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(A)synchronicity in Okun Coefficients Amongst 38 OECD Countries

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Abstract

For 38 OECD countries during the period 1991–2022, the paper estimates time-varying trajectories of unemployment-based and employment-based Okun coefficients and studies their synchronicity. Schlicht's VC method is utilized to estimate Okun coefficients and time-series clustering is applied to identify groups of economies with synchronous business cycle characteristics. The findings defy two prevalent beliefs of Okun's law since many countries display constant or almost constant trajectories of the (un)employment-output sensitivity, and for many countries Okun's law need not be stronger in a downturn. Furthermore, countries do not synchronize in their business cycle dynamics as shown in disparate trajectories of Okun coefficients, which argues against a single one-size-fits-all stabilization policy, certainly in less homogeneous economic blocks. Finally, there is strong evidence for labour market flows into and outside the labour force that are associated with informal sector size and translated into lesser sensitivity of official labour market variables across the business cycle.

Highlights

- Time-varying Okun's law is estimated for 38 OECD countries over 1991–2022.
- Both the unemployment-based and employment-based Okun's law are considered.
- Many countries display (almost) constant cosensitivity of (un)employment with output.
- Clusters of countries are identified with a similar trajectory of Okun coefficients.
- The non-existence of common clusters testifies against a universal stabilization policy.

Keywords Okun's law · Time-varying coefficients · Synchronicity · OECD countries · Gap version

JEL Classification E23 · E32

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Introduction

This paper focuses on two forms of Okun's law that appear in a certain strand of labour market research, viz. the original unemployment-based Okun's law, and the employment-based Okun's law. Okun's law in its original form considered by Okun (1962) sprouted from Keynesian ideas espoused by the US administration in the 1950s and 1960s and was designed to support full-employment policies. The original unemployment-output formulation—referred to here as the unemployment-based Okun's law—predicts negative comovements between unemployment and output. Under the gap formulation, a rise of real output above potential is associated with a decrease in unemployment below its long-term level, and vice versa. Since employment and unemployment are closely related economic categories, in a good many influential studies Okun's law is operationalized as an employment-output elasticity (e.g. Kaufman 1988; Gordon 1984, 2010; Ball et al. 2017), even though this approach is somewhat non-standard. This version is referred to as the employment-based version of Okun's law. Okun's law may be formally represented as a regression model that, in the most general case, correlates cyclical variations in (un)employment with cyclical variations in output, and translates them into a coefficient that captures sensitivity between these two business cycle measures. The resultant Okun coefficient is often viewed as a reduced-form parameter that incorporates diverse structural configurations underlying demand of firms for labour, labour supply of households, and macroeconomic production, some of which may simply be directly unobservable (e.g. Perman and Tavera 2007, p. 47; Dixon et al. 2017, p. 2749). Whereas some authors claim relative stability of the Okun coefficient for the US economy in the past decades (Ball et al. 2017, pp. 1424–1426; Furceri et al. 2020, p. 673; Ibourk and Elayanoui 2024, p. 568), the general consensus now is that the strength of (un)employment-output comovements varies across economies (Bartolucci et al. 2018; Ball et al. 2019) and that the Okun coefficient is not constant, exhibiting typically time-varying trajectories (Grant 2018; Michail 2019) different across the business cycle (Nebot et al. 2019; Boďa and Považanová 2021; Donayre 2022).

Hence, regardless of being associated with unemployment or employment, the Okun coefficient can be viewed as a descriptive quantity that captures in a condensed format the internal mechanism with which the business cycle operates within an economy. In this interpretation, the Okun coefficient may be construed as a semi-structural parameter that measures the ratio with which the cyclical (short-term) component of (un)employment varies with the cyclical (short-term) component of output, and measures the dynamics of the business cycle for an economy with a sole focus upon the labour market and the real economy. Based on the empirical evidence indicated in a number of cross-country comparative studies on Okun's law (e.g. Ball et al. 2017, 2019; Furceri et al. 2020; Boďa and Považanová 2021) and beyond it (e.g. Konstantakopoulou and Tsionas 2014; Brůha and Polanský 2015), manifestations and intensity of the business cycle vary across economies. To a great degree, this is no surprise as countries have distinct macroeconomic and institutional set-ups and environments, especially different levels of unemployment, economic prosper-

