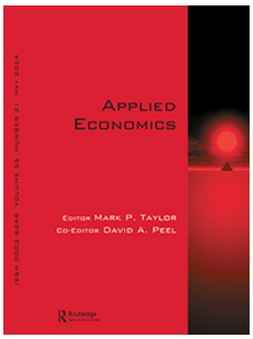

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Labour market mismatches in G7 countries: a fractional integration approach

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ABSTRACT

This paper examines the G7 labour market, analysing unemployment, job vacancies and the spread of both in terms of time series persistence from January 2002 to October 2023. Using fractional integration, we observe the series show long memory and persistence in all G7 countries. These findings differ slightly depending on the specification of the error term. If it is white noise, no evidence of mean reversion is found in any scenario except for US unemployment. With autocorrelated disturbances, mean reversion is found in unemployment rates in Canada, Germany, and the US. In France, this is the case for job vacancies, and in France and Italy, for spread. The UK is the only country that does not display any degree of reversion to the mean in the three series examined. Our results show evidence of a downward trend for unemployment and an upward trend for job vacancies in all G7 countries. Consequently, the reduction of the imbalance unemployment-vacancies seems permanent, which is a positive outcome for advanced economies.

KEYWORDS

Labour market; unemployment; job vacancies; fractional integration; G7 countries

JEL CLASSIFICATION

C22; J01; J63; J64; 057

I. Introduction

Labour mismatch is considered to be one of the most important current macroeconomic issues, impacting not only on economic efficiency but also people wellbeing. During the 2008 financial crisis, high rates of unemployment combined with increasing job vacancies were evidence of labour mismatch (Ahn and Crane 2020; Canon, Chen, and Marifian 2013; Furlanetto and Groshenny 2016). Several studies, including work by Pissarides (2013), have suggested that rising unemployment was due to declining aggregate activity, the collapse of the construction sector, poor policy-making and inadequate institutions. Recent studies (O. Blanchard, Domash, and Summers 2022; Lubik 2021) have found a similar deterioration in labour matching efficiency because of the COVID pandemic. These studies argue that the natural rate of unemployment has risen, reflecting poorer adaptation, and increasing reallocation.

In this context, the Beveridge Curve is a fundamental tool in the study of labour market frictions because compares unemployment rates with job vacancies rates in different period of times (Diamond 1982; Elsby, Michaels, and Ratner 2015; Mortensen and Pissarides 1994; Petrongolo and Pissarides 2001; Pissarides 1985; Shimer 2005, 2007).

Based on the theoretical framework of the Beveridge curve, movements along the curve indicate cyclical effects while changes in the efficiency of labour matching, associated with structural effects in the labour market, correspond to shifts in the curve (Christl 2020; Diamond 2013). Moreover, Beveridge curve provides a better understanding of the persistence of the unemployment rate and vacancy fluctuations (Elsby, Michaels, and Ratner 2015). The outward shifts in the Beveridge curve are associated with the model of hysteresis of unemployment. In this sense, the hysteresis shows a deterioration in the matching efficiency as the duration of unemployment increases (Craighead 2019). Long periods of long-term unemployment are associated with knowledge obsolescence, what tends to deepen the structural unemployment and mismatches between labour demand and supply in labour markets.

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On the other hand, the persistence of vacancies has an important implication for the job creation (Fujita and Ramey 2003) and it suggests the presence of several frictions in creating new vacancies (Fujita 2004)

The principle aim of this research article is to analyse the unemployment and job vacancies evolution in G7 countries from January 2002 to October 2023 to identify mismatches in the labour markets. The objective is also to determine whether the economic shocks have a temporary or permanent effect on the time series analysed. We applied fractional integration techniques to identify mean-reversion behaviour in the indicators, which will shed light on the impact and persistence of economic shocks on the time series. It is hoped the results will offer relevant information for future policymaking.

Within this context, expansionary monetary and fiscal policies are important for supporting labour demand while active labour market policies are more appropriate to addressing structural changes (Lubik 2021). Studies, including that by Destefanis et al. (2023), have found that passive policies, such as unemployment benefits, have an adverse impact on labour matching, while, active employment policies, including employment incentives and job training, have a positive effect. These findings are in line with those of other studies by Jackman et al. (1990), Hobijn and Şahin (2013), Bova et al. (2018), among others. A study by Nickell et al. (2003) found that labour market institutions, like labour union density or collective bargaining coordination, worsen matching efficiency, shifting the Beveridge curve outwards. However, stricter employment protection had the opposite effect.

This paper is ordered as follows: Section II explores previous empirical studies into this issue. Section IV outlines the research data and presents the methodology. Section V explains the principal results and observations are provided in Section 5.

II. Literature review

Labour market matching is a crucial aspect the job market (Bleakley and Fuhrer 1997). Inefficient labour markets are caused by mismatches between job vacancies and unemployed workers (Santos 2016).

The Beveridge Curve is an important concept in the study of the macroeconomics of labour markets (Lubik 2021) and a fundamental tool in labour market analysis and policymaking (Duffy and Jenkins 2022). A better understanding of the mechanisms incorporated into the Beveridge Curve, such as the unemployment and job vacancy rates, could help policymakers mitigate adverse impacts on employment (Del Rio-Chanona et al. 2021).

In this sense, the effectiveness of microeconomic labour market policies and aggregate policies to create new jobs depends on both the behaviour of the unemployment rate and the job vacancy rate. The fact that there have been many more unemployed persons than the number of available jobs suggests that measures for job creation or aggregate demand stimulation are important policies to lower the unemployment rate. On the other hand, if the number of job vacancies is large relative to the number of people unemployed, then microeconomic policies, such as job training programmes, measures to increase worker mobility or measures to improve the job search, would seem to be required in order to lower the unemployment rate (Abraham 1983).

Following the literature on the unemployment persistence, traditional theories of unemployment include the classical theory of the natural rate of unemployment (Friedman 1968; Phelps 1967), referring to the fluctuation of unemployment around a natural rate (Papell, Murray, and Ghiblawi 2000). According to this theory, the unemployment rate tends to return to equilibrium over the long-term (Omay, Özcan, and Shahbaz 2020). However, other theories consider the hysteresis hypothesis (O. J. Blanchard and Summers 1986), which contends that economic shocks have persistent effects on the level of unemployment (Papell, Murray, and Ghiblawi 2000).

A review of existing literature found studies, such as that by Omay et al. (2021), analysing the hysteresis hypothesis of unemployment for 23 OECD countries by applying panel unit root testing for the period 1960–2016. The authors found evidence of the hysteresis hypothesis in all countries. These conclusions are similar to those of other studies, specifically those by Lin et al.

(2008), Fosten and Ghoshray (2011), Marques et al. (2017), and Meng et al. (2017), among others.

More recently, a study by Bermejo et al. (2023) analysed persistent unemployment during the COVID pandemic in 24 European countries using fractionally integrated methods from 2010 to 2020. The results confirmed the persistence of unemployment. A comparison of persistent unemployment across all G7 countries shows wide disparities. For instance, Caporale and Gil-Alana (2008) reported that Japan and the US showed lower levels of unemployment persistence than European countries. These results are in line with the work of Alogoskoufis et al. (1988). By contrast, a study by Yilanci et al. (2020) analysed the presence of unemployment hysteresis in G7 countries between 1991 and 2019 using unit root testing. The results showed unemployment hysteresis in Canada, France, and the United Kingdom.

Other studies, such as that by Cheng (2022), have found evidence of high levels persistent unemployment over the last two decades in G7 countries, such as Italy, Japan, the United Kingdom, and the United States. Research by Akdoğan (2017) confirmed the existence of unemployment hysteresis in France, Italy, Germany, the United Kingdom, and Japan. Similarly, Mikhail et al. (2006) showed evidence of persistent unemployment in Canada using a Bayesian ARFIMA class of models. These results are consistent with the study by Mikhail et al. (2003) which used modified rescaled-range testing to analyse the persistence of Canadian sectoral unemployment. Studies on the US unemployment rate, such as that by Romero-Ávila and Usabiaga (2007), found that unemployment rates in the US were stationary from 1976 to 2004. Research by Zhang et al. (2021) also tested the validity of the hysteresis hypothesis in the United States during the pandemic.

