Output-Unemployment Asymmetry in Okun Coefficients for OECD Countries

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Abstract: Different asymmetries in Okun's law for 21 OECD countries over the period 1989 – 2019 are studied in the paper. To this end, an extended Okun equation accommodating possibly differentiated responsiveness to output and unemployment fluctuations is formulated applicable not only at the level of a whole economy, but also separately to gender-specific parts of the labor market in a system framework. For most of the countries, Okun's law asserts itself with a greater magnitude in years when output recedes than in those when it grows. In nearly all the countries, Okun's law is found stronger with decreases in unemployment and weaker or offset with rising unemployment. Finally, in the majority of the countries, male unemployment is more sensitive to output fluctuations than female unemployment, or there is no significant difference whatsoever.

Keywords: Okun's law, difference version, asymmetry, output-unemployment regimes.
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1. Introduction

In spite of some criticism and manifold reassessments, Okun's law enjoys its stable position in macroeconomic theory and applied economic policy. The criticism is not especially directed upon the fact that Okun's law is chiefly an empirically observed construct positing an inverse relationship between changes in output growth and changes in unemployment. To the contrary, it points out that the relationship need not be so simple, and emphasizes its non-linearity and time-varying features. It goes without saying that the intensity of output-unemployment fluctuations differs between economies (e.g., Freeman, 2001; Zanin and Marra, 2011; Ball et al., 2017), but there is also evidence of structural breaks in the presupposed empirical regularity (e.g., Lee, 2000; Huang and Chang, 2005), time-variance of Okun coefficients (e.g., Zanin and Marra, 2011; Huang and Lin, 2008; Boďa and Považanová, 2019) and even asymmetry over the business cycle (e.g., Cevik et al., 2013; Boďa et al., 2015; Silvapulle et al., 2004; Grant, 2018; Nebot et al., 2019). These patterns are attributable to changes in the institutional conditions affecting rigidity or causing distortions related to efficiency wages, unionization and employee protection, wage contracts, unemployment insurance, labor force participation or productivity (Silvapulle et al., 2004; Malley and Molana, 2008). Other studies highlight that the responsiveness of unemployment to business fluctuations is differentiated by gender and age cohorts (Peiró et al., 2012; Hutengs and Stadmann, 2013; Zanin, 2014; Marconi et al., 2016; Blázques-Fernández et al., 2018; Butkus and Seputiene, 2019; Dunsch, 2017). Studies on Okun's law often confine themselves to one economy (such as the US), but cross-country comparisons are popular as well, and these encompass several economies (such as the G7 or Visegrád Group countries) in a comparative fashion using typically a basal econometric framework. Yet, there are also studies that consider a possibility of the output-unemployment relationship being asymmetric by gender and the phase of the business cycle. In the latter area, examples are Belaire-Franch and Peiró (2015) who investigated this dual asymmetry for the UK and US, and Ben-Salha and Mrabet (2019) who undertook this analysis for four North African countries.

This paper is a comparative empirical study that examines for 21 OECD countries asymmetric features in Okun's law induced by different fluctuations of male and female unemployment and different directions of economic activity. Hence it is one of the few comparative studies with such a large number of countries. Although there is currently a plethora of statistical approaches suitable for modeling asymmetries in regression equations (such as threshold or Markov-switching models), the current study reposes upon an easily replicable methodology that permits capturing in a coherent manner different kinds of asymmetries. These asymmetries include not only different gender-specific reactions of unemployment to output fluctuations, but also possible departures of Okun's law from the presumed inverse relationship between output and unemployment. More precisely, albeit unemployment interacts counter-cyclically with output growth, there are well documented cases when this is not observed such as jobless recovery or labor hoarding (Ball et al., 2009; International Monetary Fund, 2010; Gordon, 2010; Oh, 2018). Using annual data for 31 years from 1989 to 2019, the focus is upon the difference version of Okun's law with extended equations for both male and female unemployment. A simple statistical framework is utilized in order to assure the comparability of the present results with those established by the previous scant studies. Okun's law continues to be in the forefront of applied economics. Yet, it is certainly unsatisfactory that many researchers commit advanced methodologies to the estimation of Okun equations in response to finesses and peculiarities of the output-unemployment relationship, which precludes the comparability of their estimated equations. Nevertheless, Okun coefficients coming from the extended equations are compatible with those originating from the basic difference equation estimated in conjunction with ordinary least squares (OLS) that remain a baseline combination for most applications. In addition, the paper discusses the ascertained differences and offers explanations for the observed gender-based and asymmetries in output and unemployment fluctuations.

The basic finding is that Okun's law does tend to vary in strength for genders and for changes in output and unemployment, which is reflected in Okun coefficients measuring responsiveness of unemployment to output fluctuations. For most or almost all of the countries, Okun's law seems stronger in years when output falls ("recessionary years") and in years when unemployment decreases. Likewise, males seem more sensitive to output fluctuations than females.

The remainder of the paper is organized into three more sections. Whilst Section 2 outlines the extended Okun equations and justifies the statistical framework, Section 3 describes the data and presents the empirical results. Finally, Section 4 discusses and Section 5 draws conclusions.

2. Modelling Framework

Two variants of Okun's law have been applied in analyzing the output-unemployment relationship, i.e. the general gap version and the simplified difference version. Albeit the former is certainly appealing as it operates directly with business cycle metrics, the output gap and the unemployment gap, its empirical application is troubled by the need to identify both the potential rate of output growth and the natural rate of unemployment. It turns out, however, that it is difficult to provide credible and generally agreed-upon estimates of these latent or unobservable variables (Zanin and Marra, 2011, pp. 92-93; Grant, 2018, p. 292; Silvapulle et al., 2004, pp. 359-360). To attenuate this problem, the simpler difference version is favoured here and estimated by OLS, as is conventional in other studies (e.g., Izyumov and Vahaly, 2002; Gabrisch and Buscher, 2006; Hutengs and Stadmann, 2013; Durech et al., 2014; Zanin, 2014; Marconi et al., 2015; Ball et al., 2017). A static Okun equation is typically estimated where the arrangement of the regressand and regressor plays a minor role since Okun's law in itself does not imply causation, but merely contemporaneous co-movement or correlation. The formula applied here reads

$$\Delta \mathrm{u}_t = a + b\Delta \mathrm{y}_t + \varepsilon_t, \tag{1}$$

in which u_t and y_t are the unemployment rate and the logarithm of real output at time t, a and b are unknown constants, and $\varepsilon_t \sim (0,\delta)$ is a random disturbance generated by a white noise process (with $\delta > 0$). Whereas the intercept a is sometimes simply dropped from the formula, the slope b is the parameter of interest that is referred to as the Okun coefficient and the counter-cyclicality of unemployment predicts that b is negative. With annual data, $\Delta \mathrm{y}_t$

and Δu_t are output growth rate and yearly increment or decrement of the unemployment rate. Specification (1) imposes that there is a universal Okun coefficient b for all configurations of economic activity irrespective of recessionary and conjunctural states. In contrast, the current stance of research is that Okun's law exhibits asymmetric effects of business fluctuations upon unemployment (e.g., Silvapulle et al., 2004; Zanin and Marra, 2012; p. 92; Boďa et al., 2015) and that these asymmetries present themselves in the male and female segments of the labor market (Peiró et al., 2012; Zanin, 2014; Belaire-Franch and Peiró, 2015; Razzu and Singleton, 2016). Nonetheless, there is no systematic manifestation of these asymmetries, the empirical testimony is mixed and so are the theoretical concepts devised to explain them (Silvapulle et al., 2004, pp. 355-358; Nebot et al., 2019, pp. 210-211)

This paper begins with a specification that accommodates possibly different responses of unemployment to positive or negative changes in output and that recognizes that these responses may differ according as unemployment rises or falls. The reason being, there are periods where product and unemployment evolve counter-intuitively and are pro-cyclical; product and unemployment either both rise, or they both fall. Such a non-conventional constellation when $\Delta y > 0$ & $\Delta u > 0$ or $\Delta y < 0$ & $\Delta u < 0$ (equivalently and uniformly written as $\Delta y \cdot \Delta u > 0$) is demonstrated for the selected 21 OECD economies in Appendix A. The last column of the table shows the number of years between 1989 and 2019 in which product and unemployment were pro-cyclical. It is not uncommon that up to one third of the investigated period there were such pro-cyclical years (Turkey with 18 years; France with 13 years; and eight other countries with 11 or 10 years). The adopted specification seeks to distinguish 4 regimes dictated by concurrent changes in product and unemployment: [R1] $\Delta y > 0$ & $\Delta u < 0$, [R2] $\Delta y < 0$ & $\Delta u < 0$, [R3] $\Delta y > 0$ & $\Delta u > 0$, and [R4] $\Delta y < 0$ & $\Delta u > 0$. It is surely not satisfactory that this classification overlooks the equality cases, but it is applicable to real conditions where a variable abounded with stochastic variation may be observed at the same level in two consecutive years only owing to a rounding protocol. The philosophy of Okun's law appertains to the development represented by regimes [R1] and [R4] where an inverse relationship is preserved, and the other two regimes [R2] and [R3] are not consistent with a typical economic development, although such situations do happen frequently. Equation (1) corresponds to regimes [R1] and [R4] and does not map the departures from the anticipated pattern and does not represent their magnitude. To recognize different regimes, equation (1) is modified into an extended formula

$$\Delta u_t = \tilde{a} + \tilde{b}\Delta y_t + \tilde{c}(\Delta y_t)^- + \tilde{d}\Delta y_t \cdot \iota_{\{\Delta u_t > 0\}} + \varepsilon_t , \tag{2}$$

where $(\cdot)^-$ is the ramp function defined as $(x)^- = \min\{x, 0\}$, and $\iota_{\{A\}}$ is the indicator function that takes a value of 1 when condition A is met and attains a value of zero otherwise. The parameters $\tilde{a}$, $\tilde{b}$, $\tilde{c}$ and $\tilde{d}$ are denoted here with tildes and inherit a very similar function as was in equation (1). However, two additional parameters $\tilde{c}$ and $\tilde{d}$ modify the Okun coefficient $\tilde{b}$ for different states. Equation (2) recognizes four different Okun coefficients: $\tilde{b}$ for regime [R1], $\tilde{b}+\tilde{c}$ for regime [R2], $\tilde{b}+\tilde{d}$ for regime [R3], and $\tilde{b}+\tilde{c}+\tilde{d}$ for regime [R4]. The modification embedded in equation (2) is a simple approach to account for non-linearity without a need of a threshold approach or transition states induced by economic activity. The interpretation of Okun coefficients for the four regimes is clarified at the end of this section.

