detected in 2001m5. In both cases, the variables appear to be integrated of order 1. As for the UK, the break-dates for the PV test appear to stay in line with the results for the ZA, perhaps with a notable difference: a higher order of integration for both variables, which now appear to contain two different stochastic trends, being apparently integrated of order 2.

Table 3: Non-linear tests for integration order. Variable: US and UK involuntary part-time employment in nº of workers (Ipt) and rate over total employment (IptRate).

Series (I)	Test (II)	H_0 (III)	H_1 (IV)	Lags (V)	Breakpoint (VI)	Stat (VII)	Decision (VIII)
US Ipt	ΔZA	I(2)	break I(1 or 0)	4	2010m4*	-8.587*	not I(2)
(T=528)	ZA	I(1)	break I(0)	4	2007m12	-2.451	I(1)
	ΔPV	break I(2)	break I(1 or 0)	16	2008m10	-3.682*	not break I(2)
	PV	break I(1)	break I(0)	16	2007m9*	-2.171	break I(1)
US IptRate	ΔZA	I(2)	break I(1 or 0)	4	2010m4*	-8.233*	not I(2)
(T=528)	ZA	I(1)	break I(0)	4	2007m12	-2.765	I(1)
	ΔPV	break I(2)	break I(1 or 0)	16	2008m10	-4.090*	not break I(2)
	PV	break I(1)	break I(0)	11	2001m5*	-2.845	break I(1)
UK Ipt	ΔZA	I(2)	break I(1 or 0)	4	2013m5*	-7.089*	not I(2)
(T=358)	ZA	I(1)	break I(0)	4	2008m5	-4.113	I(1)
	ΔPV	break I(2)	break I(1 or 0)	13	2013m2*	-3.426	break I(2)
UK IptRate	ΔZA	I(2)	break I(1 or 0)	4	2013m5*	-6.774*	not I(2)
(T=358)	ZA	I(1)	break I(0)	4	2008m5	-4.331	I(1)
	ΔPV	break I(2)	break I(1 or 0)	13	2013m2*	-3.536	break I(2)

* Null rejection at 5% level using the critical values of each distribution. Constant, no trend and standard 15% trimmed each tail. (I) Tested time series and total number of periods T; (II) Performed tests: Zivot-Andrews -ZA- and Perron-Vogelsang -PV-, run in first differences -Δ- and, where appropriate, levels to follow the Dickey and Pantula (1987) suggestion; (III-IV) Null and alternative hypothesis; (V) Lag structure chosen by general-to-specific lag selection method based on Schwarz max length criterion; (VI) Endogenous breakpoint in intercept; (VII-VIII) Test statistic and decision under the null.

The results of this section strongly confirm the hysteresis phenomenon, as "external" sources of variation (exogenous to the stochastic process implied by the unit roots) are controlled for by the deterministic break structure of the test. There is however some necessary degree of uncertainty which

[8] https://www.ons.gov.uk/economy/grossdomesticproductgdp/methodologies/communicatingtheukeconomiccycle

relates to the correct order of integration of the series. In addition to the effect resulting from the interaction between the break component and the unit roots in each series, a more accurate estimation of the appropriate order of integration is required. The fractional integration exercise, in the next section, will give us some concluding evidence, instrumental to both future research on the statistical properties of IPT and to its forecast accuracy.

5.4. Time Series fractional integration results

Finally, as a precision and robustness additional exercise, the results for the fractional alternative estimation using three different standard bandwidth values are displayed in table 4. Since this test requires the results to be constrained within the interval $[-0.5, 0.5]$, we work with the first difference (second if needed) of the original series. Subsequently, to obtain the estimated fractional integration order $\hat{d}$ of the level series, we add 1 (or 2) –depending on the degree of differentiation required to perform the GPH test–.

Note that any test specification for the US data evidences at least an integer unit root in the IPT and IPT rate series. However, while the estimated $\hat{d}$ is not significantly different from 1 using the $m = T^0.4$ specs, a higher bandwidth did find a significant fractional integration order between 1.4 and 1.8, suggesting an even stronger hysteresis non-reverting behaviour for the IPT.

Similarly, an analogous analysis for the UK IPT and IPT rate generally concludes again no significant fractional integration over the first integer unit root, except for the 0.6 bandwidth value, when an integration order close to 1.4 is significantly obtained.