Compared to the amount of literature on persistent unemployment, relatively little research has been done into the rate of job vacancies. Studies, such as that by Røed (2002), have found that the rate of job vacancies is stationary, results in line with the work of Fujita (2004) which showed a low persistence of vacancies in the labour matching model. In general, studies such as that by Lubik (2021), suggest structural changes have taken place in the labour market resulting in a deterioration of match efficiency and match elasticity.

The causes of mismatch between unemployed workers and available jobs may be explained by the institutional setting (Bouvet 2012; Klinger and Weber 2016), skills mismatches (Abbritti and Consolo 2022; Bonthuis, Jarvis, and Vanhala 2016; Brunello and Wruuck 2019; Dolado, Jansen, and Jimeno 2009; Manacorda and Petrongolo 1999), geographical and regional mismatches (Manacorda and Petrongolo 2006; Owyang, Shell, and Soques 2022), occupational and industry mismatches (Christl, Köppl–Turyna, and Kucsera 2016; Mehrotra and Sergeyev 2012), technological progress, and globalization (Destefanis et al. 2020), among others.

III. Data and methodology

Data

Our research made use of monthly data extracted from Thomson Reuters Eikon-Datastream for G7 countries: Germany, Canada, the U.S.A., Japan, France, Italy, and the UK. The time series started in January 2002 and ended in October 2023 with the number of observations amounting to 262.

We tracked unemployment in terms of the number of people unemployed and used the number of job vacancies as an indicator of labour opportunities (see Tables A1 and A2). The difference between the labour supply and demand gives us key information about structural unemployment and mismatches in the labour market, but also regarding ups and downs in the economy.

Figures A1–A7 in the Appendix show the evolution of G7 unemployment and job openings. All cases present a decrease in unemployment after the Great Recession and COVID, and an increase in job vacancies after these two crises. However, the intensity is far higher in the US and lower in France and Italy. Note that the figures are measured in thousands (person for unemployed and vacancies for job openings), but we have transformed them in logs in order to stabilize the variance.

Furthermore, we have also applied the analysis using the unemployment rate and the job vacancies rate. In Figures A8–A14 in the Appendix, we observe the classical negative slope of the Beveridge Curve for each country. However, some of them show mismatches with high

unemployment and high job openings in some periods (i.e. in U.S.A. mid-2020, Canada mid-2021, France end-2018, and Italy begin-2018 and mid-2021).

Methodology

In time series, fractional integration refers to expanding the idea of integration beyond the integer values (Gil-Alana 2006). In order to achieve stationarity, I (0), i.e. to eliminate the stochastic trend from the series, the integration of integer order into a time series requires sequential differencing of data. However, in some cases, integer order differencing is inadequate to prove stationarity, and fractional orders of integration must be addressed. Long-term memory patterns in time series, particularly those with nonlinear trends or showing progressive changes over time, can be recorded via fractional integration.

The fractional integration operator enhances integer order differencing by allowing non-integer orders. The complex gamma function and the Fourier transform are used to create the fractional differencing operator. This approach is useful in many fields of time series analysis, including finance, economics, hydrology, and telecommunications. It allows for the capturing of long-term memory qualities and offers a more adaptable tool for modelling and forecasting complex time series.

Specifically, the model analysed below is based on the following equation:

$$(1 - \mathrm{L})^{\mathrm{d}} x(\mathrm{t}) = \mathrm{u}(\mathrm{t}),\ \mathrm{t} = 0, \pm 1 \qquad (1)$$

where L represents the lag operator, i.e. $\mathrm{L}^{\mathrm{s}}\mathrm{x}(\mathrm{t}) = \mathrm{x}(\mathrm{t}\text{-}\mathrm{s})$, d is a real scalar, and where u(t) is a short memory I(0) process. In this context of fractional integration, d plays a crucial role as is taken as a measure of the degree of persistence in the data, noting that the polynomial in B in the left-hand side in Equation (1) can be expressed as:

$$(1 - B)^d = \sum_{j=0}^{\infty} \binom{d}{j} (-1)^j B^j = 1 - dB + \frac{d(d-1)}{2} B^2 - \ldots$$

and thus, if d is a fractional value, $\mathrm{x_t}$ can be expressed in terms of all its history, i.e.

$$(1 - B)^d x_t = x_t - dx_{t-1} + \frac{d(d-1)}{2} x_{t-2} - \ldots$$

Also, the representation in (1) admits an infinite MA form with the coefficients decaying hyperbolically slow to zero if d is smaller than 1. This implies that in this context the series is mean reverting with exogenous shocks disappearing in the long run. On the other hand, if d is equal to or higher than 1, there is no mean reversion, with shocks persisting forever.

Note that fractional integration is a very flexible approach in the sense that it is more general than the standard methods based on integer degrees of differentiation or unit roots. Moreover, allowing d to be a fractional value in (1) permits us to consider cases like those of nonstationary series and mean reverting if the differencing parameter d is in the interval (0.5, 1). Moreover, unemployment is likely to be a very persistent variable and the use of fractional integration has been widely used to explain its behaviour (van Dijk, Franses, and Paap 2002; Gil-Alana and Henry 2003; Leipus et al. (2014), Caporale, Gil-Alana, and Lovcha 2016; Cuestas and Gil-Alana 2023; etc.).

In addition, the x(t) process may contain deterministic terms like a constant and/or a linear time trend, i.e.

$$\mathrm{y}(\mathrm{t}) = \alpha + \beta \mathrm{t} + \mathrm{x}(\mathrm{t}) \qquad (2)$$

where α and β are parameters to be estimated from the data.

The estimation is conducted via Whittle function in the frequency domain by using a testing approach developed in Robinson (1994) and widely used in the empirical work. This method is a testing procedure based on the Lagrange Multiplier (LM) principle and has numerous advantages in relation with other approaches. In particular, it has a standard null and local limit distributions, being unaffected these regular distributions by the inclusion of deterministic terms like those described in Equation (2). This method permits us to test any real value d in (1) including those values outside the stationary region ($\mathrm{d} \geq 0.5$) and it is the most efficient one in the Pitman sense against local departures from the null.

IV. Empirical results

As a preliminary step in the analysis, we conducted several unit root tests on the series. Thus, we conducted ADF (Dickey and Fuller 1979; Phillips and Perron 1988) and (Elliott, Rothenberg, and Stock 1996) tests and the results supported the hypothesis of nonstationary and thus evidence of unit roots in all cases. Nevertheless, it should be considered that these tests have very low power if the data are in fact fractionally integrated as demonstrated in Diebold and Rudebush (1991), Hassler and Wolters (1994) and Lee and Schmidt (!996) among many others. This is in fact the main argument for the use of fractional integration in what follows.

Table 1 presents the G7 country estimates of the differencing parameter d taking a seasonal autoregressive approach for u(t) in (1) for unemployment and vacancies, and the spread of unemployment and vacancies (in logs). Thus, the estimated model is as follows:

$$y(t) = \alpha + \beta\, t + x(t),\ (1-L)^{d}x(t) = u(t),$$
$$u(t) = \rho u(t-12) + \varepsilon(t) \qquad (3)$$

The table displays the results with 95% confidence bands for the three cases studied in the literature (no terms, a constant, and a constant with a linear time trend), displaying in bold the one selected for each series. Starting with the unemployment series, we observe that the time trend coefficient is significant only in the case of Japan and that the estimates of d are relatively high in all cases. In fact, the I(1) hypothesis cannot be rejected for Japan (d = 0.95), Italy (1.04) and the US (1.05), while this hypothesis is rejected in favour of values of d above 1 in the remaining countries. As unemployment shows a downward trend in the time series examined, the economic growth during these years has had a positive impact on G7 labour markets. For vacancies, the estimates of d are also very high but mean reversion is present in the US case, with an estimated value of d being significantly below 1. For the remaining cases, the unit root null hypothesis either cannot be rejected (France and Japan) or is rejected in favour of d > 1 (Canada, Germany, Italy, and the UK). Looking at the differences between the two series, high levels of persistence are again observed and no evidence of reversion to the mean is found in any case. According to this table, the reduction of the imbalance of unemployment-vacancies is permanent, a positive outcome for advanced economies. In this regard, the log difference between U&V is

Table 1. Estimates of the order of integration d. Seasonal AR.