So far the exposition has been fairly general and has related to aggregate unemployment for the entire economy. Nonetheless, there is a consensus that output growth impacts upon male and female unemployment with a different magnitude. Male unemployment tends to be more reactive to cyclical variations than female unemployment (e.g., Peiró et al., 2012; Zanin, 2014, p. 244; Belaire-Franch and Peiró, 2015), which prompts setting-up separate equations for males and females. Introducing the superscripts M and F for males and females, respectively, equation (2) goes into the system

$$\Delta u_t^M = \tilde{a}^M + \tilde{b}^M \Delta y_t + \tilde{c}^M (\Delta y_t)^- + \tilde{d}^M \Delta y_t \cdot \iota_{\{\Delta u_t > 0\}} + \varepsilon_t^M ,$$
$$\Delta u_t^F = \tilde{a}^F + \tilde{b}^F \Delta y_t + \tilde{c}^F (\Delta y_t)^- + \tilde{d}^F \Delta y_t \cdot \iota_{\{\Delta u_t > 0\}} + \varepsilon_t^F , \quad (3)$$

in which the notational meaning is retained, but in addition $(\varepsilon_t^M, \varepsilon_t^F)' \sim (0, \nabla)$ is a bivariate white noise process (where the matrix ∇ is a positive-definite covariance matrix). System (3) is a seemingly unrelated regression (SURE) model with identical regressors shared by the individual equations. The regressors related to output fluctuations, Δy_t, $(\Delta y_t)^-$ and $\Delta y_t \cdot \iota_{\{\Delta u_t > 0\}}$, are assumed exogeneous, and only the regressands, Δu_t^M and Δu_t^F, are endogenous. The parameters can be estimated by OLS at the cost of ignoring contemporaneous correlations incorporated in ∇, or by feasible generalized least squares (FGLS) taking into account that there is bound to be a set of common factors that exert their joint influence upon both male and female unemployment.[1]

The formulation of system (3) permits investigations as to whether the sensitivity to output fluctuations differs between gender-specific segments of the labor market. According as males and females react alike to cyclical variations, there is congruence between the Okun-like coefficients standing at Δy_t, $(\Delta y_t)^-$ and $\Delta y_t \cdot \iota_{\{\Delta u_t > 0\}}$. Four congruence hypotheses [H1] to [H4] can be tested to explore differences between males and females: all the coefficients are equal, i.e. $\tilde{b}^M = \tilde{b}^F$ & $\tilde{c}^M = \tilde{c}^F$ & $\tilde{d}^M = \tilde{d}^F$ [H1], only the coefficients at Δy_t are equal, i.e. $\tilde{b}^M = \tilde{b}^F$ [H2], only the coefficients at $(\Delta y_t)^-$ are equal, i.e. $\tilde{c}^M = \tilde{c}^F$ [H3], and only the coefficients at $\Delta y_t \cdot \iota_{\{\Delta u_t^M > 0\}}$ are equal, i.e. $\tilde{d}^M = \tilde{d}^F$ [H4]. These four hypotheses can be converted into testing the equality of male and female Okun coefficients in different regimes. For instance, the identical responsiveness of male and female unemployment in regime [R2] would require that [H1] and [H2] both hold at once. Since all these hypotheses are linear, they are easily testable in a conventional readily available framework using Wald-type F or Chi-square tests as well as likelihood-ratio based tests (Judge et al., 1980, pp. 472-476).

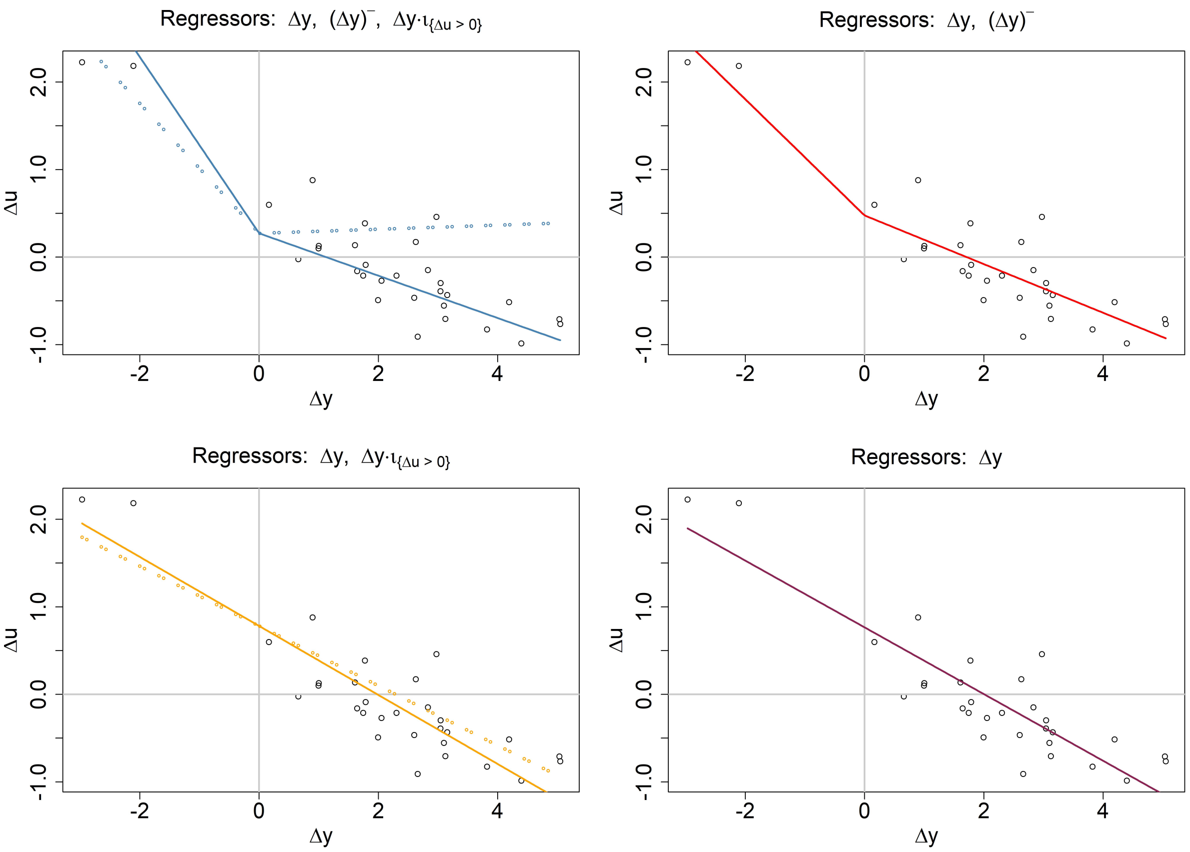
By no means does the statement of models (2) and (3) imply that all three regressors must be present. As a matter of fact, it is advisable to confront data with the intended regression specification and to identify a suitable subset of the regressors in a conventional manner so that the regressor Δy_t alongside the intercept is always included. Instead of the reliance upon statistical significance of regression coefficients in selecting the regression specification, a more prudent approach is to employ an information criterion such as the Akaike information criterion (AIC) or the Bayesian information criterion (BIC). This has an advantage that it separates the initial stage of regression specification from the stage of statistical significance checking or hypothesis testing that ensues thereafter. Statistical inference should be run independently from model selection in order to avoid bias arising if these two statistical procedures are run simultaneously.

What actually happens for the trends governed by the extended Okun equation in $\langle \Delta y, \Delta u \rangle$ space is illustrated in Figure 1 drawn using data for Canada analyzed alongside data for other countries in the next section. The quartet of charts is produced for equation (2) and its three possible reductions until the bare basic Okun equation specified in (1) is obtained. This traditional case with only one regressor Δy imposing symmetry and linearity leads to a single line. Adding another regressor $(\Delta y)^-$, Okun's law encompasses two piece-wise linear trends broken at a zero output growth, i.e. $\Delta y = 0$. Finally, admitting the regressor $\Delta y \cdot \iota_{\{\Delta u > 0\}}$ inducing unemployment-related asymmetry causes a rotation of the single line or the piece-wise broken line as seen in the bottom and top row of Figure 1, respectively. From a statistical viewpoint,

[1] That being said, when the same set of regressors appears in the male and female equation, there is no gain of OLS over FGLS as FGLS estimates collapse into OLS estimates (Judge et al., 1980, p. 468). Nonetheless, if the system is modified so that the regressors differ between the equations, then FGLS is preferable. It is a fact appreciated also here since the pursued empirical strategy seeks to choose the most plausible system representation with possibly different regressors in the male and female equation.

the full specification with a fit exhibited in the top left-hand chart is also a convenient way of picking-up non-linearities, slightly curved patterns or dispersed clusters. The demonstration of the assertion is readily available in the $\langle \Delta y > 0, \Delta u > 0 \rangle$ quadrant dominated by a nearly leveled-off dotted line. The role of the regressor $\Delta y \cdot \iota_{\{\Delta u>0\}}$ is even more imperative for the gender-specific bivariate specification in (3) since males and females are documented to respond to output fluctuations with different magnitudes. It is worth noting that the regression with the full set of regressors displayed in the left-hand top chart of Figure 1 is a general specification that encompasses all the other three options. If the coefficients at $(\Delta y)^{-}$ and/or $\Delta y \cdot \iota_{\{\Delta u>0\}}$ are zero (either literally or owing to insignificance), the dual piece-wise broken pattern simplifies, or even collapses into the traditional Okun's law displayed in the right-hand bottom chart.

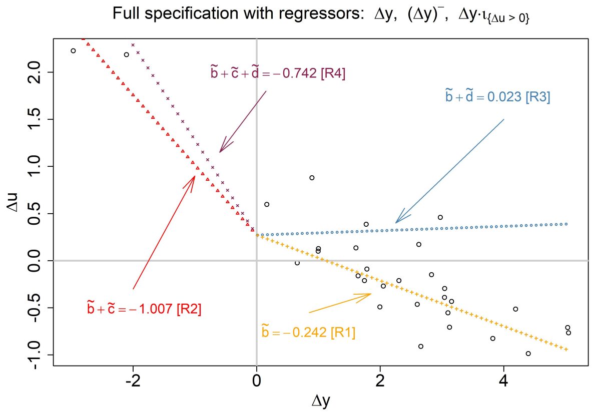
Figure 1 Patterns behind the extended Okun equation across diverse regimes



Note: The charts are all produced for the Canadian data over the investigated period 1989 – 2019. Dotted lines in the left-hand column answer to situations with rising unemployment $\Delta u > 0$, or when $\Delta y \cdot \iota_{\{\Delta u > 0\}}$ is non-zero. In contrast, solid lines are effective for situations with declining unemployment $\Delta u > 0$, or when $\Delta y \cdot \iota_{\{\Delta u > 0\}}$ is zero.

Okun coefficients for different regimes introduced beneath equation (2) measure the presence and intensity of the compensating relationship of output-unemployment fluctuations. Still, there may be some difficulties in interpreting their meaning especially for regimes [R2] and [R3]. Figure 2 replicates the upper left-hand chart of Figure 1 for Canada with a full regression specification, but now identifies four Okun coefficients and presents their (estimated) values. The quadrants $\langle \Delta y > 0, \Delta u < 0 \rangle$ and $\langle \Delta y < 0, \Delta u > 0 \rangle$ are consistent with the counter-cyclical spirit of Okun's law and answer to regimes [R1] and [R4]. Equation (2) produces for these quadrants downward sloping linear fits of the Okun relationship that differ only in steepness as is corroborated by the different values -0.242 and -0.742. Hence, Okun's law holds for regimes [R1] and [R4], but presents itself diversely with asymmetries. The other two quadrants $\langle \Delta y < 0, \Delta u < 0 \rangle$ and $\langle \Delta y > 0, \Delta u > 0 \rangle$ appertain to pro-cyclical movement of output and unemployment and correspond to regimes [R2] and [R3]. Pro-cyclicality of regimes [R2] and [R3] does not prevent Okun's law from being in effect as it all comes down to the scatter of points $[\Delta y, \Delta u]$ in the two quadrants. Observations may be dispersed in an arrangement sloping downward and agree thus with Okun's law, or they may contradict it. For example, in Figure 2 for Canada, the few observations in the $\langle \Delta y > 0, \Delta u > 0 \rangle$ quadrant are dispersed in a horizontal position, causing the Okun coefficient for regime [R3] to be a very small and positive value, almost zero, 0.023. This value confronted with the displayed arrangement of points reveals departures from Okun's law, and specifically to insensitivity of unemployment to upturns in output. In contrast, there are no observations in the $\langle \Delta y < 0, \Delta u < 0 \rangle$ quadrant for regime [R2], so the fit answering to this regime is pulled up to an adjacent upper quadrant, preserving the right sign. In such a case, the estimated Okun coefficient -1.007 is not reasonable, and should be reported with a cautionary remark. Yet, the full specification of equation (2) is needed to obtain statistically relevant estimates for the other three quadrants. It must be said in this respect that recessionary years coincide with falling unemployment only very rarely and infrequently. The extremity of this scenario led economists to call it a labor market miracle, which is the case of Germany observed during the Great Recession of 2008 – 2009 (e.g., Burda and Hunt, 2011; Rinne & Zimmerman, 2012). In consequence, the case of pro-cyclical output and unemployment does necessarily entail that Okun's law may not hold. In fact, Okun coefficients for regimes [R3] and [R2] also act as measures of pro-cyclicality, but their information value hinges on the presence of observations in the respective quadrants.