ity, structural policies and exposure to structural shocks (Evans 2018, p. 3; An et al. 2022, p. 4227). Albeit cross-country differences in Okun coefficients have been sufficiently described in the literature, and recently it has become a standard to seek an explanation for these differences (e.g. Ball et al. 2017, 2019; Gonzales Prieto et al. 2018; An et al. 2019, 2022; Ibourk and Elayanoui 2024), no attempt has been made to date to compare the business cycle dynamics for a larger number of economies in terms of their dual (un)employment-output sensitivity and to justify the observed cross-country heterogeneity. This absence prescribes an agenda for this paper that strives to examine and explain the (a)synchronicity in the business cycle dynamics documented by the trajectories of Okun coefficients for more than three dozen world economies (most of which are high-income countries). Several aspects are accommodated therewith at a time.

In full cognizance of the likely non-constancy of Okun's law, the paper applies concurrently the unemployment-based and employment-based version of Okun's law for 38 OECD countries for the period of three decades between 1991 and 2022 with a view to investigating and explaining the possible synchronicity in the trajectories of Okun coefficients. The gap formulation of Okun's law is applied for each country so as to account for (un)employment-output variation stemming from shifts in both aggregate demand, and is estimated by the VC (varying-coefficient) method of Schlicht (1985, 2021) that allows Okun coefficients to vary in time. A time-series clustering algorithm is utilized to identify groups of countries with similar trajectories of Okun coefficients, and the estimated trajectories of Okun coefficients are matched against a number of candidate factors describing economic, labour force, structural and institutional heterogeneity amongst the OECD countries. On the one hand, the concurrent reliance upon the unemployment-based and employment-based Okun's law facilitates deeper insights into the effects of flows into and outside the labour force upon the business cycle dynamics. On the other hand, it produces burdensome statistical output and requires additional analyses confronting unemployment-based and employment-based Okun coefficients.

This paper makes an addition to this strand of business cycle literature represented by extensive cross-country comparative studies such as Dixon et al. (2017), Bartolucci et al. (2018), An et al. (2019), Ball et al. (2019), Jalles (2019), Furceri et al. (2020). They study mostly the unemployment-based version of Okun's law under the simple difference version, they often stipulate constant Okun coefficients, engage in hybrid formulations of the Okun equation, and not all of them are interested in explaining the observed heterogeneity in the (un)employment-output sensitivity. To the contrary, this study considers both versions of Okun's law simultaneously, compares the resulting Okun coefficients more thoroughly and particularly through their trajectories extending over a period of almost three decades, strives not only to justify factors behind the observed patterns in the estimated Okun coefficients, but also seeks to establish whether there exists synchronicity in the trajectories of Okun coefficients for different economies and to explain (a)synchronous patterns.

Amongst other things, the results challenge two popular prevalent beliefs on Okun's law that are often presented as universal in nature. For many countries, either unemployment or employment may be insensitive to cyclical fluctuations, where the Okun coefficient is found constant or statistically constant. Likewise, Okun's law

may not always be stronger in economic decline, albeit there is no apparent regularity. In addition, the absence of universal clusters in the temporal variation of Okun coefficients for both versions of Okun's law suggests that there may not exist one general model of stabilization policy that would assure the synchronicity of labour market reactions to cyclical variations in a non-homogeneous set of economies as the OECD certainly is.

The balance of the paper consists of five more sections. Once "Okun's Law, its interpretation and variant formulations" section has sketched fundamental aspects of Okun's law requisite for the conceptual framework of this study, "Details on the empirical set-up, and data" section explains the methodology and comments on the data employed in the analysis. "Results" section presents the results, and is followed by "Discussion" section that discusses. Finally, "Concluding notes" section concludes.

Okun's Law, its Interpretation and Variant Formulations

In spite of its empirical nature, Okun's law is one of the key notions of contemporary macroeconomics that underpins the derivation of the short-run aggregate supply curve when combined with the Phillips curve (e.g. Mankiw and Ball 2011, pp. 342–343). Likewise, it is a useful planning instrument of stabilization policy as it measures the cost of higher unemployment in terms of a loss in economic growth (e.g. Huang and Lin 2006, p. 325). This section describes two alternative formulations of Okun's law and relates them to labour market flows, and to the mechanism of business cycles.