Country	No terms	A constant	A constant with a time trend
i) Unemployment (in logs)			
CANADA	0.98 (0.90, 1.09)	**1.29 (1.15, 1.49)**	1.29 (1.15, 1.49)
FRANCE	0.98 (0.89, 1.09)	**1.23 (1.13, 1.37)**	1.23 (1.13, 1.37)
GERMANY	0.98 (0.88, 1.08)	**1.47 (1.33, 1.65)**	1.47 (1.33, 1.64)
ITALY	0.98 (0.89, 1.09)	**1.04 (0.97, 1.13)**	1.04 (0.97, 1.13)
JAPAN	0.99 (0.90, 1.09)	0.95 (0.89, 1.03)	**0.95 (0.89, 1.03)**
UK	0.99 (0.90, 1.09)	**1.33 (1.27, 1.42)**	1.33 (1.27, 1.42)
U.S.A.	0.99 (0.90, 1.09)	**1.05 (0.94, 1.18)**	1.05 (0.94, 1.18)
ii) Vacancies (in logs)			
CANADA	0.95 (0.82, 1.13)	**1.82 (1.61, 2.10)**	1.87 (1.64, 2.14)
FRANCE	0.99 (0.91, 1.09)	**0.86 (0.74, 1.03)**	0.86 (0.74, 1.03)
GERMANY	0.98 (0.90, 1.08)	**1.64 (1.56, 1.74)**	1.64 (1.55, 1.74)
ITALY	0.97 (0.83, 1.16)	**1.47 (1.21, 1.85)**	1.47 (1.21, 1.85)
JAPAN	0.99 (0.90, 1.09)	**0.97 (0.91, 1.05)**	0.98 (0.92, 1.05)
UK	0.99 (0.90, 1.09)	**1.68 (1.49, 1.92)**	1.68 (1.49, 1.92)
U.S.A.	0.95 (0.87, 1.06)	0.78 (0.71, 0.86)	**0.77 (0.70, 0.85)***
iii) Differences (log Unemployment – log Vacancies)			
CANADA	1.12 (0.98, 1.32)	**1.46 (1.25, 1.78)**	1.47 (1.25, 1.78)
FRANCE	0.95 (0.95, 1.07)	**0.94 (0.83, 1.10)**	0.94 (0.83, 1.10)
GERMANY	1.02 (1.02, 1.12)	**1.63 (1.51, 1.78)**	1.63 (1.51, 1.78)
ITALY	0.96 (0.96, 1.17)	**1.32 (1.02, 1.86)**	1.32 (1.02, 1.86)
JAPAN	1.01 (1.01, 1.11)	**1.05 (0.99, 1.12)**	1.05 (0.99, 1.12)
UK	1.25 (1.25, 1.37)	**1.65 (1.51, 1.83)**	1.65 (1.51, 1.83)
U.S.A.	0.98 (0.89, 1.09)	**0.96 (0.87, 1.07)**	0.96 (0.87, 1.07)

The values in parenthesis in columns 2, 3 and 4 refer to the 95% confidence intervals of the estimates of d. In bold, the estimates correspond to the selected specification for each series. *: Evidence of mean reversion at the 95% level.

referred to the slope of the Beveridge Curve (see Figure A8–A14 in the Appendix). Higher slope will mean a recessive business cycle and lesser slope will represent an expansive business cycle.

In Appendix C we report the results based on the rates, and as you can see, they are completely in line with those reported in Table 1.

These results are also confirmed in Table 2 showing the estimates of the order of integration d considering the Bloomfield (1973) model for the error term in (1). This is a non-parametric approach used to consider the weak dependence in u(t). It is non-parametric because it does not have an explicit functional form, simply defined in terms of its spectral density function that is,

$$f(\lambda;\tau) = \left[\frac{\sigma 2}{2\pi}\right] \exp[2\sum_{i=0}^{n} \tau_i \cos(\lambda i)], \qquad (4)$$

where σ^2 is the variance of the error term and n indicates the number of the short run dynamics. The logged form of the above expressions was found to be a well-behaved function with a form very close to the one produced by a stationary and invertible ARMA (p, q) process of form when p and q are small values. Moreover, this form does not require the estimation of so many parameters as in the ARMA models, which always results tedious in terms of estimation, testing and model specification. In addition, the model of Bloomfield (1973) is stationary across all its values (See, Gil-Alana 2004). Most notably, the values are now generally lower than in the previous table. For unemployment, mean reversion (d < 1) takes place in the cases of Canada (d = 0.77), Germany (d = 0.55) and the US (D = 0.83), while d is in the I(1) interval or above 1 in the remaining cases. For vacancies, France is the only country showing mean reversion and also, along with Italy, displays this property in the difference between the two series. The same behaviour is observed when using the rates in Appendix C.

V. Conclusion and discussion

The primary aim of this article was to analyse the labour markets of the G7 countries between January 2002 and October 2023 and to identify whether shocks present with a temporary or permanent effect on unemployment, job vacancies, and the spread of unemployment-vacancies. We used fractional integration techniques to discover the indicators' mean-reversion tendency. The principal findings of the research are as follows:

Table 2. Estimates of the order of integration d. Bloomfield errors.

Country	No terms	A constant	A constant with a time trend
i) Unemployment (in logs)			
CANADA	0.95 (0.83, 1.12)	**0.77 (0.63, 0.96)***	0.77 (0.62, 0.96)
FRANCE	0.97 (0.83, 1.13)	**1.02 (0.91, 1.14)**	1.02 (0.91, 1.14)
GERMANY	0.96 (0.85, 1.12)	0.62 (0.55, 0.72)	**0.55 (0.44, 0.70)***
ITALY	0.96 (0.83, 1.15)	**0.99 (0.91, 1.11)**	0.99 (0.91, 1.11)
JAPAN	0.95 (0.84, 1.12)	**1.03 (0.91, 1.20)**	1.03 (0.92, 1.20)
UK	0.97 (0.85, 1.14)	**1.45 (1.30, 1.66)**	1.45 (1.30, 1.66)
U.S.A.	0.96 (0.84, 1.13)	**0.83 (0.70, 0.99)***	0.83 (0.69, 0.99)
ii) Vacancies (in logs)			
CANADA	0.87 (0.63, 1.17)	**1.13 (0.85, 1.62)**	1.16 (0.78, 1.61)
FRANCE	0.95 (0.83, 1.13)	**0.44 (0.31, 0.60)***	0.45 (0.33, 0.60)
GERMANY	0.94 (0.81, 1.12)	**1.65 (1.50, 1.85)**	1.64 (1.49, 1.84)
ITALY	0.90 (0.65, 1.21)	0.88 (0.62, 1.25)	**0.88 (0.65, 1.25)**
JAPAN	0.95 (0.79, 1.14)	**1.24 (1.10, 1.41)**	1.24 (1.10, 1.40)
UK	0.96 (0.84, 1.13)	**1.02 (0.86, 1.24)**	1.02 (0.85, 1.24)
U.S.A.	0.97 (0.84, 1.15)	**0.93 (0.80, 1.11)**	0.92 (0.79, 1.11)
iii) Differences (log Unemployment – log Vacancies)			
CANADA	0.98 (0.75, 1.31)	0.92 (0.71, 1.22)	**0.91 (0.67, 1.22)**
FRANCE	0.80 (0.69, 0.97)	**0.59 (0.49, 0.72)***	0.59 (0.48, 0.72)
GERMANY	1.03 (0.92, 1.18)	**1.04 (0.93, 1.20)**	1.04 (0.92, 1.20)
ITALY	0.86 (0.60, 1.19)	0.62 (0.47, 0.84)	**0.56 (0.37, 0.83)***
JAPAN	0.96 (0.83, 1.13)	**1.27 (1.15, 1.41)**	1.27 (1.14, 1.41)
UK	1.16 (1.00, 1.38)	**1.24 (1.09, 1.44)**	1.24 (1.10, 1.44)
U.S.A.	0.89 (0.77, 1.05)	**0.90 (0.78, 1.07)**	0.90 (0.77, 1.07)

The values in parenthesis in columns 2, 3 and 4 refer to the 95% confidence intervals of the estimates of d. In bold, the estimates correspond to the selected specification for each series. *: Evidence of mean reversion at the 95% level.