Figure 2 Okun coefficients in different regimes



3. Data and Results

The comparative analysis considers as many as 21 OECD countries that are fully listed in Table 1 and Appendixes A and B and builds upon annual data covering a span of 31 years from 1989 to 2019. The selection of countries and the choice of the time frame were carefully weighed and adjusted so as to admit the greatest number of economies for the largest period into the analysis. Four time series were downloaded from the official OECD statistical database OECD.Stat available online at https://stats.oecd.org as of 1 July 2020. The output series was represented by gross domestic product denominated in US$ at constant prices and constant purchasing power parities (PPPs) related to the OECD reference year 2015. The three unemployment series consisted of whole-economy, male and female unemployment rates for the working age population comprising those aged 15 to 64 years. The 31 years of observations yielded 30 annual changes of (logarithmized) real output and unemployment rates, Δy, Δu, Δu^M and Δu^F. For convenience, all the variables are presented as percentages.

The analysis was performed in entirety in program R (R Core Team, 2019) exploiting R packages `DescTools`, `MASS`, `MVN`, `nortest`, `portes`, `systemfit`, and `urca`.

A basic statistical summary for these four variables and for the other two output-related variables, $(\Delta y)^{-}$ and $\Delta y \cdot \iota_{\{\Delta u>0\}}$, is organized in the extensive table of Appendix A. To demonstrate the sensibility of the statistical framework, the key variables Δy, Δu, Δu^{M} and Δu^{F} where non-stationarity might be an issue were tested for unit roots using two well-established procedures. The augmented Dickey-Fuller (ADF) posits a unit root in the null hypothesis as opposed to the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test that stylizes a unit root in the alternative hypothesis. The combined use of the ADF and KPSS test is a recommended route to checking unit root non-stationarity (e.g., Schlitzer, 1995, 1996). The details on the adopted configuration of the tests are placed into the note beneath the table in Appendix A. For most of the time series stationarity is confirmed unanimously by both unit root tests, but some doubts arise in a few rare case in which the stationarity tests produce conflicting results.[2] Nonetheless, informal means of stationarity inspection does not attest to a presence of a unit root, so this issue is only noted without any further action.

The descriptive statistics illustrate that the 21 OECD economies varied in their experience with the intensity of business and unemployment fluctuations. For instance, Australia reported only in one year a decline in real output and all other years were marked with a positive output growth, whereas the trajectories of real output for countries like Greece, Ireland, Korea or Turkey were rather erratic. Still, each economy ascended along an upward average output growth trajectory, whereas the unemployment rates manifested average zero fluctuations, albeit mostly with markedly different magnitudes between the genders. The last column of Appendix A displays the frequency of yearly changes observed for the period 1989 – 2019 with a decline in real output ($\Delta y < 0$, which is somewhat loosely referred to as recessionary patterns), with an occurrence of pro-cyclical development of unemployment answering schematically to regimes [R2] and [R3] ($\Delta y \cdot \Delta u > 0$, which is termed as non-conventional patterns) and with a converse movement of male and female unemployment ($\Delta u^{M} \cdot \Delta u^{F} < 0$). These frequencies are for the majority of the examined economies non-negligible and vindicate investigations of how Okun's law reacts to recessionary patterns described by the term $(\Delta y)^{-}$, how it varies with pro-cyclical fluctuations of unemployment embodied by the term $\Delta y \cdot \iota_{\{\Delta u>0\}}$, and how it differs for males and females as is represented by the distinct unemployment rates and their changes, Δu^{M} and Δu^{M}. However, the table omits the fact that observations in regime [R2] with both product and unemployment on the decline were inconveniently in short supply. In 15 countries no instance of regime [R2] was recorded, one instance was observed in five countries, and three years in regime [R2] for one country. Hence, regime [R2] remained for the period in question sort of a hypothetical concept.

Instead of estimating equations according to the full specification given by (2) and (3), a search for the most data-based representation was conducted using the BIC as a guide, which is well-known to yield parsimonious models. The search was restricted, and included a few models ranging between the minimalist model (the intercept and Δy as regressors) and the full model (the intercept, Δy, $(\Delta y)^{-}$, and $\Delta y \cdot \iota_{\{\Delta u>0\}}$ as regressors) with a permission of differing regressors for gender-specific equations. Models arising from the whole-economy specification (2) were estimated by OLS in contrast to those stemming from the bivariate system (3) estimated by FGLS.[3] The estimated coefficients for the models identified as best

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[2] Depending somewhat on the accepted level of significance, the few cases include Greece (Δy, Δu^{F}), Ireland (Δu, Δu^{M}, Δu^{F}), Italy (Δy, Δu^{M}), Japan (Δu, Δu^{M}, Δu^{F}), Korea (Δy), the Netherlands (Δy), Portugal (Δu^{M}), Spain (Δy, Δu, Δu^{F}) and the UK (Δu^{F}).

[3] In step with the comment in Footnote 1, except for the UK where the gender-specific equations differed, FGLS produced the same estimates as would be obtained by OLS.

with respect to the BIC are organized in a tabular report in Appendix B with traditional significance flags. Absent parameters indicate that those regressors were not included in the equation. For instance, in the case of Australia the Okun equations comprise only three regressors, viz. the intercept, Δy, and $\Delta y \cdot \iota_{\{\Delta u>0\}}$, regardless of whether it is the whole-economy equation or the gender-specific equations. The table reports traditional metrics of goodness-of-fit for individual equations (adjusted R^2) and for the bivariate system (adjusted R^2 and McElroy R^2) alongside Pearson correlations between the residuals of male and female equations. The R^2 measures indicate that the estimated models are a mediocre or good fit except a handful of cases. These scarce exceptions of a miserable fit are Finland (female equation, adjusted R^2 around 0.3), Italy (male and female equation, adjusted R^2 around 0.3 and 0.1, respectively), Japan (male and female equation, adjusted R^2 around 0.2 in either case), and Turkey (female equation, adjusted R^2 virtually zero). In these cases, Okun equations, although optimal with respect to their information content, are not consistent with the modeled reality, which is also discernible in the diagnostic results. The estimated models were checked for normality of residuals and absence of autocorrelation. Mostly, the assumption of Gaussianity and uncorrelatedness needed for the reported significance and congruence testing were not found violated. Nonetheless, the few cases with a poor fit noted earlier did not fare well in the diagnostic check, which indicates that the linear form or static equation of the Okun equation may be not sufficient. The correlation between the residuals of gender-specific equations is fairly high and ranges from 0.355 (Canada) to 0.937 (Japan).

The last columns of the table in Appendix B exhibit the results of testing for the congruence between male and female Okun coefficients. Hypothesis [H1] as formulated in Section 3 is testable only when the full system specification is estimated, which is the case of seven countries. Otherwise it is unreported. Unreported are also the hypotheses that are not testable for the reason that the respective Okun-like coefficients are not present in the specification.

Most of the estimated Okun and Okun-like coefficients, $\tilde{b}$, $\tilde{c}$ and $\tilde{d}$, reported in Appendix B are statistically significant even at very low levels of significance. Neglecting the intercept, issues with insignificance at a significance level of 0.05 are detected for Greece, Italy, Japan, New Zealand, Spain, Turkey and the UK. In order to make the estimated coefficients more informative, they are translated in Table 1 into Okun coefficients for the four different regimes as discussed after equation (2). The translation accounted for statistical insignificance. If any coefficient was not statistically significant at the level 0.05, it was treated as zero, which was the issue only for seven of the 21 OECD countries. For Greece, Italy, Japan and Turkey, for one or more regimes all components were statistically insignificant indicating that Okun's did not manifest itself for those regimes. Such cases are indicated with dots rather than with zero coefficients. Furthermore, counter-intuitive positive Okun coefficients are marked in boldface. In addition, Okun coefficients for regime [R2] are reported in the table only for the sake of completeness and must be taken with care owing to the absence or dearth of observations for this particular regime.

Table 1 Okun coefficients for different regimes of output-unemployment combinations

Country	Whole economy as a block				Males				Females			
	$\Delta y > 0$ $\Delta u < 0$ [R1]	$\Delta y < 0$ $\Delta u < 0$ [R2]	$\Delta y > 0$ $\Delta u > 0$ [R3]	$\Delta y < 0$ $\Delta u > 0$ [R4]	$\Delta y > 0$ $\Delta u < 0$ [R1]	$\Delta y < 0$ $\Delta u < 0$ [R2]	$\Delta y > 0$ $\Delta u > 0$ [R3]	$\Delta y < 0$ $\Delta u > 0$ [R4]	$\Delta y > 0$ $\Delta u < 0$ [R1]	$\Delta y < 0$ $\Delta u < 0$ [R2]	$\Delta y > 0$ $\Delta u > 0$ [R3]	$\Delta y < 0$ $\Delta u > 0$ [R4]
Australia	-0.396	-0.396	-0.123	-0.123	-0.482	-0.482	-0.160	-0.160	-0.281	-0.281	-0.068	-0.068
Belgium	-0.299	-1.080	**0.193**	-0.587	-0.450	-0.450	-0.080	-0.080	-0.439	-0.439	**0.101**	**0.101**
Canada	-0.242	-1.007	**0.023**	-0.742	-0.302	-1.248	-0.008	-0.953	-0.170	-0.743	**0.067**	-0.507
Denmark	-0.449	-0.932	-0.083	-0.566	-0.582	-0.582	-0.582	-0.582	-0.377	-0.377	-0.377	-0.377
Finland	-0.356	-0.356	-0.356	-0.356	-0.441	-0.441	-0.441	-0.441	-0.263	-0.263	-0.263	-0.263
France	-0.276	-0.918	**0.089**	-0.553	-0.333	-0.975	**0.044**	-0.598	-0.212	-0.853	**0.139**	-0.501
Germany	-0.389	-0.389	**0.060**	**0.060**	-0.429	-0.429	-0.007	-0.007	-0.340	-0.340	**0.139**	**0.139**
Greece	·	-1.280	**0.430**	-0.850	·	-1.160	**0.272**	-0.888	·	-1.449	**0.650**	-0.799
Ireland	-0.142	-1.212	**0.202**	-0.867	-0.128	-1.557	**0.254**	-1.175	-0.161	-0.779	**0.133**	-0.486
Israel	-0.298	-0.298	**0.058**	**0.058**	-0.312	-0.312	**0.009**	**0.009**	-0.283	-0.283	**0.121**	**0.121**
Italy	·	-0.658	**0.459**	-0.199	-0.255	-0.255	-0.255	-0.255	-0.220	-0.220	-0.220	-0.220
Japan	·	-0.280	**0.149**	-0.131	-0.113	-0.113	-0.113	-0.113	-0.101	-0.101	-0.101	-0.101
Korea	-0.069	-0.882	**0.033**	-0.779	-0.080	-1.000	**0.027**	-0.893	-0.051	-0.700	**0.043**	-0.605
Netherlands	-0.410	-0.410	-0.045	-0.045	-0.399	-0.399	-0.102	-0.102	-0.431	-0.431	**0.023**	**0.023**
New Zealand	-0.208	-0.208	**0.189**	**0.189**	-0.383	-0.383	-0.383	-0.383	-0.297	-0.297	-0.297	-0.297
Portugal	-0.299	-1.229	**0.186**	-0.744	-0.447	-0.447	-0.447	-0.447	-0.347	-0.347	-0.347	-0.347
Spain	-0.806	-0.806	-0.113	-0.113	-0.920	-0.920	-0.920	-0.920	-0.893	-0.893	-0.893	-0.893
Sweden	-0.366	-0.973	-0.012	-0.619	-0.416	-1.129	-0.074	-0.787	-0.312	-0.801	**0.054**	-0.435
Turkey	-0.219	-0.219	-0.085	-0.085	-0.184	-0.184	-0.184	-0.184	·	·	·	·
United Kingdom	-0.367	-0.367	-0.052	-0.052	-0.628	-0.628	-0.309	-0.309	-0.162	-0.542	**0.066**	-0.314
United States	-0.244	-1.631	**0.097**	-1.290	-0.284	-1.948	**0.097**	-1.568	-0.196	-1.272	**0.098**	-0.978

Note: The table reports Okun coefficients that arise by summing statistically significant coefficients estimated for Δy, $(\Delta y)^{-}$ and $\Delta y \cdot \iota_{\{\Delta u > 0\}}$. In this, all estimated coefficients otherwise reported in Appendix B that were not found statistically significant at the 0.05 level were handled as zeros. In the light of ever-present year-on-year changes, it does not matter as to whether strict inequalities "<" and ">" are replaced by weak inequalities "≤" and "≥", respectively.