Unemployment-Based Okun's Law

With the unemployment-based version, an equation of Okun's law results from a simplifying assumption that unemployment is a suitable proxy of all other idle resources, which is the case when other factors of production happen to vary *pari passu* with unemployed labour (Okun 1962, p. 102) and explains why Okun's law is in fact a reduced-form relationship (e.g. Owyang and Sekhposyan 2012, p. 399; Ismihan 2016, p. 177). The so-called *gap formulation* of Okun's law relates unemployment and output through a regression model that confronts cyclical fluctuations of unemployment and output as measured by the unemployment and output gaps, respectively. In estimating the unemployment-output equation, Okun himself arranged variation in unemployment on the left-hand side in a position that qualified it as dependent on output (Okun 1962, pp. 99–100), and this pro-Keynesian arrangement is now prevalent in Okunian studies (e.g. Dixon et al. 2017; Bartolucci et al. 2018; Ball et al. 2019; Jalles 2019; Furceri et al. 2020; Boďa and Považanová 2021; Ibourk and Elayanoui 2024). With this consensus, a simple static linear Okun equation for an autonomous economic system at time t goes as

$$u_t - \overline{u}_t = b + \beta(y_t - \overline{y}_t), \tag{1}$$

wherein y is the logarithm of real output, and u is the unemployment rate. Bars over the symbols represent their long-term or equilibrium values that answer to notions of potential output or the natural rate of unemployment.[1] The resulting output gap $y - \overline{y}$ measures the tendency towards overheating the economy, and the unemployment gap $u - \overline{u}$ proxies utilization of labour. Out of two regression coefficients, b fulfils the role of an intercept, and β is the Okun coefficient that can be portrayed as the elasticity of unemployment to output.

Employment-Based Okun's Law

Okun's law is traditionally and most often interpreted as the unemployment-output nexus, which is mirrored in most Okunian studies. In some quarters, the relationship between employment and output is not qualified as Okun's law (e.g. Daly et al. 2013, p. 2), and the authors of this paper would normally endorse this orthodox interpretation. Yet, there is an unorthodox approach with the resultant relationship called Okun's law as well since Okun himself applied a variant of an Okun equation relating output and unemployment in a manner that he called the "fitted trend and elasticity" method (Okun 1962, p. 100). The actual proliferation of the employment-based Okun's law may very likely be traced to Sögner and Stiassny (2002) who—in their discussion of Okun's law as a relationship between unemployment (u) and output (y)—posited two additional equations that relate output to employment (e) as labour demand and to labour force (l) as labour supply. This triangular format, schematically representable as $u \sim y$, $e \sim y$ and $l \sim y$, was also followed and estimated by Ball et al. (2019), Gonzalez Prieto et al. (2018) and An et al. (2022). By contrast, Ball et al. (2017) combined two equations, $e \sim y$ and $u \sim e$, in order to obtain an Okun equation in the familiar form $u \sim y$, and actually estimated the triplet of equations, $e \sim y$, $u \sim e$ and $u \sim y$. In the April 2010 World Economic Outlook by the International Monetary Fund (2010) two versions of Okun's law, arranged as $u \sim y$ and $e \sim y$, are treated as equal. Only a single equation in the schematic form $e \sim y$, answering to the employment-based Okun's law, was considered by Hartwig (2014), An et al. (2019), and by van Ours (2015) as a robustness check. Most of these studies utilized (the logarithm of) the total employed labour force as a measure of e (Sögner and Stiassny 2002; International Monetary Fund 2010; Ball et al. 2017, 2019; An et al. 2019, 2022), rarely the employment rate relative to the labour force (Gordon 1984; Hamada and Kurosaka 1984; Kaufman 1988; van Ours 2015).