- All G7 economies show downward trends in unemployment and upward trends in job vacancies after the Great Recession and COVID. Thus, we observe a decline in the spread of unemployment-vacancies which may indicate fewer problems of structural unemployment.
- Applying an ARFIMA model, the time series analysed show long memory and high levels of persistence. Thus, G7 countries show not only an improvement in their labour markets but this improvement appears permanent during the time series considered. In fact, looking at the differences between U&V, high levels of persistence are observed, and no evidence of mean reversion is found in any case. Thus, the reduction of the imbalance of unemployment-vacancies is permanent, what may improve hysteresis problems.
- However, the results differ slightly depending on the specification of the error term. If it is white noise, no evidence of mean reversion is seen in any scenario except for US unemployment. Under autocorrelated disturbances, reversion to the mean is found in unemployment in Canada, Germany, and the US. In France, this was found for vacancies, and in France and Italy, it was found for the difference between the two series.
- Of the three series analysed, the United Kingdom was the only G7 nation not showing any degree of mean reversion.
- Very similar results were obtained when working with unlogged values and rates, although the number of cases with mean reversion was higher than in the differenced series.

From a policy perspective, the foregoing results suggest that active labour market policies would have a significant impact on improving matching efficiency. Especially if policies reduce skills gaps and are focused on the long-term unemployed (Bova, Tovar Jalles, and Kolerus 2018). Nevertheless, due to the current tightening monetary policy, it may be possible that persistence can be modified. Although the data is still insufficient to assess a break in tendency and persistence.

In addition, from a methodological viewpoint, the development of alternative approaches, such as non-linear models or structural breaks, can be used to analyse whether shocks like the 2008 financial crisis or the pandemic have affected all behaviours of the series. It is a well-known stylized fact that fractional integration and nonlinearities/breaks are issues which may be intimately related (e.g. Granger and Hyung 2004). Moreover, the possibility of cointegration between unemployment and vacancies, and more in particular, the issue of fractional cointegration (see, e.g. the fractional CVAR, FCVAR approach of Johansen and Nielsen 2010, 2012) between the two variables is another line of potential research in the future. The analysis of these points might provide added value to the research described in this paper.

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Appendices

Appendix A

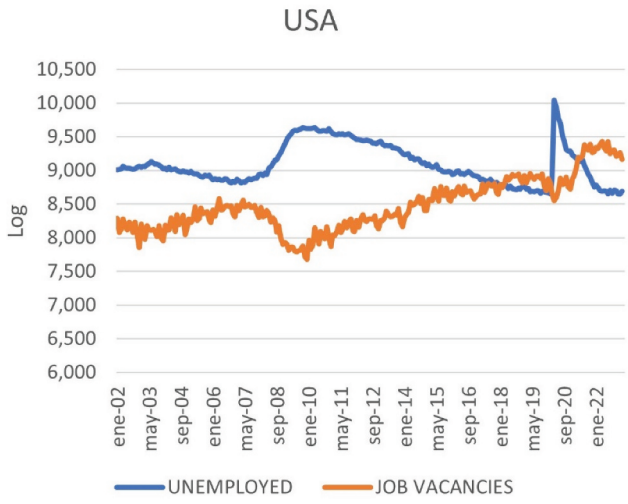

Figure A1. Unemployed & job vacancies in U.S.A.

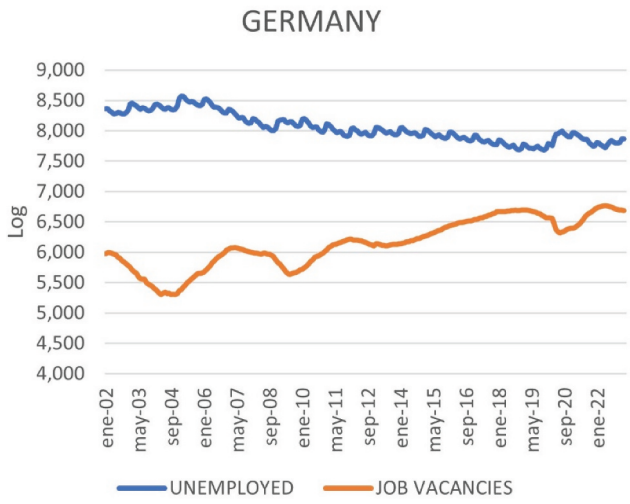

Figure A2. Unemployed & job vacancies in Germany.

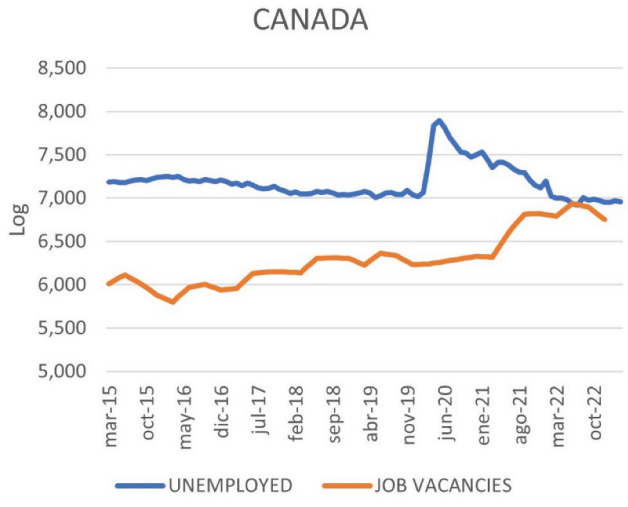

Figure A3. Unemployed & job vacancies in Canada.

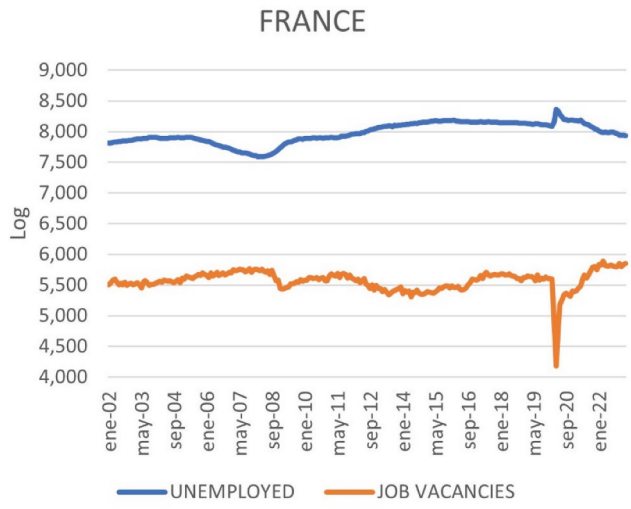

Figure A4. Unemployed & job vacancies in France.