Caveat: Utmost caution must be exercised in interpreting Okun coefficients for regime [R2] since the situation of simultaneous decreases in both output and unemployment was never observed during the investigated period, or such instances were rare.

Legend: The dot symbol "·" in the cells of the table shows that the respective Okun coefficient was in fact nil when statistical insignificance was taken into account. Boldface highlights cases where Okun coefficients, contrary to wisdom and expectations, are positive.

It is natural that the results are not uniform across the block of OECD countries, but there are some general patterns worthy of notice. The following comments reflect only the coefficients significant at a significance level of 0.05.

1. Whole-economy equations typically coincide with gender-specific equations as concerns the relevant regressors identified during the specification search. Exceptions are Belgium, Denmark, Italy, Japan, New Zealand, Portugal, Spain, Turkey, and the UK. Usually, gender-specific equations are sparser. The different structure of regressors shows that in these countries genders react to output growth differently than the labor market as a whole. The distinction between aggregate reaction and gender-specific reactions suggests asymmetric effects in Okun's law upon the labor market.
2. More than half of the countries display asymmetric output-unemployment reactions different for conjunctural and recessionary years as is attested by a statistically significant coefficient at $(\Delta y)^{-}$. For a whole economy, it is eleven OECD countries: Belgium, Canada, Denmark, France, Greece, Ireland, Italy, Japan, Korea, Portugal, Sweden, and the

US. However, for genders, the list of countries with output-related asymmetry is shorter and misses Belgium, Denmark, Italy, Japan, Portugal, and the UK (only females).

3. Whenever there is an asymmetry in Okun's law in regard to changes in output, unemployment is more sensitive in recessionary years than in conjunctural years. That is to say, recessions heighten the sensitivity of unemployment to output fluctuations and intensify the value of Okun coefficients. With declines in output, Okun coefficients are greater in absolute value (or "more negative") and Okun's law is stronger.
4. For almost all of the countries, Okun's law is affected by the direction of changes in unemployment as follows from a statistically significant coefficient at $\Delta y \cdot \iota_{\{\Delta u>0\}}$. Okun's law is diminished in intensity by rises in the unemployment rate as the coefficient at $\Delta y \cdot \iota_{\{\Delta u>0\}}$ is always positive. Conversely, Okun's law is stronger for decreases in unemployment. The unemployment-related asymmetry for both the whole economy and gender-specific parts of the labor market is not detected for Finland, and is detected only for the whole economy for Denmark, Italy, Japan, New Zealand, Portugal, Spain and Turkey.
5. Overall, the responsiveness of unemployment to output fluctuations may seem uniformly most pronounced for regime [R2] where both output and unemployment decrease, and Okun coefficients have all correct negative signs. Notwithstanding, this is perhaps a hypothetical empirical combination since the studied OECD countries seldom reported simultaneous declines in output and unemployment as is also emphasized in the description of Table 1. Therefore, the results for regime [R2] may be freely disregarded, or must be interpreted with a critical eye. Interestingly, in regime [R3] with output and unemployment both increasing, Okun coefficients are frequently counter-intuitive with positive signs, frequently negligible when compared to the values for other regimes. For a few countries, such situations are also observed for regime [R4]. These observations are valid not only for a whole economy, but also for gender-specific cases.
6. By comparison, Okun coefficients for the whole economy, males and females are regulated by a simple arrangement: male Okun coefficients are smallest ("most negative"), female Okun coefficients are largest ("least negative"), and whole-economy Okun coefficients are in-between as their notional average. In each country, males appear at first glance more sensitive to output-unemployment fluctuations than females. All the same, when the congruence in male and female Okun coefficients is tested and statistical differences are taken into account, differences between male and female sensitivity are provable only for fifteen countries. For Belgium, Israel, Italy, Japan, Portugal, Spain, the estimated Okun coefficients are identical for males and females, and genders respond to business fluctuations in like manner.
7. In the typical regimes [R1] and [R4] with opposing developments of output and unemployment, the largest responsiveness is revealed by Spain for [R1] and the US for [R4]. In other words, in comparative terms, with an output growth and unemployment decrease, Okun's law operates strongest in Spain (with an Okun coefficient of -0.806 for the whole economy), but with an output decline and unemployment rise, Okun's law is strongest in the US (with an Okun coefficient of -1.290 for the whole economy).
8. No offsetting Okun relationship between output and unemployment was detected for females in Turkey in any regime, and for Greece whatsoever in regime [R1].

The cross-country heterogeneity in Okun coefficients and their varying patterns across the four regimes, reported in detail in Appendix B and compacted into Table 1, are a legacy of specific economic histories and institutional environments of the analyzed OECD countries. Three examples can be offered, bearing in mind that the analysis covered the period between 1989 and 2019, and these encompass Japan, Germany and Spain.

The Japanese economy struggled in the 1990s with a long era of deflation and recession that came to be known as the lost decade. Attempts to revive the economy necessitated a zero-interest rate policy, quantitative easing and various financial stimuli. Economic stagnation with mediocre output fluctuations lasted until the early 2010s when the three policy arrows of Abenomics were launched to boost the economy whilst maintaining fiscal discipline. Productivity-oriented measures had to address the inherent inflexibility of Japanese labor force characterized by “three sacred treasures” of long-term employment, seniority-based wages, and enterprise unionism (Kitagawa et al., 2018). Especially, shrinking and ageing population was understood as a problem and it was needed to tackle a sharp decline in working-age population (Jones and Seitani, 2019). The policy response was centered upon a relatively low labor force attachment amongst female workers. Female labor market participation increased in the 2000s and 2010s and was compensated by a decrease in male participation (Kwaguchi and Mori, 2017). All in all, owing to small output fluctuations in the last three decades and mild shifts in unemployment marked by rigidity of jobs, responses of both male and female unemployment to changes in output were small in comparison to other countries and were found uniform across the four regimes (Okun coefficients of -0.113 and -0.101 for males and females, respectively). Nevertheless, the reform pressures aiming to reduce the disparities in labor force participation and remuneration by genders in the past two decades are obviously the reason why Okun coefficients reveal a completely different pattern across the regimes when the gender-specific equations are aggregated and estimated for the economy en bloc.

Germany exhibits an asymmetry in Okun's law with respect to unemployment since the responsiveness of total, male and female unemployment to output changes varies according as the labor market is on the rise or decline. With rising unemployment, male workers are more sensitive to declines in output than are females (Okun coefficients -0.429 and -0.340, respectively). In contrast, with declining unemployment, male unemployment is unresponsive whilst female unemployment is slightly pro-cyclical (Okun coefficients -0.007 and 0.139, respectively). The key feature is that the asymmetry is induced by unemployment that ensued after the unification in 1990 and persisted on high levels for a decade, for which Germany was accorded a moniker "sick man of Europe" (Dustmann et al., 2014; Rinne and Zimmerman, 2013). An explanation was in high levels of employment protection, high labor costs and strict labor market regulations (Schneider and Rinne, 2019), and the labor market was subjected to massive reforms (the Hartz reforms) to reduce long-term unemployment by dint of encouraging flexible and temporary employment contracts and lowering long-term unemployment benefits (Rinne and Zimmerman, 2013). Unemployment peaked in the early 2000s, and was suppressed by reform efforts whose effects entailed that during the Great Recession the economy encountered a downturn combined with declining unemployment, referred to as the German labor miracle (Burda and Hunt, 2011). Nevertheless, this experience was accompanied by a rising prevalence of precarious and atypical work especially amongst women. Although female participation in German labor force bases especially on part-time and low-quality jobs, these are stable over the business cycle (Weinkopf, 2014). A cliché argument is also the presence of occupational segregation by gender that is deeply rooted in Germany. On the one hand, German women are less represented in occupations that otherwise require special training and in occupations with higher working volumes and overtime work (Damelang and Ebensperger, 2020), and are in consequence a more flexible labor force. On the other hand, Germany is a strongly export-driven economy whose key industries are dominated by men (Rosenfeld et al., 2004; Seifert and Schlenker, 2014), which explains their greater vulnerability to changes in output. All things considered, females are less vulnerable to output fluctuations than are males.

The last country discussed, Spain, reveals no asymmetries in Okun's law for gender-specific unemployments, but there is an asymmetry in how total unemployment responds to output fluctuations in cases when unemployment rises or declines. Okun coefficients for males and females are not different and identical across the regimes (with values -0.920 and -0.893, respectively). By all standards, Spain's gender-specific coefficients are high, and comparatively are the largest in the group of OECD countries, which evinces that unemployment of either gender is extremely sensitive to output. The reasons are historical and emanate from dysfunctional labor market institutions characterized by dual employment protection legislation and a rigid collective bargaining system (OECD, 2013). The reform package enacted in 2012 sought to address both sore areas, but also to improve active labor market policies in an attempt to tackle youth and long-term unemployment that soared during the Great Recession. Nonetheless, since then youth and long-term unemployment has not fallen (Stepanyan and Salas, 2020, Sanz-de-Galdeano and Terskaya, 2020). For one thing, the duality of the Spanish labor market consists in the coexistence of (rather frequent) temporary contracts with low firing costs and open-ended contracts with high firing costs. For another, temporary employment of youth after the Great Recession rose notably, and contributed to the counter-cyclical nature of unemployment over the business cycle (Sanz-de-Galdeano and Terskaya, 2020). Finally, in the last decade, in consequence of the Great Recession, labor participation rates by genders changed and offset to some degree, viz., a reduction in male participation was accompanied by an increase in female participation. The line of reasoning treads alongside the added worker and discouraged worker effects discussed in the next section. These effects, coupled with changes in sectoral occupations by genders (Sanz-de-Galdeano and Terskaya, 2020), explains the asymmetric reaction to output fluctuations.

4. Discussion

Courtney (1991) and Palley (1993) were first to note that Okun's law may be asymmetric and may evince itself with different strengths in expansions and contractions. This observation has been appreciated since, and many empirical studies have found it appealing to model asymmetries over the business cycle. Inspired by the stylized fact that contractions are more intense that expansions, Lee (2000) initiated formal investigations of asymmetry in Okun's law in terms of output variations, and was soon followed by Virén (2001) and Harris and Silverstone (2001). Silvapulle et al. (2004) reviewed and advanced three basal theoretical explanations for asymmetric Okun's law that were summarized by Nebot et al. (2019) as (i) the institutional rigidity hypothesis, (ii) the labor hoarding hypothesis, and (iii) the risk aversion hypothesis. Under (i), the output-unemployment relationship is affected by institutional constraints that bind decisions of firms to lay off workers. Whereas employment protection legislation makes it easy for firms to hire workers, firms find it difficult to dismiss workers even in adverse periods. In consequence of this rigidity, in a recession, unemployment may not respond swiftly to an otherwise steep decline in product. In contrast, in an expansion, the elasticity of unemployment remains intact. Under (ii), firms that invest into the training and skills of their workers have a good motivation to preserve their human capital even in contractions. When firms are disinclined to lay off skilled workers with developed competences and they do hoard labor, the output-unemployment relationship is in contractions less elastic. At last, under (iii), contractions are viewed with graver pessimism and expansions are deemed with moderate optimism. Assigning more relevance to pessimistic scenarios and being risk averse, firms respond to contractions with briskness and lay off workers more intensely than they hire them in expansions. As noted by an anonymous reviewer, the first of these hypotheses, (i) and (ii), are especially useful in explaining a reduced or lukewarm response of unemployment to an economic contraction with ($\Delta u \approx 0$), but not a pro-cyclical one (with $\Delta u > 0$). In addition, there is a possibility of the discouraged worker effect that might explain a pro-cyclical reaction and that refers to the skepticism of job-seeking individual who lose their hope in finding a satisfactory position and decide of their own will to recoil from the labor market. This explanation is explored later in the text.