In this paper both versions of Okun's law are studied concurrently juxtaposed in an effort to provide a more complete picture of the labour market flows across the three disjunct categories making up the working-age (hence, economically active) popula-

[1] Even though Okun's law was initially framed in a context of pursuing full-employment stabilization policy with a fixed 4 percent value for $\overline{u}$ as the target full-employment unemployment rate (Okun 1962, p. 99), current implementations of Okun's law tend to allow full time-variance to $\overline{u}$ and portray it not as a full-employment unemployment rate, but rather as a natural or long-term rate of unemployment around which the actual unemployment rate fluctuates. However, this does not contradict the Keynesian spirit of Okun's law as Keynesian textbooks have lately shifted towards this interpretation (e.g. Mankiw and Taylor 2023, p. 140; Krugman et al. 2024, p. 225).

tion: the employed, the unemployed and those outside the labour force. Towards this end, instead of total employment or the employment rate relative to the labour force, the employment rate relative to the working-age population is considered, denoted generically as e, with its long-term value denoted as $\overline{e}$.[2] Hence, an employment-based version of Okun's law, companion to the gap formulation considered in Eq. (2), can be represented as

$$e_t - \overline{e}_t = c + \gamma(y_t - \overline{y}_t), \tag{2}$$

in which the Okun coefficient γ now features as a measure of the employment-output elasticity and c is the usual intercept term.

Okun's Law and Labour Market Flows

It must once again be emphasized that the employment rate is defined here in step with convention as total employment over the working-age population, which is the definition applied by international agencies and public authorities such as the International Labour Organization (ILO) or the OECD. In consequence, the unemployment rate and employment rate are not complementary, but differ by the proportion of people who are outside the labour force, which offers a possibility of a deeper structural analysis. The reason being, the system-wise consideration of Okun's law described simultaneously by Eqs. (1) and (2) is a convenient means of capturing labour market flows whose significance for (un)employment dynamics was lately emphasized by Dixon et al. (2015) and later framed in respect of Okun's law by Lim et al. (2019). Across the business cycle, flows in the labour market are not restricted to exchanges between the unemployed and employed labour force, but sometimes individuals choose to leave the labour force and become economically inactive or their decisions may be to (re)join the labour force as employed or unemployed. To say nothing about natural population changes and migration effects, flows from or to the labour force may happen for a variety of reasons, out of which the discouraged/encouraged-worker effect (DWE/EWE) and added-worker effect (AWE) echo most in economics literature (e.g. Lee and Parasnis 2014; Evans 2018), and are mentioned also by Okun (1962, p. 102) as a factor to be borne in mind when reviewing the unemployment-output sensitivity. With the employment rate defined more broadly as "employed persons / working-age population", any outflow from, or inflow to, the labour force is reflected in the denominator. When compared to the unemployment rate defined as "unemployed persons / total labour force", it immediately informs of withdrawals from the labour force or additions to it. Should such flows be negligible, there would be little informational discrepancy between unemployment-based and employment-based Okun coefficients in the sense of an approximate relation $\beta \propto_{approx} -\gamma$, which would hold perfectly if the definition of an employment rate relative to the labour force were adopted. Thus, if several estimates of unemployment-based and employment-based Okun coefficients are available for an economy

[2] Similarly as in the case of $\overline{u}$, $\overline{e}$ represents an employment rate, subject to temporal variation, around which the actual employment rate fluctuates across the business cycle.

(e.g. for subperiods or time-varying trajectories), notable departures from an almost straight line passing through the pairs of estimates points to the increased role of factors like the DWE, EWE, AWE, natural population changes and migration.