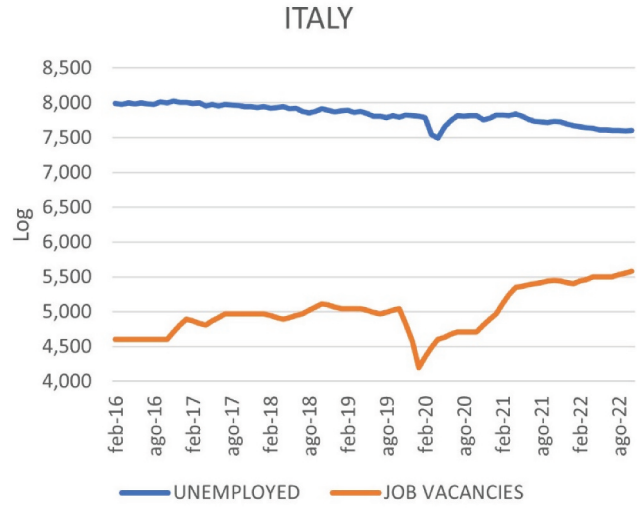

Figure A5. Unemployed & job vacancies in Italy.

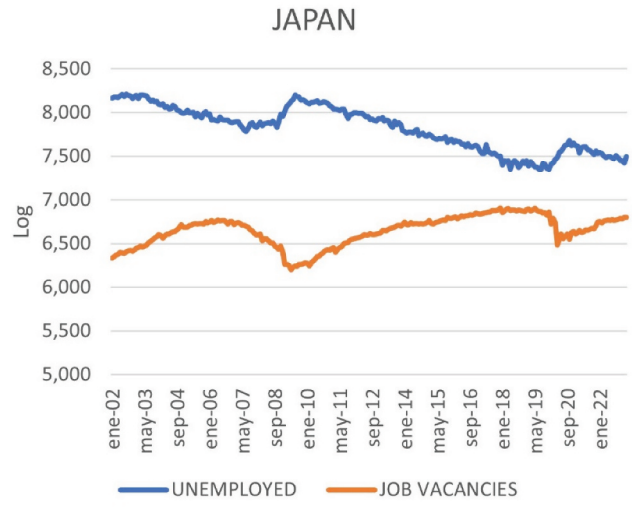

Figure A6. Unemployed & job vacancies in Japan para.

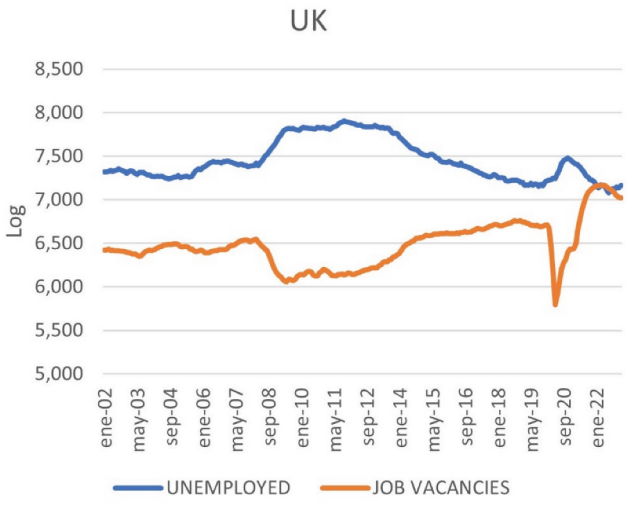

Figure A7. Unemployed & job vacancies in UK.

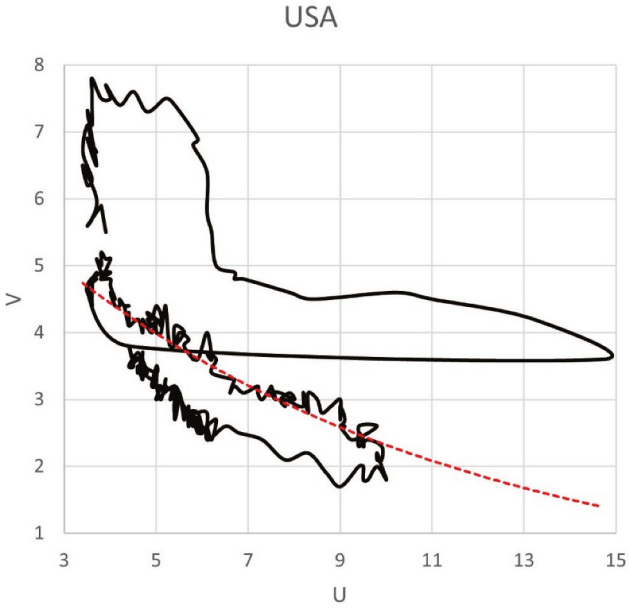

Figure A8. Beveridge Curve in U.S.A. U is unemployment rate and V refers to job vacancies rate. Furthermore, the non-linear trend shows the negative slope of the BC.

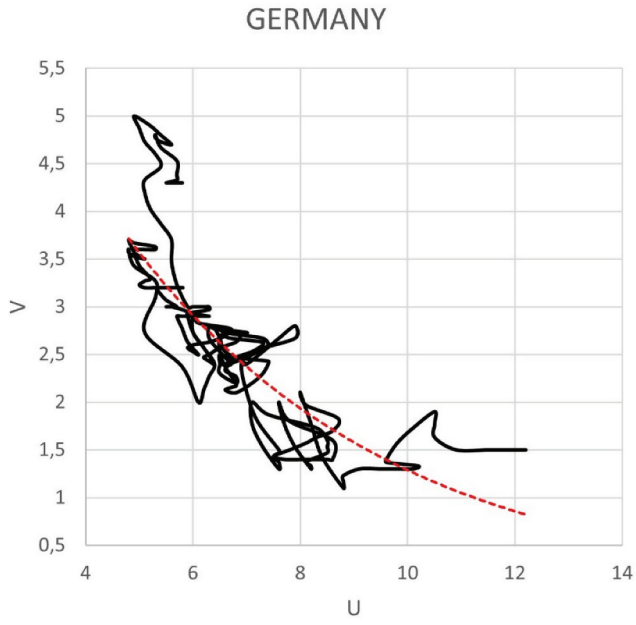

Figure A9. Beveridge curve in Germany. U is unemployment rate and V refers to job vacancies rate. Furthermore, the non-linear trend shows the negative slope of the BC.

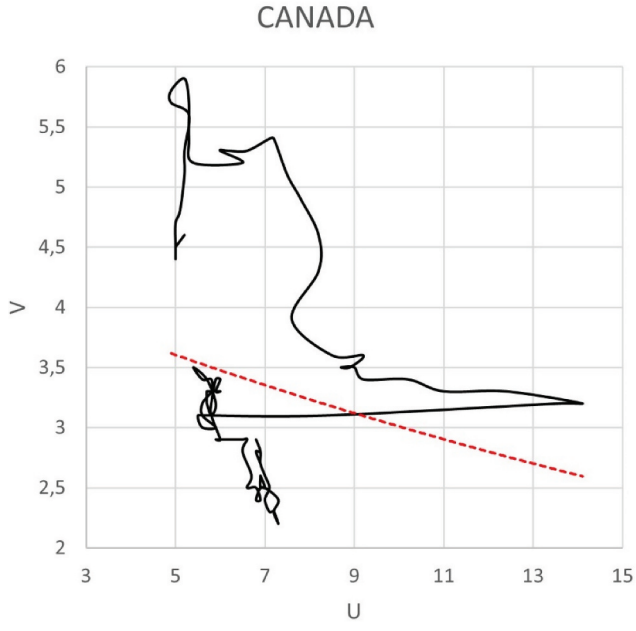

Figure A10. Beveridge curve in Canada para. U is unemployment rate and V refers to job vacancies rate. Furthermore, the non-linear trend shows the negative slope of the BC.