The implications of these major hypotheses for Okun coefficients in expansions and contractions are discernible in the parameters of model (2) and system (3). For a whole economy, the Okun coefficients are $\tilde{b}$ and $\tilde{b}+\tilde{c}$ for periods of increasing and decreasing output. Assuming, that both these Okun coefficients have conventional negative signs, then Okun's law under (i) and (ii) is steeper for expansions, i.e. $|\tilde{b}|>|\tilde{b}+\tilde{c}|$, but under (iii) it is steeper for contractions, i.e. $|\tilde{b}|<|\tilde{b}+\tilde{c}|$. The former entails that $\tilde{c}>0$, whilst the latter means that $\tilde{c}<0$. This reasoning holds analogically for the gender-specific parameters of system (3). The table in Appendix B reveals that whenever coefficients $\tilde{c}$, $\tilde{c}^{M}$, $\tilde{c}^{F}$ are estimated, they are negative irrespective of their significance status. This universal pattern points to the dominance of the risk aversion hypothesis under which unemployment responds more flexibly and promptly to contractions than to expansions. Risk aversion is detected for 13 OECD economies (Belgium, Canada, Denmark, France, Greece, Ireland, Italy, Japan, Korea, Portugal, Sweden, the UK, and the US) and is consistent with the findings the previous studies. Silvapulle et al. (2004) concluded risk aversion for the US post-war economy, and Nebot et al. (2019) confirmed this hypothesis for Germany, France, the Netherlands, and Spain with an indication of labor hoarding behavior or institutional rigidities. Nonetheless, their methodology, investigated time frame and data frequency are completely different. Moreover, asymmetry with respect to output variation is estimated for Spain only for the entire economy, and the coefficient $\tilde{c}$ is not proven significant at a level of 0.05.

The observed asymmetry of Okun coefficients also agrees with the concept of a jobless recovery whose explanations differ. For Europe, an acceptable justification is that labor market rigidities cause high persistence of unemployment and induce hysteretic effects (Blanchard and Summers, 1986), whilst for flexible labor markets such the US or Canada, reasons are sought in structural change, uncertainty and rising health costs (Groshen and Potter, 2003). Nonetheless, after the Great Recession jobless recoveries became a common phenomenon symptomatic to economics with different institutional and competitive settings and slower recoveries in employment have become a fact (Elroukh et al., 2020). This behavior of unemployment helped to establish links between labor market and financial market frictions (Calvo et al., 2012; Wesselbaum, 2019) as another argument for its occurrence. The examined period 1989 – 2019 overlaps with the Great Recession, and some economies encountered various economic turbulences in different phases of this 31-year period. Jobless recovery entails asymmetry in Okun's law consistent with the risk aversion hypothesis, and as this was established at work for most of the countries, the proposition of labor market rigidities will not stand and is overridden by other forces. Although the labor markets in most of the countries in question are regulated and their markets suffer from various institutional constraints (Organizational for Economic Co-operation and Development, 2010, 2020), the effects of labor rigidities are suppressed by risk aversion of firms.

The findings also support asymmetry in gender-specific responsiveness to output fluctuations. It has been known for some time that the dynamics of male and female unemployment over the business cycle is not gender neutral (e.g., Clark and Summers, 1981; Blank, 1989), and that there is some degree of persistence in the differences between male and female unemployment rates (Quenau and Sen, 2008, 2009, 2010)[4]. The former is associated

[4] That said, the persistence in unemployment rates is an ardently discussed issue and the evidence for their hysteretic trajectories is rather inconclusive. It seems that all comes down to the methodology that is used in the detection of persistence. Whilst Marques et al. (2017) convincingly argue for hysteresis in unemployment rates

with the stylized fact that women exhibit a more elastic labor supply curve (Peiró et al., 2012; Belaire-Franch and Peiró, 2015), whilst the latter is ascribed to structural and institutional factors such as different labor force participation and industry composition, different job search behavior, anti-discrimination employee protection and gender segregation. All in all, the traditional account is that female participation decisions are more adaptable to changing labor market conditions so women are less vulnerable to output fluctuations (e.g. Hotchkiss and Robertson, 2012), and that dismissal of a man is typically more preferred than dismissal of a woman (Azmat et al., 2006). Hence, it is widely accepted men are more exposed to the business cycle in contractions and women are more helped during expansions (Hoynes et al., 2012; Razzu and Singleton, 2016; Bredemeier et al., 2017). The first studies that investigated gender-specific disparities in connection to Okun's law were Peiró et al. (2012) and Hutengs and Stadtmann (2014). These studies, and those of Zanin (2014) and Marconi et al. (2016), all confirmed that Okun's law does act upon men stronger than upon women. The heightened responsiveness of men to output fluctuations tallies also with the results of this paper for most of the countries under analysis. Whenever there is a difference between males and females in system (3), male Okun coefficients indicate higher sensitivity than female Okun coefficients do.

The detected uneven gender sensitivity is associated with the existence of gender unemployment gaps. Attempts to provide a universal explanation for gender unemployment gaps across a block of OECD countries are unsuccessful at large (Azmat et al., 2006), and the afore-cited mixed evidence regarding their persistence indicates that gender-specific unemployment rates are subject to different dynamics. Two factors should be highlighted therein in giving insights into gender differences that are eventually manifested in Okun's law. A first factor is linked with the role of flows within the labor force amongst employment, unemployment, and non-participation; and is represented by the added-worker effect (AWE) and the discouraged-worker effect (DWE). The AWE describes an increased labor supply of married women as secondary workers after their spouses as breadwinners have become unemployed. In contrast, the DWE refers to a loss of interest of individuals in job offers who are convinced that there are no jobs available for them and exit thus voluntarily from the labor force. These transitions within the labor force have received after the Great Recession new attention (e.g., Kesserling and Bremmer, 2015; Mankart and Oikonomou, 2016; Evans, 2018). Nonetheless, the consensus is that for developed countries the AWE is unusual and is superseded by the DWE (Prieto-Rodríguez and Rodríguez-Gutiérrez, 2003. Lee and Parasnis, 2014) and is gender neutral (Cho and Newhouse, 2013). Since the DWE is attributed typically to females as secondary workers (Fuchs and Weber, 2017), male unemployment rates should more with output than female unemployment rates do. The sketched train of though is jeopardized by the findings of recent research that has started to focus on the sociological background of discouraged workers and pointed out that gender as such is not so determining a factor (e.g., Lee and Parasnis, 2014; Kesselring and Bremmer, 2015). A second factor rests in precarious (non-standard) work that is represented at different rates amongst genders. The different engagement of males and females in precarious employment, however, fails to provide the desired insights. Over the past few decades, part-time employment and various forms of temporary contracts have become utilized all over the world. In adverse times, these contracts are first for firms to terminate and optimize, and the prevalence of such flexible contracts heightens the responsiveness of unemployment to changes in output. A simple logic

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of OECD countries, Khraief et al. (2020) employ a non-linear framework to reject the unemployment hysteresis hypothesis. Concerning gender unemployment rates and in gender unemployment gaps in particular, Bakas and Pappetrou (2014) for 15 European countries substantiate persistence only when more refined modeling aspect are allowed to the analysis says that a high utilization of temporary contracts incurs smaller adjustment costs of employment to output shocks and Okun's law should be then stronger. Indeed, Dixon et al. (2017) proved that the proliferation of temporary employment contributed historically to a rise in Okun coefficients and that the effect on genders was asymmetric. This is fully understandable since part-time employment rates and temporary contract rates are typically unequal by a substantial margin. More precisely, women in OECD countries work more frequently on part-time or temporary contracts (Organization for Economic Development and Co-operation, 2002, 2010, 2020). Therefore, female Okun coefficients should be greater in magnitude than male coefficients, which runs counter to the analysis. Nonetheless, considering gender alone without interaction with age may not suffice to give the full picture of the situation or the role of precarious employment may be overstated.

There is a question to what extent the present results are compatible with, or discordant from, other studies. As it happens, owing to different methodologies and the scarcity of comparative analyses on Okun's law in OECD economies, it is problematic to make a comprehensive analysis. Table 2 juxtaposes the estimated Okun coefficients extracted for regimes [R1] and [R4] from Table 1 with Okun coefficient of three other studies. The chosen regimes are those when unemployment and product behave counter-cyclically. Truth to tell, these coefficients are not completely comparable thanks to different data and time spans, during which institutional settings were subject to unavoidable change and evolved. In spite of this limitation, Table 2 reveals that the extended Okun equations devised to distinguish different configurations of output and unemployment changes and to tackle non-linearity are not at odds with simple basal Okun equations that do not reflect asymmetries. Apparently, the coefficients obtained by dint of the extended Okun equations answer roughly to the coefficients estimated in other studies. Yet, the latter do not distinguish differentiated responses of unemployment to output in periods of an upturn and a downturn.

Table 2 Comparison of Okun coefficients with other studies

Country	**This study†)** Whole economy		Males		Females		**Ball et al. (2017) ‡)**	**Lee (2000)‡)**	**Zanin (2014)‡)**	
	[R1]	[R4]	[R1]	[R4]	[R1]	[R4]	Whole economy		Males	Females
Australia	-0.40	-0.12	-0.48	-0.16	-0.28	-0.07	-0.46^{***}	-0.65^{***}	$-0.57^{*/**/***}$	$-0.31^{*/**/***}$
Belgium	-0.30	-0.59	-0.45	-0.08	-0.44	**0.10**	-0.32^{***}	-0.92^{***}	$-0.36^{*/**/***}$	-0.22^{ns}
Canada	-0.24	-0.74	-0.30	-0.95	-0.17	-0.51	-0.43^{***}	-0.60^{**}	$-0.46^{*/**/***}$	$-0.23^{*/**/***}$
Denmark	-0.45	-0.57	-0.58	-0.58	-0.38	-0.38	-0.35^{***}	-0.83^{***}	$-0.38^{*/**/***}$	$-0.23^{*/**/***}$
Finland	-0.36	-0.36	-0.44	-0.44	-0.26	-0.26	-0.34^{**}	-0.58^{***}	$-0.26^{*/**/***}$	$-0.09^{*/**/***}$
France	-0.28	-0.55	-0.33	-0.60	-0.21	-0.50	-0.27^{***}	-0.34^{***}	$-0.39^{*/**/***}$	$-0.29^{*/**/***}$
Germany	-0.39	**0.06**	-0.43	-0.01	-0.34	**0.14**	-0.22^{*}	-0.40^{***}	$-0.27^{*/**/***}$	-0.13^{ns}
Greece	·	-0.85	·	-0.89	·	-0.80			$-0.45^{*/**/***}$	$-0.48^{*/**/***}$
Ireland	-0.14	-0.87	-0.13	-1.18	-0.16	-0.49	-0.35^{***}		$-0.47^{*/**/***}$	$-0.24^{*/**/***}$
Israel	-0.30	**0.06**	-0.31	**0.01**	-0.28	**0.12**			$-0.27^{*/**/***}$	$-0.57^{*/**/***}$
Italy	·	-0.20	-0.26	-0.26	-0.22	-0.22	-0.17^{*}	-0.92^{***}	$-0.30^{*/**/***}$	$-0.34^{*/**/***}$
Japan	·	-0.13	-0.11	-0.11	-0.10	-0.10	-0.08^{***}	-0.23^{*}	$-0.13^{*/**/***}$	$-0.13^{*/**/***}$
Korea	-0.07	-0.78	-0.08	-0.89	-0.05	-0.61			$-0.16^{*/**/***}$	$-0.13^{*/**/***}$
Netherlands	-0.41	-0.05	-0.40	-0.10	-0.43	**0.02**	-0.36^{***}	-0.90^{**}	$-0.25^{*/**/***}$	$-0.21^{*/**/***}$
New Zealand	-0.21	**0.19**	-0.38	-0.38	-0.30	-0.30	-0.31^{***}		$-0.34^{*/**/***}$	$-0.26^{*/**/***}$
Portugal	-0.30	-0.74	-0.45	-0.45	-0.35	-0.35	-0.30^{***}		$-0.49^{*/**/***}$	$-0.57^{*/**/***}$
Spain	-0.81	-0.11	-0.92	-0.92	-0.89	-0.89	-0.80^{***}		$-0.99^{*/**/***}$	$-0.99^{*/**/***}$
Sweden	-0.37	-0.62	-0.42	-0.79	-0.31	-0.44	-0.39^{***}	-0.53^{***}	$-0.26^{*/**/***}$	-0.12^{ns}
Turkey	-0.22	-0.09	-0.18	-0.18	·	·			$-0.23^{*/**/***}$	$-0.15^{*/**/***}$
United Kingdom	-0.37	-0.05	-0.63	-0.31	-0.16	-0.31	-0.33^{***}	-0.72^{***}	$-0.31^{*/**/***}$	$-0.17^{*/**/***}$