Okun Coefficient as a Characteristic of the Business Cycle

Since Eq. (1) arose by accepting a reductionist route under a *pari passu* stipulation, the Okun coefficient β represents a semi-structural quantity that confronts short-run cyclical fluctuations on the labour market (represented by the overutilization or underutilization of labour, $u - \overline{u}$) with short-run cyclical fluctuations in the real economy (represented by inflationary and recessionary pressures, $y - \overline{y}$). As these are both different manifestations of the business cycle in an economy and the Okun coefficient can be expressed in a fractional form that relates fluctuations in labour utilization and those in economic performance as $\beta \approx (u - \overline{u})/(y - \overline{y})$, it sheds some light on the internal working of the business cycle in a given economy. Incidentally, consistent with the present interpretation, to Daly et al. (2015, p. 1), the comovement of unemployment and output embodied by Okun's law remains "a defining feature of business cycle". Naturally, there is no reason to surmise that with the changing unemployment gap in the numerator and the changing output gap in the denominator this ratio remains constant. As a matter of fact, Sögner and Stiassny (2002, p. 1777) or Li and Mendieta-Muñoz (2020, p. 209) argue by formal methods that this ratio depends on parameters of aggregate supply, which are certainly time-variant. In the same vein, a rival derivation of Okun's law footed upon Keynesian thoughts by Ismihan (2016) evinces that the Okun coefficient contains several structural parameters that characterize the adjustment process over the business cycle. Of course, this train of reasoning applies analogically to the employment-based Okun's law.

Several decades ago, integration and globalization efforts triggered an enormous research front engaged in assessing and explaining the extent of synchronization in business cycles. Even though economies involved in a monetary union (such as eurozone members) are most likely candidates for such inquiries, in fact any higher level of economic cooperation and coordination sparks an interest in business cycle synchronization. This is also true of OECD countries as less volatile and synchronized business cycles make stabilization policies more effective (e.g. Inklaar et al. 2008; Konstantakopoulou and Tsionas 2014; Kunroo 2024). Yet, empirical evidence demonstrates that larger samples of countries may form distinct clusters with different cycles (e.g. Konstantakopoulou and Tsionas 2014; Arčabić et al. 2024) and the intensity of synchronization may differ considerably over long decades (e.g. Antonakakis et al. 2016), and the analysis typically hinges on output gaps that are confronted across a sample of countries. Some studies underline the role of labour market variables and their cyclical components in the process (Brůha and Polanský 2015). Yet, to the best knowledge of the authors, there has not been a study that would take a short-cut and looked directly at synchronicity in Okun's law, albeit this is a convenient package of the business cycle dynamics. Instead of measuring synchronicity in Okun's law, it is more reasonable to study temporal profiles communicated by Okun's law and attempt to identify countries that show a satisfactory degree of synchronicity.

Details on the Empirical Set-Up, and Data

As the analytical framework of this study consists of a few elements, they are expounded in brief in this section, and organized under five separate headings.

Estimation of the Gap Variables

Operationalization of the gap version of Okun's law in Eq. (1) necessitates estimation of the unemployment and output gaps, which stirs much discussion and generates potentially grave technical difficulties that may mar the actual applicability or empirical credibility of Okun's law. Both gap variables are typically implemented as cyclical movements around a non-observable long-term trend that arise owing to business cycles (e.g. Mankiw and Taylor 2023, pp. 140, 293, Krugman et al. 2024, pp. 225, 362). Numerous approaches have been devised for estimation of gap variables, but none of these methods is ideal as is discussed by Boďa and Považanová (2023). Following extensive discussions that arose during the review process, the primary analysis hinges on output and (un)employment gaps estimated by means of the band-pass filter of Christiano and Fitzgerald (1999, 2003). That said, the smoothing filter of Hodrick and Prescott (1997) has been the most popular in Okunian studies over the past decade provided they adopted the gap formulation (e.g. Ball et al. 2017, 2019; Furceri et al. 2020; An et al. 2022, Ibourk and Elayanoui 2024), and has become, to some degree, a benchmark method. The Hodrick-Prescott filter has also withstood the recent blow of criticism (e.g. Hall and Thomson 2021; Franke et al. 2024; Schüler 2024). Given the proliferation of the Hodrick-Prescott filter, the paper also reports in Online Supplement dual results derived from gap variables estimated by the Hodrick-Prescott filter. Yet, these are left without comments. In fact, the final conclusions of the paper remain identical regardless of adopting either filter. A characteristic feature of the Christiano-Fitzgerald "random walk" filter is that it is a band-pass filter, which is implemented here for typical business cycle frequencies spanning two to eight years. In contrast, Ravn and Uhlig (2002, p. 373) interpret the Hodrick-Prescott filter as a high-pass filter. To the best knowledge of the authors, there are only three relevant studies that compare the performance of the Christiano-Fitzgerald and Hodrick-Prescott filters in various settings, indicating tentative or convincing favour towards the former over the latter (Christiano and Fitzgerald 1999, pp. 454–463; Nilsson and Gyomai 2011, Issever Grochová and Rozmahel 2015).