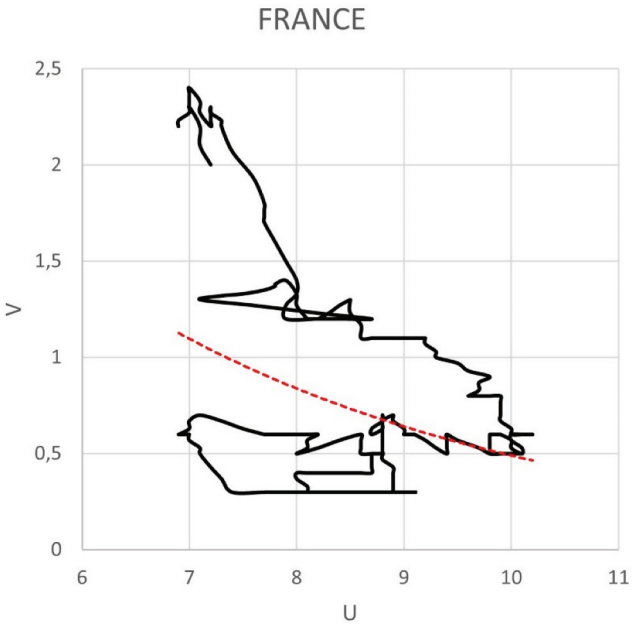

Figure A11. Beveridge curve in France. U is unemployment rate and V refers to job vacancies rate. Furthermore, the non-linear trend shows the negative slope of the BC.

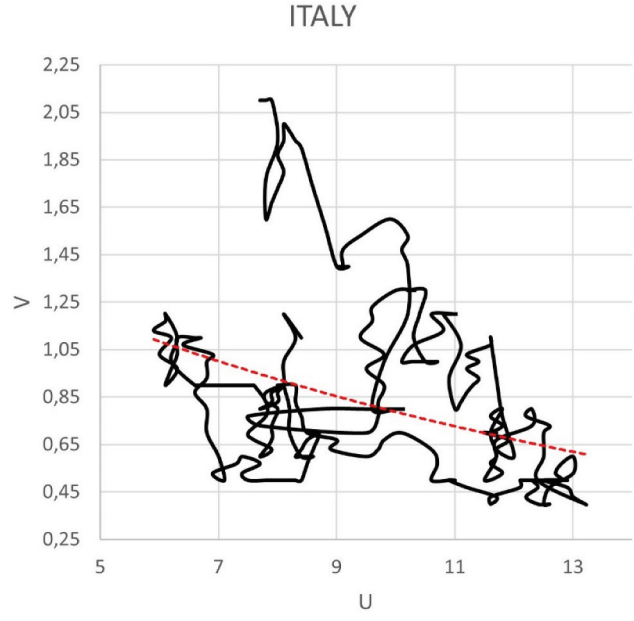

Figure A12. Beveridge curve in Italy. U is unemployment rate and V refers to job vacancies rate. Furthermore, the non-linear trend shows the negative slope of the BC.

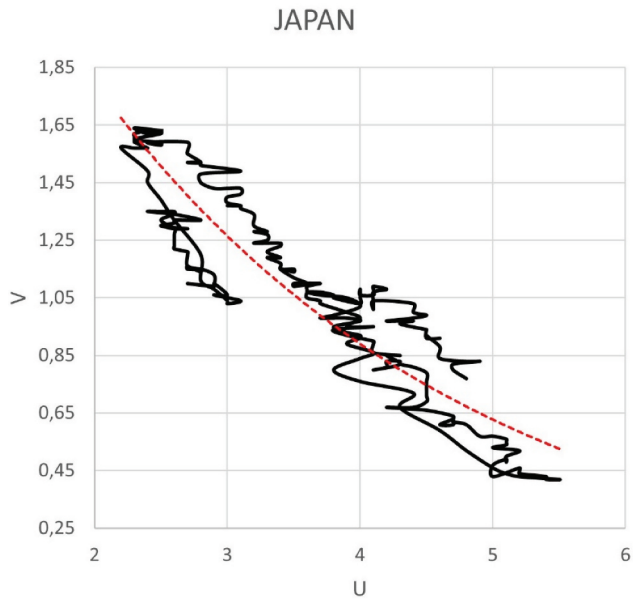

Figure A13. Beveridge curve in Japan. U is unemployment rate and V refers to job vacancies rate. Furthermore, the non-linear trend shows the negative slope of the BC.

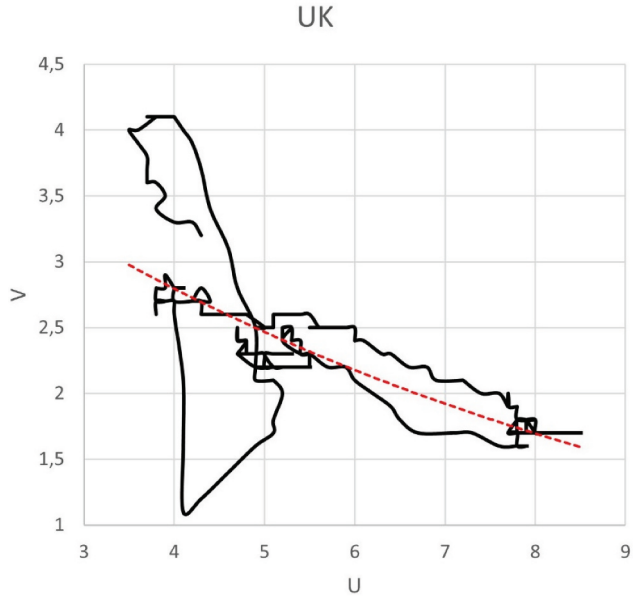

Figure A14. Beveridge curve in UK. U is unemployment rate and V refers to job vacancies rate. Furthermore, the non-linear trend shows the negative slope of the BC.

Table A1. Data description I: unemployment.

Variable	Definition	Description
Unemployed in Germany	This is the registered unemployed, defined in the statistics collected by the Federal Employment Office and based on the register of persons out of work are all those persons who have reached the age of 15 but not yet the age of 65 who have no job or only a part-time job (at present less than 15 hours a week) and are looking for a job subject to compulsory insurance with a working time of no less than 15 hours a week. They must have registered at the appropriate job centre and must not be certified as unfit for work.	Data from Deutsche Bundesbank. First measured in thousands person, and then using rates as a percentage of labour force population. Seasonally adjusted.
Unemployed in Canada	Unemployed persons are those who, during reference week: a) were on temporary layoff during the reference week with an expectation of recall and were available for work, or b) were without work, had actively looked for work in the past four weeks, and were available for work, or c) had a new job to start within four weeks from reference week, and were available for work.	Data from CANSIM – Statistics Canada. First measured in thousands person, and then using rates as a percentage of labour force population. Seasonally adjusted.
Unemployed in USA	Persons aged 16 years and older who had no employment during the reference week, were available for work, except for temporary illness, and had made specific efforts to find employment sometime during the 4-week period ending with the reference week. Persons who were waiting to be recalled to a job from which they had been laid off need not have been looking for work to be classified as unemployed.	Data from Bureau of Labour Statistics. First measured in thousands person, and then using rates as a percentage of labour force population. Seasonally adjusted.
Unemployed in Japan	Unemployed persons (persons who have no job, are looking for a job, and are ready to work immediately is a job is available). Unemployed persons consist of all persons above a certain age who (1) do not hold a job – are neither paid employed persons nor self-employed persons (2) can actually work – can engage in paid employment or self-employment (3) looked for a job – took special measures to engage in paid employment or self-employment.	Data from Ministry of Internal Affairs and Communications. First measured in thousands person, and then using rates as a percentage of labour force population. Seasonally adjusted.
Unemployed in France	Jobseekers are people who are registered with «Pôle emploi». Registration on the «Pôle emploi» lists is subject to certain conditions, but jobseekers may or may not be receiving compensation, and some may be in employment. Depending on their situation with regard to the obligation to seek employment and whether or not they are in employment, they are grouped into five categories: category A includes jobless jobseekers obliged to actively seek a job; category B includes jobseekers having performed a short-term reduced activity and obliged to actively seek a job (i.e. 78 hours or less in the course of the month); category C includes jobseekers having performed a long-term reduced activity and obliged to actively seek a job (i.e. more than 78 hours in the course of the month); category D includes jobless jobseekers not obliged to actively seek a job (because of an internship, a training course, an illness, etc.) Including the jobseekers in agreement of personalized reclassifying (CRP), in contract of professional transition (CTP) and in professional safeguard contract (CSP); category E includes employed jobseekers not obliged to actively seek a job (for example: beneficiaries of subsidized contracts, business creators).	Data from DARES – Direction de l'animation de la recherche, des etudes et des statistiques. First measured in thousands person, and then using rates as a percentage of labour force population. Seasonally adjusted.
Unemployed in Italy	Unemployed persons 15 years and more. Persons who have no job, are looking for a job, and are ready to work immediately is a job is available.	Data from Istat – National Institute of Statistics. First measured in thousands person, and then using rates as a percentage of labour force population. Seasonally adjusted.
Unemployed in UK	The definition of unemployment covers people who are: not in employment, want a job, have actively sought work in the previous four weeks and are available to start work within the next fortnight or; out of work and have accepted a job which they are waiting to start next fortnight.	Data from ONS – Office for National Statistics. First measured in thousands person, and then using rates as a percentage of labour force population. Seasonally adjusted.