United States	-0.24	-1.29	-0.28	-1.57	-0.20	-0.98	-0.43***	-0.54***	-0.61*/**/***	-0.39*/**/***

Note: †) The reported Okun coefficients are reprinted from Table 1 of this study, and are obtained by summing Okun and Okun-like coefficients that were statistically significant at a level of 0.05. Dots "·" signalize that the respective Okun coefficient was in fact nil when statistical insignificance was taken into account. ‡) The Okun coefficients in the last four columns come from Table 8 of Ball et al. (2017, p. 1433), Table 2 of Lee (2000, p. 341) and Tables 1 and 2 of Zanin (2014, pp. 245-246). All these three studies made use of annual data. Whilst Ball et al. (2017) analyzed the period 1980 – 2013, Lee (2000) covered the period 1955 – 1966, and Zanin (2014) examined the period 1998 – 2012. Inasmuch as Lee (2000) chose an opposite arrangement of the Okun equation, i.e. $\Delta y_t = a + b\Delta u_t + \varepsilon_t$, his estimates were recomputed by taking a reciprocal transformation. In view of the caveat raised by Plosser and Schwert (1979), a reciprocal transformation neglects correlation between Δy and Δu, but suffices purposes of this comparison.
Caveat: The comparability of Okun coefficients is hindered by different statistical frameworks and time spans adopted by the studies the results of which are juxtaposed in the table.
Legend: Significance labels displayed at computed statistics convey the following meaning: *** for p-values ≤ 0.001, ** for p-values ≤ 0.01, * for p-values ≤ 0.05, • for p-values ≤ 0.10, and ns for p-values > 0.10. Empty cells in the last four columns inform that the respective OECD country was not subject of research.

Finally, the present analysis did not take into consideration dynamic auto-regressive effects. For simplicity, only the static version of equations (2) and (3) was entertained and estimated without any attempt to incorporate lags of the explained variable or any of the regressors. To a great degree, auto-regressive analysis is a way to deal with non-linearities, but these were modeled now explicitly. Still, the significance of the coefficients or even their signs might change if a dynamic framework were accommodated, albeit the credibility of the estimates would be jeopardized by the diminished degrees of freedom resulting from a more complex model.

5. Conclusion

In comparison to other studies that utilized statistically more intensive and computationally more demanding approaches to demonstrate non-linear features in Okun's law over the business cycle (e.g., Huang and Lin, 2006; Nebot et al., 2019; Christopoulos et al. 2019), the empirical analysis of this paper is based on an adaptable extension of the basic Okun equation. The extension recognizes four regimes of output-unemployment changes and defines four quadrants specified by a zero threshold applied to both changes in output and changes in unemployment, which implies different Okun equations for upturns and downturns in output and rises or falls in unemployment. The thresholds need not be necessarily around zero, and so this approach may be further generalized to identify the most plausible threshold for both variables that are assigned here responsibility for asymmetry in Okun's law (such as in Boďa et al., 2015). Alternatively, it is possible to impute a time-varying nature to parameters in the extended Okun equation and to add thus one more dimension that takes the linear model closer to reality (such as in Huang and Lin, 2006). Notwithstanding these possibilities, the extended Okun equation is cast into a bivariate model to study different responses of male and female unemployment to output variations.

The empirical analysis reposes upon data of 21 OECD countries for a period spanning 31 years from 1989 to 2019, and shows that Okun's law is not symmetric and is non-linear. Unemployment responds to changes in output asymmetrically depending on the regime. In contractions, the response is stronger, and in upturns, the response is attenuated. In standard counter-cyclical regimes when output and unemployment offset each other, Okun's law conforms to wisdom and exhibits a negative relationship. Yet, when output and unemployment are both on the rise, Okun's law escapes a conventional interpretation as Okun coefficients are often positive. Finally, Okun's law is found stronger for males than for females. These general patterns are in accord with the findings of other studies whose scope and analytical choices were completely dissimilar. Finally, it should be noted that there have been only a few studies that a comparative Okunian analysis for a larger number of OECD countries with a unified methodology, and it is therefore difficult to have a more exhaustive picture into similarities and disparities amongst OECD countries concerning the intensity of output-unemployment fluctuations.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A Statistical properties of input data and incidence of recessionary or non-conventional patterns

Country		Descriptive statistics$^{\dagger)}$			Stationarity tests			Descriptive statistics			Stationarity tests		# cases of recessionary or non-conventional patterns	
		Mean	Minimum	Maximum	ADF$^{\ddagger)}$	KPSS$^{\ddagger)}$		Mean	Minimum	Maximum	ADF$^{\ddagger)}$	KPSS$^{\ddagger)}$		
Australia	Δy	2.924	-0.398	4.949	-4.315$^{**/***}$	0.216^{ns}	Δu	-0.031	-1.257	2.684	-5.293$^{**/***}$	0.125^{ns}	$\{\Delta y < 0\}$	1
	$(\Delta y)^{-}$	-0.013	-0.398	0.000			Δu^{M}	-0.013	-1.527	3.190	-5.339$^{**/***}$	0.132^{ns}	$\{\Delta y \cdot \Delta u > 0\}$	10
	$\Delta y \cdot \iota_{\{\Delta u > 0\}}$	0.923	-0.398	3.950			Δu^{F}	-0.054	-1.258	1.982	-4.683$^{**/***}$	0.112^{ns}	$\{\Delta u^{M}\ \Delta u^{F} < 0\}$	1
Belgium	Δy	1.825	-2.041	3.723	-4.090$^{**/***}$	0.243^{ns}	Δu	-0.097	-1.661	1.583	-4.213$^{**/***}$	0.109^{ns}	$\{\Delta y < 0\}$	2
	$(\Delta y)^{-}$	-0.100	-2.041	0.000			Δu^{M}	0.016	-1.745	1.556	-4.146$^{**/***}$	0.160^{ns}	$\{\Delta y \cdot \Delta u > 0\}$	11
	$\Delta y \cdot \iota_{\{\Delta u > 0\}}$	0.585	-2.041	3.509			Δu^{F}	-0.269	-1.565	1.617	-3.742$^{**/***}$	0.053^{ns}	$\{\Delta u^{M}\ \Delta u^{F} < 0\}$	4
Canada	Δy	2.172	-2.970	5.048	-4.005$^{**/***}$	0.130^{ns}	Δu	-0.063	-0.986	2.227	-4.696$^{**/***}$	0.120^{ns}	$\{\Delta y < 0\}$	2
	$(\Delta y)^{-}$	-0.169	-2.970	0.000			Δu^{M}	-0.044	-1.096	3.010	-4.706$^{**/***}$	0.120^{ns}	$\{\Delta y \cdot \Delta u > 0\}$	8
	$\Delta y \cdot \iota_{\{\Delta u > 0\}}$	0.232	-2.970	2.973			Δu^{F}	-0.084	-0.936	1.579	-4.426$^{**/***}$	0.115^{ns}	$\{\Delta u^{M}\ \Delta u^{F} < 0\}$	2
Denmark	Δy	1.726	-5.031	5.195	-2.917$^{\bullet}$	0.167^{ns}	Δu	-0.113	-2.786	3.468	-3.290*	0.082^{ns}	$\{\Delta y < 0\}$	2
	$(\Delta y)^{-}$	-0.185	-5.031	0.000			Δu^{M}	-0.097	-3.326	4.402	-3.559*	0.077^{ns}	$\{\Delta y \cdot \Delta u > 0\}$	11
	$\Delta y \cdot \iota_{\{\Delta u > 0\}}$	0.266	-5.031	2.905			Δu^{F}	-0.131	-2.151	2.429	-3.028*	0.087^{ns}	$\{\Delta u^{M}\ \Delta u^{F} < 0\}$	6
Finland	Δy	1.668	-8.419	6.142	-3.617$^{**/***}$	0.133^{ns}	Δu	0.119	-1.827	5.119	-3.649$^{**/***}$	0.207^{ns}	$\{\Delta y < 0\}$	7
	$(\Delta y)^{-}$	-0.706	-8.419	0.000			Δu^{M}	0.135	-2.409	5.557	-3.877$^{**/***}$	0.176^{ns}	$\{\Delta y \cdot \Delta u > 0\}$	4
	$\Delta y \cdot \iota_{\{\Delta u > 0\}}$	-0.407	-8.419	3.887			Δu^{F}	0.103	-1.867	4.784	-2.935*	0.241^{ns}	$\{\Delta u^{M}\ \Delta u^{F} < 0\}$	3
France	Δy	1.598	-2.915	3.849	-3.429*	0.228^{ns}	Δu	0.010	-1.418	1.694	-3.456*	0.110^{ns}	$\{\Delta y < 0\}$	2
	$(\Delta y)^{-}$	-0.118	-2.915	0.000			Δu^{M}	0.073	-1.475	1.934	-3.616$^{**/***}$	0.121^{ns}	$\{\Delta y \cdot \Delta u > 0\}$	13
	$\Delta y \cdot \iota_{\{\Delta u > 0\}}$	0.515	-2.915	2.790			Δu^{F}	-0.070	-1.360	1.428	-3.346*	0.086^{ns}	$\{\Delta u^{M}\ \Delta u^{F} < 0\}$	2
Germany	Δy	1.604	-5.866	5.122	-6.137$^{**/***}$	0.159^{ns}	Δu	-0.080	-1.670	1.260	-3.779$^{**/***}$	0.389^{ns}	$\{\Delta y < 0\}$	4
	$(\Delta y)^{-}$	-0.259	-5.866	0.000			Δu^{M}	-0.043	-1.860	1.273	-3.855$^{**/***}$	0.383^{ns}	$\{\Delta y \cdot \Delta u > 0\}$	8
	$\Delta y \cdot \iota_{\{\Delta u > 0\}}$	0.256	-5.866	4.982			Δu^{F}	-0.130	-1.441	1.352	-3.827$^{**/***}$	0.352^{ns}	$\{\Delta u^{M}\ \Delta u^{F} < 0\}$	0
Greece	Δy	0.881	-9.577	5.633	-1.932^{ns}	0.294^{ns}	Δu	0.328	-2.200	6.587	-2.738$^{\bullet}$	0.084^{ns}	$\{\Delta y < 0\}$	9
	$(\Delta y)^{-}$	-1.102	-9.577	0.000			Δu^{M}	0.313	-2.467	6.440	-3.264*	0.088^{ns}	$\{\Delta y \cdot \Delta u > 0\}$	10
	$\Delta y \cdot \iota_{\{\Delta u > 0\}}$	-0.389	-9.577	4.937			Δu^{F}	0.302	-2.768	6.698	-2.278^{ns}	0.079^{ns}	$\{\Delta u^{M}\ \Delta u^{F} < 0\}$	3
Ireland	Δy	5.365	-5.213	22.444	-2.650$^{\bullet}$	0.112^{ns}	Δu	-0.368	-2.705	6.068	-2.221^{ns}	0.124^{ns}	$\{\Delta y < 0\}$	2
	$(\Delta y)^{-}$	-0.327	-5.213	0.000			Δu^{M}	-0.349	-2.929	7.774	-2.508^{ns}	0.113^{ns}	$\{\Delta y \cdot \Delta u > 0\}$	10
	$\Delta y \cdot \iota_{\{\Delta u > 0\}}$	0.643	-5.213	5.751			Δu^{F}	-0.391	-2.942	3.991	-1.865^{ns}	0.148^{ns}	$\{\Delta u^{M}\ \Delta u^{F} < 0\}$	0