Overall, even though minor modifications in the GPH specifications lead to varying numerical outcomes for the fractional unit roots of the series, the concept of a sustained, non-stationary long memory pattern in the IPT remains valid as every outcome confirms the existence of at least one unit root in any of the studied series, or even more (fractionally). This latter result also appears to also be consistent with some of the results from the Hadri stationarity tests we have seen in the panel section and some of the outcomes of the unit root testing for each separate series when the PV with a break-point nested in the alternative was considered: in both instances, some higher degree of integration (between 1 and 2), conditional on the lag structure, was ultimately detected.

Table 4: GPH test for fractional integration order.

	$m = T^{0.4}$	$m = T^{0.5}$	$m = T^{0.6}$	
Series	$\hat{d}$	$\hat{d}$	$\hat{d}$	T
(I)	(II)	(III)	(IV)	(V)
US Ipt	1.081 (0.158)	1.500* (0.165)	1.744a* (0.101)	527
US IptRate	1.054 (0.161)	1.441* (0.137)	1.796a (0.117)	527
UK Ipt	1.801 (0.358)	1.315 (0.214)	1.410* (0.145)	357
UK IptRate	1.746 (0.359)	1.312 (0.215)	1.468* (0.149)	357

Null hypothesis of no fractional integration over I(1). Subscript a denotes a null shift to no fractional integration over I(2) due to an additional differentiation needed. * Null rejection at 5% level. (I) Tested time series; (II-II-IV) Reported $\hat{d}$ coefficient is the fractional integration order estimated (standard errors in parenthesis) for any selected bandwidth: 0.4, 0.5, 0.6 respectively; (V) Total number of time periods.

6. Conclusion and discussion

In the post-recovery phase after the Great Recession, the labour markets of most Western economies did not return to a situation where open-ended full-time contracts predominated. Instead, they moved towards a market dominated by more flexible forms of employment, and where involuntary part-time employment became chronic even in scenarios of full employment.

This is how the IPT shifted from exhibiting countercyclical behaviour to showing signs of persistence, becoming part of the employment agendas of governments concerned about the quality of work. In other words, analysts moved from questioning whether the job creation intensity of this recovery phase was lower than previous ones or whether this recession, unlike previous ones, had accelerated some labor market trends that had become chronic. The aim of this paper was to test the persistence of the shocks in involuntary part-time employment (IPT) from the US and the UK, i.e., testing its hysteresis. Our analysis employs a macro-econometric approach utilizing canonical methods commonly employed in empirical literature to test labour market series persistence. However, these methods have not been applied in the context of involuntary part-time employment (IPT) before. Our procedure consists of a battery of time series unit root and stationarity tests, which we employ to confirm the integration process in the large historical series of IPT in the US and UK. This confirms the hysteresis hypothesis of IPT. To investigate the time properties of the series further, we utilized structural break automatic detection methods to identify a discontinuity in the level of the series, which generally occurred around the time of the Great Recession. This change is part of the series and coexists with the unit root behaviour of the processes. However, its interaction with the unit roots serves as a mechanism for additional propagation of the unit root behaviour rather than being the cause of the long memory process of the series. Despite any possible external shocks to the IPT that may have occurred in the last decade, including the Great Recession, the hysteresis phenomenon remains an autonomous property of the series, capable of altering its mean at any given point in time.

The findings of our study have significant policy implications, as any shock affecting IPT is likely to have long-lasting effects due to the series' persistent long-memory structure. Therefore, policymakers and labour market institutions should consider the effectiveness of policies aimed at reducing the need for IPT. If such policies are successfully implemented, the long-term steady-state level of IPT is likely to be lower, leading to a new equilibrium average with fewer involuntary part-time workers. Our results also support the idea that IPT is a structural phenomenon in the labour market, as the shocks affecting it have persisted over time. However, this does not mean that the counter-cyclical behaviour of IPT has disappeared. Additionally, we have demonstrated through our statistical exercise that a one-time shock, if correctly modelled, can affect the long-term average value of IPT. This means that shocks can cause a change in the mean, but they are not the underlying cause of the hysteresis phenomenon.

It is important to note that our study does not address the question of whether shocks like the Great Recession are deeply linked to the persistent structural components of IPT. This is an issue that could be addressed in future research.

Given the nature of our study, it is relevant to discuss the causes and drivers of the hysteresis phenomenon in IPT. Why full-time work no longer pays? What are the reasons for the failure of underemployment rates to return to their pre-recession levels? Previous literature has suggested that changes in firm organization, such as task fragmentation, digitization, and the gig economy, may be the main drivers of the persistent structural components of IPT that we have confirmed. Additionally, the shift from industrial to service-dominated economies may also play a role. Future research could investigate the micro-level causal processes underlying recent IPT dynamics, complementing our macro-level analysis.

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