Table A2. Data description II: job vacancies.

Variable	Definition	Description
Job vacancies in Germany	A job opening requires that: 1) a specific position exists and there is work available for that position; 2) work could start within 30 days regardless of whether a suitable candidate is found; and 3) the employer is actively recruiting from outside the establishment to fill the position.	Data from Deutsche Bundesbank. First measured in thousands, and then using rates as a percentage of total number of jobs. Seasonally adjusted.
Job vacancies in Canada	A job opening requires that: 1) a specific position exists and there is work available for that position; 2) work could start within 30 days regardless of whether a suitable candidate is found; and 3) the employer is actively recruiting from outside the establishment to fill the position.	Data from CANSIM – Statistics Canada. First measured in thousands, and then using rates as a percentage of total number of jobs. Seasonally adjusted and monthly interpolated.
Job vacancies in USA	A job opening requires that: 1) a specific position exists and there is work available for that position; 2) work could start within 30 days regardless of whether a suitable candidate is found; and 3) the employer is actively recruiting from outside the establishment to fill the position.	Data from Bureau of Labour Statistics. First measured in thousands, and then using rates as a percentage of total number of jobs. Seasonally adjusted.
Job vacancies in Japan	A job opening requires that: 1) a specific position exists and there is work available for that position; 2) work could start within 30 days regardless of whether a suitable candidate is found; and 3) the employer is actively recruiting from outside the establishment to fill the position.	Data from Ministry of Health, Labour and Welfare. First measured in thousands, and then using rates as a percentage of total number of jobs. Seasonally adjusted.
Job vacancies in France	A job opening requires that: 1) a specific position exists and there is work available for that position; 2) work could start within 30 days regardless of whether a suitable candidate is found; and 3) the employer is actively recruiting from outside the establishment to fill the position.	Data from DARES – Direction de l'animation de la recherche, des etudes et des statistiques. First measured in thousands, and then using rates as a percentage of total number of jobs. Seasonally adjusted.
Job vacancies in Italy	A job opening requires that: 1) a specific position exists and there is work available for that position; 2) work could start within 30 days regardless of whether a suitable candidate is found; and 3) the employer is actively recruiting from outside the establishment to fill the position.	Data from Eurostat. First measured in thousands, and then using rates as a percentage of total number of jobs. Seasonally adjusted and monthly interpolated.
Job vacancies in UK	A job opening requires that: 1) a specific position exists and there is work available for that position; 2) work could start within 30 days regardless of whether a suitable candidate is found; and 3) the employer is actively recruiting from outside the establishment to fill the position.	Data from ONS – Office for National Statistics. First measured in thousands, and then using rates as a percentage of total number of jobs. Excludes agriculture, forestry, and fishing. Seasonally adjusted.

Appendix B

Table B1. Estimates of the differencing parameter d. Seasonal AR (Results based on the original data).

Country	No terms	A constant	A constant with a time trend
i) Unemployment			
CANADA	1.10 (0.98, 1.25)	**1.36 (1.18, 1.61)**	1.36 (1.18, 1.61)
FRANCE	0.99 (0.90, 1.10)	**1.14 (1.03, 1.28)**	1.14 (1.03, 1.28)
GERMANY	0.97 (0.88, 1.09)	**1.54 (1.38, 1.73)**	1.53 (1.38, 1.73)
ITALY	0.96 (0.88, 1.07)	**1.03 (0.97, 1.12)**	1.03 (0.97, 1.12)
JAPAN	1.01 (0.93, 1.12)	**0.98 (0.92, 1.07)**	0.98 (0.92, 1.06)
UK	1.07 (0.98, 1.18)	**1.38 (1.31, 1.47)**	1.38 (1.31, 1.47)
USA	0.94 (0.85, 1.07)	**0.93 (0.83, 1.06)**	0.93 (0.83, 1.06)
ii) Vacancies			
CANADA	0.98 (0.84, 1.19)	**1.87 (1.67, 2.15)**	1.89 (1.68, 2.16)
FRANCE	1.00 (0.91, 1.11)	**0.93 (0.83, 1.10)**	0.93 (0.83, 1.05)
GERMANY	1.08 (0.99, 1.18)	**1.65 (1.56, 1.77)**	1.65 (1.56, 1.77)
ITALY	1.18 (1.03, 1.41)	**1.67 (1.40, 2.04)**	1.67 (1.40, 2.04)
JAPAN	0.99 (0.92, 1.08)	**0.95 (0.89, 1.02)**	0.95 (0.90, 1.02)
UK	1.15 (1.06, 1.26)	**1.91 (1.72, 2.14)**	1.91 (1.72, 2.14)
USA	0.82 (0.74, 0.90)	**0.87 (0.80, 0.96)**	0.87 (0.79, 0.96)
iii) Differences (log Unemployment – log Vacancies)			
CANADA	1.23 (1.04, 1.52)	**1.45 (1.17, 1.89)**	1.45 (1.18, 1.89)
FRANCE	1.00 (0.91, 1.11)	**1.16 (1.04, 1.32)**	1.16 (1.04, 1.32)
GERMANY	0.99 (0.90, 1.10)	**1.58 (1.43, 1.77)**	1.58 (1.43, 1.77)
ITALY	1.01 (0.87, 1.23)	0.84 (0.48, 1.25)	**0.78 (0.44, 1.25)**
JAPAN	1.02 (0.94, 1.12)	**1.04 (0.97, 1.11)**	1.04 (0.97, 1.11)
UK	1.25 (1.17, 1.35)	**1.55 (1.47, 1.65)**	1.55 (1.47, 1.65)
USA	0.97 (0.87, 1.09)	**0.95 (0.86, 1.07)**	0.95 (0.85, 1.07)

In bold, the selected specification for each series in relation with the deterministic terms

Table B2. Estimates of the differencing parameter d. Bloomfield errors (results based on the original data).