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Country		Descriptive statistics†)			Stationarity tests			Descriptive statistics			Stationarity tests		# cases of recessionary or non-conventional patterns	
		Mean	Minimum	Maximum	ADF‡)	KPSS‡)		Mean	Minimum	Maximum	ADF‡)	KPSS‡)		
Israel	Δy	4.242	-0.176	8.475	-3.441^{*}	0.451^{ns}	Δu	-0.255	-2.787	1.850	$-3.837^{**/***}$	0.139^{ns}	$\{\Delta y < 0\}$	1
	$(\Delta y)^{-}$	-0.006	-0.176	0.000			Δu^{M}	-0.227	-3.059	2.296	$-3.833^{**/***}$	0.158^{ns}	$\{\Delta y \cdot \Delta u > 0\}$	9
	$\Delta y \cdot \iota_{\{\Delta u > 0\}}$	1.192	-0.176	7.473			Δu^{F}	-0.298	-2.489	2.254	$-4.150^{**/***}$	0.105^{ns}	$\{\Delta u^{M}\,\Delta u^{F} < 0\}$	2
Italy	Δy	0.746	-5.425	3.717	$-3.588^{**/***}$	$0.394^{\bullet}$	Δu	-0.068	-1.635	2.330	$-2.642^{\bullet}$	0.136^{ns}	$\{\Delta y < 0\}$	6
	$(\Delta y)^{-}$	-0.405	-5.425	0.000			Δu^{M}	0.036	-0.781	2.342	-2.526^{ns}	0.106^{ns}	$\{\Delta y \cdot \Delta u > 0\}$	8
	$\Delta y \cdot \iota_{\{\Delta u > 0\}}$	0.036	-5.425	2.846			Δu^{F}	-0.255	-2.868	2.284	$-2.866^{\bullet}$	0.210^{ns}	$\{\Delta u^{M}\,\Delta u^{F} < 0\}$	1
Japan	Δy	1.086	-5.569	4.777	$-4.964^{**/***}$	0.215^{ns}	Δu	0.004	-0.544	1.111	-3.019^{*}	$0.442^{\bullet}$	$\{\Delta y < 0\}$	6
	$(\Delta y)^{-}$	-0.290	-5.569	0.000			Δu^{M}	0.011	-0.640	1.208	-3.185^{*}	$0.423^{\bullet}$	$\{\Delta y \cdot \Delta u > 0\}$	9
	$\Delta y \cdot \iota_{\{\Delta u > 0\}}$	0.213	-5.569	4.106			Δu^{F}	-0.004	-0.480	0.980	$-2.766^{\bullet}$	0.468^{*}	$\{\Delta u^{M}\,\Delta u^{F} < 0\}$	1
Korea	Δy	4.928	-5.627	10.714	-3.549^{*}	$0.772^{**/***}$	Δu	0.039	-1.987	4.484	$-4.771^{**/***}$	0.051^{ns}	$\{\Delta y < 0\}$	1
	$(\Delta y)^{-}$	-0.188	-5.627	0.000			Δu^{M}	0.028	-2.315	5.142	$-4.748^{**/***}$	0.050^{ns}	$\{\Delta y \cdot \Delta u > 0\}$	11
	$\Delta y \cdot \iota_{\{\Delta u > 0\}}$	1.246	-5.627	6.623			Δu^{F}	0.057	-1.484	3.477	$-4.788^{**/***}$	0.053^{ns}	$\{\Delta u^{M}\,\Delta u^{F} < 0\}$	2
Netherlands	Δy	2.099	-3.736	4.911	-2.952^{*}	$0.349^{\bullet}$	Δu	-0.163	-1.463	1.759	$-3.344^{**/***}$	0.096^{ns}	$\{\Delta y < 0\}$	3
	$(\Delta y)^{-}$	-0.163	-3.736	0.000			Δu^{M}	-0.096	-1.133	1.742	$-3.346^{**/***}$	0.081^{ns}	$\{\Delta y \cdot \Delta u > 0\}$	9
	$\Delta y \cdot \iota_{\{\Delta u > 0\}}$	0.315	-3.736	3.068			Δu^{F}	-0.271	-2.177	2.044	$-3.350^{**/***}$	0.128^{ns}	$\{\Delta u^{M}\,\Delta u^{F} < 0\}$	4
New Zealand	Δy	2.848	-1.665	6.328	$-3.865^{**/***}$	0.074^{ns}	Δu	-0.103	-1.920	2.661	$-4.911^{**/***}$	0.066^{ns}	$\{\Delta y < 0\}$	2
	$(\Delta y)^{-}$	-0.110	-1.665	0.000			Δu^{M}	-0.119	-2.375	2.913	$-4.997^{**/***}$	0.064^{ns}	$\{\Delta y \cdot \Delta u > 0\}$	8
	$\Delta y \cdot \iota_{\{\Delta u > 0\}}$	0.351	-1.665	2.952			Δu^{F}	-0.086	-1.348	2.346	$-4.517^{**/***}$	0.069^{ns}	$\{\Delta u^{M}\,\Delta u^{F} < 0\}$	2
Portugal	Δy	1.520	-4.142	4.696	-2.961^{*}	0.283^{ns}	Δu	0.053	-2.503	2.996	$-2.613^{\bullet}$	0.153^{ns}	$\{\Delta y < 0\}$	6
	$(\Delta y)^{-}$	-0.432	-4.142	0.000			Δu^{M}	0.088	-2.794	3.399	-2.490^{ns}	0.154^{ns}	$\{\Delta y \cdot \Delta u > 0\}$	10
	$\Delta y \cdot \iota_{\{\Delta u > 0\}}$	0.223	-4.142	4.194			Δu^{F}	0.000	-2.203	2.569	$-2.646^{\bullet}$	0.147^{ns}	$\{\Delta u^{M}\,\Delta u^{F} < 0\}$	2
Spain	Δy	2.072	-3.836	5.113	-2.483^{ns}	0.218^{ns}	Δu	-0.098	-3.411	6.642	-2.565^{ns}	0.096^{ns}	$\{\Delta y < 0\}$	5
	$(\Delta y)^{-}$	-0.338	-3.836	0.000			Δu^{M}	-0.003	-2.833	7.629	$-2.705^{\bullet}$	0.101^{ns}	$\{\Delta y \cdot \Delta u > 0\}$	7
	$\Delta y \cdot \iota_{\{\Delta u > 0\}}$	0.078	-3.836	2.938			Δu^{F}	-0.329	-5.332	5.332	-2.366^{ns}	0.095^{ns}	$\{\Delta u^{M}\,\Delta u^{F} < 0\}$	1
Sweden	Δy	2.065	-4.437	5.782	$-4.217^{**/***}$	0.124^{ns}	Δu	0.177	-1.725	3.656	-3.536^{*}	0.199^{ns}	$\{\Delta y < 0\}$	6
	$(\Delta y)^{-}$	-0.329	-4.437	0.000			Δu^{M}	0.176	-1.740	4.209	$-3.691^{**/***}$	0.199^{ns}	$\{\Delta y \cdot \Delta u > 0\}$	11
	$\Delta y \cdot \iota_{\{\Delta u > 0\}}$	0.633	-4.437	5.782			Δu^{F}	0.179	-1.712	3.052	-3.242^{*}	0.186^{ns}	$\{\Delta u^{M}\,\Delta u^{F} < 0\}$	1
Turkey	Δy	4.411	-6.147	10.538	$-3.699^{**/***}$	0.066^{ns}	Δu	0.175	-2.201	3.122	$-4.022^{**/***}$	0.118^{ns}	$\{\Delta y < 0\}$	4
	$(\Delta y)^{-}$	-0.667	-6.147	0.000			Δu^{M}	0.143	-2.542	3.234	$-4.039^{**/***}$	0.079^{ns}	$\{\Delta y \cdot \Delta u > 0\}$	18
	$\Delta y \cdot \iota_{\{\Delta u > 0\}}$	2.337	-6.147	9.207			Δu^{F}	0.238	-1.732	2.792	$-4.428^{**/***}$	0.249^{ns}	$\{\Delta u^{M}\,\Delta u^{F} < 0\}$	4

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Country		Descriptive statistics†)			Stationarity tests			Descriptive statistics			Stationarity tests		# cases of recessionary or non-conventional patterns	
		Mean	Minimum	Maximum	ADF‡)	KPSS‡)		Mean	Minimum	Maximum	ADF‡)	KPSS‡)		
United Kingdom	Δy	1.942	-4.341	3.782	-3.282*	0.143 ns	Δu	-0.108	-1.299	2.000	-2.976*	0.106 ns	$\{\Delta y < 0\}$	3
	$(\Delta y)^{-}$	-0.191	-4.341	0.000			Δu^M	-0.106	-1.549	2.509	-3.553*	0.109 ns	$\{\Delta y \cdot \Delta u > 0\}$	7
	$\Delta y \cdot \iota_{\{\Delta u > 0\}}$	0.292	-4.341	3.130			Δu^F	-0.110	-1.024	1.412	-1.922 ns	0.120 ns	$\{\Delta u^M \Delta u^F < 0\}$	0
United States	Δy	2.433	-2.569	4.644	-2.861•	0.217 ns	Δu	-0.054	-1.232	3.530	-3.856**/**	0.112 ns	$\{\Delta y < 0\}$	3
	$(\Delta y)^{-}$	-0.094	-2.569	0.000			Δu^M	-0.050	-1.398	4.292	-3.972**/**	0.106 ns	$\{\Delta y \cdot \Delta u > 0\}$	6
	$\Delta y \cdot \iota_{\{\Delta u > 0\}}$	0.353	-2.569	3.462			Δu^F	-0.059	-1.044	2.668	-3.673**/**	0.120 ns	$\{\Delta u^M \Delta u^F < 0\}$	1

Note: †) The variables are presented as percentages or percentage points per annum. ‡) Two different approaches to testing for unit roots are reported, viz. the augmented Dickey-Fuller test with a drift ("ADF test") formulated by Said and Dickey (1984), and the “mu” version of the Kwiatkowski–Phillips–Schmidt–Shin test ("KPSS test") developed by Kwiatkowski et al. (1992). Note that the unit root for the ADF test is formulated in the null hypothesis, whereas for the KPSS test it is encapsulated in the alternative hypothesis. Computed test statistics are confronted with asymptotic critical values for these tests assembled from Dickey and Fuller (1981), Hamilton (1994) and Kwiatkowski et al. (1992).
Legend: Significance labels displayed at computed statistics convey the following meaning: **/*** for p-values ≤ 0.01, * for p-values ≤ 0.05, • for p-values ≤ 0.10, and ns for p-values > 0.10.