Data for the analysis were obtained from the World Bank database at an annual frequency and are commented in Appendix A (details in Table 5, summaries in Table 6). Unemployment and employment gaps are expressed in percentage points, (real) output gaps are measured as (continuously expressed) percentage deviations.

Estimation of Okun Coefficients in a Time-Varying Set-Up, and Study of Their Statistical Significance

In order to reflect the non-static reality of economic conditions, Okun coefficients—as semi-structural parameters—are allowed to vary in time and adjust to structural changes in the economic environment. The time-varying feature of the Okun coef-

ficient is a convenient means of addressing possible asymmetries or non-linearities that oftentimes transpire in Okunian analyses. The time-varying setting is accommodated through the VC method of Schlicht (1985, 2021), by which Okun coefficients are modelled as a random walk in which they exhibit some degree of temporal persistence and update slowly over time. Yet, it should be noted that the modelling approach also directly permits constant Okun coefficients or mild jumps in the trajectory according to the assumptions placed on random terms. Furthermore, its implementation may easily be modified to include effects of one-time structural shocks as is done here. Equation (1) of the unemployment-based version of Okun's law at time t is operationalized as

$$u_t - \overline{u}_t = b + \beta_t(y_t - \overline{y}_t) + \sum_{i=1}^{i=o} d_i D_{it} + \varepsilon_t, \quad \beta_t = \beta_{t-1} + \delta_{t-1}, \tag{3}$$

where the Okun equation is equipped with the error term ε_t with white-noise properties and extended by the effect of o random one-time structural breaks modelled by dummy variables $D_{1t}, ..., D_{ot}$ taking a value of one in a particular year and zero elsewhere. For countries with no apparent structural breaks in the output or unemployment gap, the summation term over dummy variables is simply not present in the equation. As in Jalles (2019) and Furceri et al. (2020), the intercept b is still constant, but the Okun coefficient β_t is possibly time-variant and evolves as a random walk where the random innovation δ_{t-1}, with white-noise properties uncorrelated with ε_t, has an updating function.[3] Should the variance of δ_{t-1} be zero, the Okun coefficient becomes a constant. No distributional assumption is technically required apart from standard white-noise and uncorrelatedness properties pertaining to ε_t and δ_{t-1}. In point of fact, Eq. (3) consists of a measurement equation (the Okun equation) and a state equation (the random walk equation), and can be handled in a state-space framework. In contrast to the conventional Kalman filter employed to estimate systems like (3), the VC method is less sensitive to the choice of input values necessary to initialize the algorithm and its technical demands are comparable those required for running a common linear regression. As argued by Schlicht (2021, p. 1164), unlike the Kalman filter, the VC method operates as a two-sided filter and better exploits information to estimate intermediate states. Finally, in a recent comparative study of estimation algorithms for time-varying coefficients in linear models, the VC method and the state space approach based on the Kalman filter emerged best in terms of accuracy in comparison to flexible linear squares and kernel-based techniques, albeit the VC method was found somewhat more demanding in terms of computational time (Lucchetti and Valentini 2024, pp. 3536–3537). Schlicht's VC method is applied independently to Eq. (3) for the unemployment-based version of Okun's law and

[3] One reviewer raised an apt objection to the assumed uncorrelatedness of the two stochastic terms incorporated in Eq. (3), ε_t and δ_{t-1}, by arguing that any events or shocks that affect the output and (un) employment gaps must affect Okun coefficients. Yet, the present study makes use of annual data, and shocks that arise in one time period $t-1$ (and present themselves through δ_{t-1}) are likely to fade away in the next period t after a year (and do not pass into ε_t). With annual data employed here, the uncorrelatedness assumption of ε_t and δ_{t-1} is realistic. Its tenability is corroborated by the fact that the dummy variables utilized in Eq. (3) never appear in two consecutive years, but appear roughly after a decade.

to its analogue for the employment-based version, which produced for each OECD economy estimated trajectories of unemployment-based and employment based Okun coefficients.[4]