Country	No terms	A constant	A constant with a time trend
i) Unemployment			
CANADA	0.79 (0.63, 0.98)	**0.91 (0.48, 0.80)**	0.61 (0.47, 0.80)
FRANCE	0.92 (0.78, 1.10)	**0.91 (0.81, 1.02)**	0.91 (0.80, 1.02)
GERMANY	0.92 (0.81, 1.07)	0.63 (0.56, 0.74)	**0.57 (0.46, 0.72)**
ITALY	0.95 (0.82, 1.13)	**1.02 (0.92, 1.14)**	1.02 (0.92, 1.14)
JAPAN	0.97 (0.84, 1.14)	**1.07 (0.93, 1.23)**	1.07 (0.94, 1.23)
UK	1.06 (0.93, 1.24)	**1.49 (1.34, 1.68)**	1.49 (1.34, 1.69)
USA	0.77 (0.65 0.94)	**0.73 (0.60, 0.89)**	0.72 (0.60, 0.89)
ii) Vacancies (in logs)			
CANADA	0.82 (0.64, 41.12)	**1.22 (0.92, 1.70)**	1.22 (0.89, 1.71)
FRANCE	0.92 (0.80, 1.07)	**0.73 (0.61, 0.91)**	0.74 (0.62, 0.91)
GERMANY	1.05 (0.90, 1.26)	**1.54 (1.38, 1.71)**	1.54 (1.38, 1.71)
ITALY	1.00 (0.77, 1.34)	1.03 (0.80, 1.41)	**1.03 (0.81, 1.41)**
JAPAN	1.08 (0.96, 1.25)	**1.26 (1.13, 1.41)**	1.26 (1.12, 1.41)
UK	1.05 (0.91, 1.24)	**1.24 (1.05, 1.48)**	1.24 (1.05, 1.48)
USA	0.96 (0.84, 1.16)	**0.99 (0.86, 1.19)**	0.99 (0.84, 1.19)
iii) Differences (log Unemployment – log Vacancies)			
CANADA	0.77 (0.52, 1.10)	0.66 (0.42, 0.96)	**0.65 (0.42, 0.96)**
FRANCE	0.90 (0.76, 1.07)	**0.85 (0.76, 0.98)**	0.85 (0.75, 098)
GERMANY	0.93 (0.81, 1.07)	0.67 (0.60, 0.81)	**0.65 (0.52, 0.79)**
ITALY	0.86 (0.65, 1.22)	0.54 (0.43, 0.69)	**0.03 (−0.36, 0.47)**
JAPAN	0.97 (0.85, 1.14)	**1.17 (1.04, 1.34)**	1.17 (1.04, 1.35)
UK	1.31 (1.15, 1.51)	**1.63 (1.43, 1.84)**	1.63 (1.43, 1.84)
USA	0.80 (0.69, 0.96)	**0.77 (0.68, 0.95)**	0.80 (0.68, 0.95)

In bold, the selected specification for each series in relation with the deterministic terms.

Appendix C: Growth rates results

Table C1. Estimates of the order of integration d. Seasonal AR.

Country	No terms	A constant	A constant with a time trend
i) Unemployment Rate			
CANADA	1.02 (0.93, 1.13)	**1.27 (1.12, 1.47)**	1.27 (1.12, 1.47)
FRANCE	0.99 (0.91, 1.10)	**1.37 (1.25, 1.52)**	1.37 (1.25, 1.52)
GERMANY	0.95 (0.86, 1.06)	**1.39 (1.28, 1.52)**	1.39 (1.28, 1.52)
ITALY	0.98 (0.89, 1.08)	**1.03 (0.97, 1.12)**	1.03 (0.97, 1.12)
JAPAN	0.97 (0.90, 1.07)	0.96 (0.84, 1.02)	**0.96 (0.84, 1.02)**
UK	1.04 (0.95, 1.14)	**1.29 (1.21, 1.38)**	1.29 (1.22, 1.38)
USA	1.02 (0.93, 1.13)	**1.03 (0.93, 1.17)**	1.03 (0.93, 1.17)
ii) Job Vacancy Rate			
CANADA	1.01 (0.85, 1.15)	**1.40 (1.26, 1.59)**	1.40 (1.25, 1.58)
FRANCE	1.09 (0.92, 1.10)	**0.89 (0.82, 1.07)**	0.89 (0.82, 1.07)
GERMANY	0.97 (0.92, 1.10)	**1.64 (1.33, 1.78)**	1.64 (1.34, 1.79)
ITALY	1.02 (0.87, 1.19)	**1.65 (1.45, 1.89)**	1.65 (1.44, 1.87)
JAPAN	1.02 (0.91, 1.10)	**0.99 (0.88, 1.11)**	0.99 (0.88, 1.12)
UK	1.03 (0.91, 1.12)	**1.44 (1.31, 1.61)**	1.44 (1.32, 1.62)
USA	1.05 (0.89, 1.14)	0.85 (0.80, 0.91)	**0.84 (0.79, 0.91)***
iii) Differences (Unemployment Rate – Job Vacancy Rate)			
CANADA	1.21 (1.02, 1.52)	**1.37 (1.10, 1.82)**	1.37 (1.10, 1.84)
FRANCE	1.04 (0.96, 1.14)	**1.42 (1.30, 1.57)**	1.42 (1.31, 1.57)
GERMANY	0.97 (1.87, 1.11)	**1.56 (1.42, 1.72)**	1.54 (1.40, 1.70)
ITALY	0.97 (0.89, 1.10)	**1.08 (1.01, 1.16)**	1.08 (1.01, 1.16)
JAPAN	0.98 (1.90, 1.07)	**1.06 (0.99, 1.14)**	1.06 (0.99, 1.14)
UK	1.26 (1.18, 1.36)	**1.45 (1.38, 1.55)**	1.45 (1.38, 1.55)
USA	0.98 (0.88, 1.10)	**0.97 (0.88, 1.09)**	0.97 (0.88, 1.09)

The values in parenthesis in columns 2, 3 and 4 refer to the 95% confidence intervals of the estimates of d. In bold, the estimates correspond to the selected specification for each series. *: Evidence of mean reversion at the 95% level.

Table C2. Estimates of the order of integration d. Bloomfield errors.

Country	No terms	A constant	A constant with a time trend
i) Unemployment Rate			
CANADA	0.94 (0.81, 1.13)	**0.70 (0.57, 0.89)***	0.69 (0.56, 0.89)
FRANCE	0.97 (0.86, 1.14)	**1.12 (0.99, 1.29)**	1.12 (0.98, 1.29)
GERMANY	0.94 (0.83, 1.10)	0.64 (0.57, 0.73)	**0.58 (0.45, 0.72)***
ITALY	0.94 (0.81, 1.14)	**1.03 (0.95, 1.16)**	1.03 (0.95, 1.16)
JAPAN	0.97 (0.86, 1.14)	**1.01 (0.90, 1.15)**	1.01 (0.90, 1.15)
UK	1.04 (0.90, 1.22)	**1.38 (1.23, 1.55)**	1.38 (1.23, 1.54)
USA	0.94 (0.80, 1.11)	**0.83 (0.70, 0.99)***	0.83 (0.69, 0.99)
ii) Job Vacancy Rate			
CANADA	0.74 (0.52, 1.19)	**1.07 (0.89, 1.79)**	1.07 (0.89, 1.79)
FRANCE	1.00 (0.86, 1.17)	**0.56 (0.32, 0.77)***	0.56 (0.32, 0.77)*
GERMANY	0.93 (0.76, 1.09)	**1.49 (1.12, 1.51)**	1.49 (1.12, 1.51)
ITALY	0.99 (0.76, 1.13)	0.90 (0.68, 1.19)	**0.90 (0.68, 1.19)**
JAPAN	0.99 (0.83, 1.22)	**1.34 (1.05, 1.65)**	1.34 (1.05, 1.65)
UK	0.99 (0.84, 1.18)	**1.04 (0.87, 1.30)**	1.04 (0.87, 1.30)
USA	1.03 (0.90, 1.23)	**0.99 (0.79, 1.21)**	0.99 (0.79, 1.21)
iii) Differences (Unemployment Rate – Job Vacancy Rate)			
CANADA	0.73 (0.51, 1.01)	0.98 (0.74, 1.18)	**0.96 (0.62, 1.22)**
FRANCE	1.01 (0.89, 1.22)	**0.64 (0.50, 0.79)***	0.63 (0.55, 0.77)
GERMANY	0.83 (0.70, 1.02)	**1.09 (0.91, 1.38)**	1.09 (0.95, 1.24)
ITALY	0.99 (0.85, 1.18)	0.68 (0.44, 0.93)	**0.67 (0.39, 0.89)***
JAPAN	1.02 (0.90, 1.18)	**1.21 (1.08, 1.37)**	1.21 (1.09, 1.36)
UK	1.34 (1.17, 1.54)	**1.57 (1.38, 1.69)**	1.57 (1.3, 1.79)
USA	0.84 (0.72, 1.02)	**0.83 (0.71, 1.03)**	0.82 (0.73, 1.05)

The values in parenthesis in columns 2, 3 and 4 refer to the 95% confidence intervals of the estimates of d. In bold, the estimates correspond to the selected specification for each series. *: Evidence of mean reversion at the 95% level.