Appendix B Results for both the univariate and system estimation

Country	Equation and regressand	Estimated parameters[†)]				Adjusted R^2	Other system metrics		Congruence tests of gender-specific estimates[‡)]			
		Intercept	Δy	$(\Delta y)^{-}$	$\Delta y \cdot \iota_{\{\Delta u > 0\}}$				[H1]	[H2]	[H3]	[H4]
Australia	Whole economy: Δu	0.876^{**}	-0.396^{***}		0.273^{***}	0.483	Adjusted R^2 (system)	0.471				
	System – males: Δu_M	1.098^{***}	-0.482^{***}		0.322^{***}	0.480	McElroy R^2 (system)	0.357		11.985^{***}		6.081^{*}
	System – females: Δu_F	0.571^{*}	-0.281^{***}		0.213^{***}	0.450	Inter-equation correlation	0.877				
Belgium	Whole economy: Δu	0.083^{ns}	-0.299^{**}	-0.781^{*}	0.493^{***}	0.608	Adjusted R^2 (system)	0.491				
	System – males: Δu_M	0.621^{**}	-0.450^{***}		0.369^{***}	0.466	McElroy R^2 (system)	0.430		0.017^{ns}		$3.430^{\bullet}$
	System – females: Δu_F	0.216^{ns}	-0.439^{***}		0.540^{***}	0.510	Inter-equation correlation	0.572				
Canada	Whole economy: Δu	0.272^{*}	-0.242^{***}	-0.765^{***}	0.265^{***}	0.897	Adjusted R^2 (system)	0.866				
	System – males: Δu_M	0.383^{*}	-0.302^{***}	-0.946^{***}	0.294^{***}	0.883	McElroy R^2 (system)	0.837	30.363^{***}	6.672^{**}	4.743^{*}	0.623^{ns}
	System – females: Δu_F	0.134^{ns}	-0.170^{***}	-0.573^{***}	0.237^{***}	0.818	Inter-equation correlation	0.355				
Denmark	Whole economy: Δu	0.476^{*}	-0.449^{***}	-0.483^{*}	0.366^{**}	0.708	Adjusted R^2 (system)	0.599				
	System – males: Δu_M	0.908^{***}	-0.582^{***}			0.641	McElroy R^2 (system)	0.498		8.614^{**}		
	System – females: Δu_F	0.520^{**}	-0.377^{***}			0.519	Inter-equation correlation	0.593				
Finland	Whole economy: Δu	0.714^{**}	-0.356^{***}			0.499	Adjusted R^2 (system)	0.489				
	System – males: Δu_M	0.871^{***}	-0.441^{***}			0.601	McElroy R^2 (system)	0.505		17.818^{***}		
	System – females: Δu_F	0.542^{*}	-0.263^{***}			0.316	Inter-equation correlation	0.848				
France	Whole economy: Δu	0.188^{ns}	-0.276^{***}	-0.641^{**}	0.365^{***}	0.679	Adjusted R^2 (system)	0.645				
	System – males: Δu_M	$0.335^{\bullet}$	-0.333^{***}	-0.642^{**}	0.377^{***}	0.666	McElroy R^2 (system)	0.565	$6.851^{\bullet}$	4.107^{*}	0.000^{ns}	0.168^{ns}
	System – females: Δu_F	0.012^{ns}	-0.212^{**}	-0.641^{**}	0.352^{***}	0.614	Inter-equation correlation	0.685				
Germany	Whole economy: Δu	0.430^{**}	-0.389^{***}		0.449^{***}	0.584	Adjusted R^2 (system)	0.568				
	System – males: Δu_M	0.538^{***}	-0.429^{***}		0.422^{***}	0.588	McElroy R^2 (system)	0.532		5.381^{*}		1.479^{ns}
	System – females: Δu_F	0.293^{*}	-0.340^{***}		0.479^{***}	0.546	Inter-equation correlation	0.826				
Greece	Whole economy: Δu	-0.973^{***}	0.064^{ns}	-1.280^{***}	0.430^{***}	0.838	Adjusted R^2 (system)	0.825				
	System – males: Δu_M	-0.961^{**}	0.115^{ns}	-1.160^{***}	0.272^{*}	0.811	McElroy R^2 (system)	0.770	16.449^{***}	$2.972^{\bullet}$	5.615^{*}	16.211^{***}
	System – females: Δu_F	-1.041^{***}	-0.002^{ns}	-1.449^{***}	0.650^{***}	0.836	Inter-equation correlation	0.751				
Ireland	Whole economy: Δu	-0.175^{ns}	-0.142^{**}	-1.070^{***}	0.345^{**}	0.693	Adjusted R^2 (system)	0.678				
	System – males: Δu_M	-0.377^{ns}	-0.128^{*}	-1.429^{***}	0.382^{**}	0.704	McElroy R^2 (system)	0.635	29.490^{***}	1.260^{ns}	20.418^{***}	1.550^{ns}
	System – females: Δu_F	0.080^{ns}	-0.161^{***}	-0.619^{**}	0.294^{**}	0.625	Inter-equation correlation	0.814				

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Country	Equation and regressand	Estimated parameters†) Intercept	Δy	$(\Delta y)^{-}$	$\Delta y \cdot \iota_{\{\Delta u > 0\}}$	Adjusted R^2	Other system metrics		Congruence tests of gender-specific estimates‡) [H1]	[H2]	[H3]	[H4]
Israel	Whole economy: Δu	0.585^{*}	-0.298^{***}		0.356^{***}	0.618	Adjusted R^2 (system)	0.562				
	System – males: Δu_M	0.714^{*}	-0.312^{***}		0.322^{***}	0.515	McElroy R^2 (system)	0.498		0.210^{ns}		2.017^{ns}
	System – females: Δu_F	0.422^{ns}	-0.283^{***}		0.404^{***}	0.603	Inter-equation correlation	0.540				
Italy	Whole economy: Δu	-0.209^{ns}	-0.190^{ns}	-0.658^{*}	0.459^{**}	0.399	Adjusted R^2 (system)	0.191				
	System – males: Δu_M	0.226^{ns}	-0.255^{***}			0.316	McElroy R^2 (system)	0.264		0.468^{ns}		
	System – females: Δu_F	-0.090^{ns}	-0.220^{*}			0.118	Inter-equation correlation	0.880				
Japan	Whole economy: Δu	-0.009^{ns}	$-0.091^{\bullet}$	-0.280^{**}	0.149^{**}	0.460	Adjusted R^2 (system)	0.238				
	System – males: Δu_M	0.133^{ns}	-0.113^{**}			0.220	McElroy R^2 (system)	0.170		0.714^{ns}		
	System – females: Δu_F	0.106^{ns}	-0.101^{**}			0.263	Inter-equation correlation	0.937				
Korea	Whole economy: Δu	0.099^{ns}	-0.069^{*}	-0.813^{***}	0.102^{**}	0.851	Adjusted R^2 (system)	0.836				
	System – males: Δu_M	0.117^{ns}	-0.080^{*}	-0.920^{***}	0.107^{**}	0.856	McElroy R^2 (system)	0.772	31.812^{***}	$2.729^{\bullet}$	14.536^{***}	0.388^{ns}
	System – females: Δu_F	0.072^{ns}	-0.051^{*}	-0.648^{***}	0.094^{**}	0.795	Inter-equation correlation	0.785				
Netherlands	Whole economy: Δu	0.583^{***}	-0.410^{***}		0.366^{***}	0.641	Adjusted R^2 (system)	0.604				
	System – males: Δu_M	0.648^{***}	-0.399^{***}		0.297^{***}	0.620	McElroy R^2 (system)	0.517		0.504^{ns}		5.122^{*}
	System – females: Δu_F	0.492^{**}	-0.431^{***}		0.454^{***}	0.591	Inter-equation correlation	0.726				
New Zealand	Whole economy: Δu	0.239^{ns}	-0.208^{*}	$-1.002^{\bullet}$	0.397^{*}	0.530	Adjusted R^2 (system)	0.424				
	System – males: Δu_M	0.972^{***}	-0.383^{***}			0.435	McElroy R^2 (system)	0.299		4.717^{*}		
	System – females: Δu_F	0.760^{**}	-0.297^{***}			0.407	Inter-equation correlation	0.868				
Portugal	Whole economy: Δu	-0.002^{ns}	-0.299^{*}	-0.930^{**}	0.485^{**}	0.603	Adjusted R^2 (system)	0.418				
	System – males: Δu_M	0.767^{**}	-0.447^{***}			0.458	McElroy R^2 (system)	0.313		$3.581^{\bullet}$		
	System – females: Δu_F	0.527^{*}	-0.347^{***}			0.365	Inter-equation correlation	0.808				
Spain	Whole economy: Δu	1.171^{*}	-0.806^{***}	$-1.028^{\bullet}$	0.692^{**}	0.762	Adjusted R^2 (system)	0.686				
	System – males: Δu_M	1.904^{***}	-0.920^{***}			0.674	McElroy R^2 (system)	0.574		0.111^{ns}		
	System – females: Δu_F	1.522^{***}	-0.893^{***}			0.699	Inter-equation correlation	0.726				
Sweden	Whole economy: Δu	$0.509^{\bullet}$	-0.366^{***}	-0.607^{**}	0.353^{***}	0.695	Adjusted R^2 (system)	0.682				
	System – males: Δu_M	$0.582^{\bullet}$	-0.416^{***}	-0.713^{**}	0.342^{***}	0.723	McElroy R^2 (system)	0.637	26.303^{***}	$3.798^{\bullet}$	$2.891^{\bullet}$	0.240^{ns}
	System – females: Δu_F	$0.430^{\bullet}$	-0.312^{***}	-0.489^{*}	0.366^{***}	0.607	Inter-equation correlation	0.821				
Turkey	Whole economy: Δu	0.828^{**}	-0.219^{***}		0.134^{*}	0.415	Adjusted R^2 (system)	0.219				
	System – males: Δu_M	0.954^{***}	-0.184^{***}			0.411	McElroy R^2 (system)	0.382		11.503^{***}		
	System – females: Δu_F	$0.547^{\bullet}$	-0.070^{ns}			0.029	Inter-equation correlation	0.786				

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Country	Equation and regressand	Estimated parameters†)				Adjusted R^2	Other system metrics		Congruence tests of gender-specific estimates‡)			
		Intercept	Δy	$(\Delta y)^{-}$	$\Delta y \cdot \iota_{\{\Delta u > 0\}}$				[H1]	[H2]	[H3]	[H4]
United Kingdom	Whole economy: Δu	0.446^{*}	-0.367^{***}	$-0.347^{\bullet}$	0.315^{***}	0.717	Adjusted R^2 (system)	0.663				
	System – males: Δu_M	1.021^{***}	-0.628^{***}		0.319^{**}	0.675	McElroy R^2 (system)	0.609		29.347^{***}		1.068^{ns}
	System – females: Δu_F	0.066^{ns}	-0.162^{**}	-0.380^{**}	0.229^{***}	0.631	Inter-equation correlation	0.458				
United States	Whole economy: Δu	0.288^{ns}	-0.244^{**}	-1.387^{***}	0.340^{***}	0.768	Adjusted R^2 (system)	0.755				
	System – males: Δu_M	0.350^{ns}	-0.284^{**}	-1.665^{***}	0.381^{***}	0.758	McElroy R^2 (system)	0.660	29.361^{***}	$3.442^{\bullet}$	11.133^{***}	2.468^{ns}
	System – females: Δu_F	0.213^{ns}	-0.196^{**}	-1.076^{***}	0.294^{***}	0.747	Inter-equation correlation	0.847				

Note: †) The estimated models were identified by searching over the set of possible models that included both the intercept and Δy as regressors, whereupon the model optimal with respect to the Bayesian information criterion (BIC) was selected. Univariate (whole-economy) estimates were obtained by ordinary least squares (OLS), whereas system (gender-specific) estimates followed from feasible generalized least squares (FGLS). The reported significances are derived from heteroskedasticity and autocorrelations consistent standard errors of Newey and West (1987, 1994). In addition to these conventional approaches, a resistant approach based on M-estimators was employed alongside without qualitative as well as substantial quantitative differences. Owing to the similarity and the limited space, these are not reported. ‡) The hypotheses [H1] to [H4] confront the coefficients of male and female equations, and are tested by dint of the traditional likelihood-ratio based test. Nonetheless, the results are identical to those arising from Wald-type F and Chi-square tests, which are not reported here in order to avoid duplicity. The null hypothesis in each case is the congruence of the parameters of gender-specific equations. The general hypothesis [H1] that male and female coefficients at Δy, $(\Delta y)^{-}$ and $\Delta y \cdot \iota_{\{\Delta u > 0\}}$ are identical for a country is broken down into three partial hypotheses requiring the sameness of male and female coefficients only at Δy [H2], $(\Delta y)^{-}$ [H3] and $\Delta y \cdot \iota_{\{\Delta u > 0\}}$ [H4], respectively. Naturally, [H1] is testable only when the fully specified equations are applied for both male and female unemployment.

Legend: Significance labels displayed at computed statistics convey the following meaning: *** for p-values ≤ 0.001, ** for p-values ≤ 0.01, * for p-values ≤ 0.05, $^{\bullet}$ for p-values ≤ 0.10, and ^{ns} for p-values > 0.10.