In addition to a point-wise estimate of the Okun coefficient $\hat{\beta}_t$ at each time t, the VC method yields the corresponding standard error $se(\hat{\beta}_t)$ that may be applied in statistical inference justified on conventional asymptotic or Gaussian grounds. In particular, an approximate 0.95 confidence interval for the true value of the Okun coefficient β_t ensues as $(\hat{\beta}_t - 2 \cdot se(\hat{\beta}_t), \hat{\beta}_t + 2 \cdot se(\hat{\beta}_t))$, and when the interval happens to exclude zero, the estimated Okun coefficient $\hat{\beta}_t$ may be deemed statistically significant at an approximate 0.05 level of significance. This procedure is exploited to construct approximate confidence bands and permits zeroing out portions of estimated Okunian trajectories that exhibit strong variation and may not be distinguished from zero. As Okun's law is expected to vary in strength over time, it is supposable that there are instances or years when unemployment or employment may covary feebly with output, and the Okun coefficient may then be virtually zero. The analysis in later stages is primarily conducted for the trajectories of Okun coefficients adjusted for significance, and results for the originally estimated trajectories unadjusted for significance are reported in appendices. Yet, this duality actually constitutes only minute differences in the results.

Explanation of the Observed Heterogeneity in the Estimated Okun Coefficients

The trajectories of Okun coefficients estimated by Schlicht's VC method are regressed in a panel data framework upon a set of explanatory variables describing various economic, labour market, structural and institutional conditions of national economies. These variables were compiled on the basis of the extant research, but were confronted with currently available data, mostly sourced from the World Bank database. These include (gendered) labour force participation (Evans 2018; An et al. 2022; Ibourk and Elaynaoui 2024), initial (un)employment-output configuration (Ball et al. 2017, 2019; Jalles 2019; Furceri et al. 2020), size of the informal economy (An et al. 2019; Ball et al. 2019; Jalles 2019), production structure of the economy (Ball et al. 2019; Furceri et al. 2020), labour market and business regulations (An et al. 2019; Ball et al. 2019; Jalles 2019; Furceri et al. 2020), political stability (Ibourk and Elaynaoui 2024), youth participation rates (Evans 2018), urban population (Furceri et al. 2020), stage of the business cycle (Jalles 2019; An et al. 2022; Furceri et al. 2020). In this respect, Appendix A lists all variables considered with definitional comments (Table 5) or some basic descriptive statistics (Table 6). Most of the variables utilized conform closely to those considered in the cited studies; yet, the list is longer and also contains employee compensation, net migration effects, and school enrolment (as a proxy of human capital). The explanation itself hinges upon a biequa-

[4] A by-product of this approach is that Okun coefficients are presumed *ab initio* integrated of order one, which implies that they are likely to contain trending patterns unless their trajectory is found constant. Still, this poses no difficulties for further econometric procedures since spurious patterns are excluded by the fact that macroeconomic processes are expected to have persistent imprints on the trajectories of Okun coefficients.

tional system with panel fixed effects articulated in a seemingly unrelated regression (SUR) framework, where one equation corresponds to unemployment-based Okun coefficients and the other equation is for employment-based coefficients.[5] Since the regressands are estimated coefficients, simple OLS techniques result in inefficient estimates, although are frequently used (e.g. International Monetary Fund 2010; Ball et al. 2017, 2019). Instead, the methods of Saxonhouse (1976) and Hanushek (1974) are employed in juxtaposition. Whilst the former is grounded in naïve weighted least squares (WLS) and is fairly proliferated in Okunian studies (e.g. Jalles 2019; Furceri et al. 2020), the latter employs a variation of estimated generalized least squares (EGLS) and may collapse to the former. Naturally, both are combined with the traditional within estimator for the equations and SUR estimator for the system. By using the full set of candidate explanatory variables, a search across available submodels is conducted and the final model is selected for each equation on the basis of the Bayesian information criterion (BIC). In consequence, some of the variables initially considered are simply not represented in the final model. It is imperative to note that there are bound to be endogeneity issues when some potential explanatory variables are entered as regressors (such as unemployment rate: unemr_t, real output per capita: rgdp_pc). To circumvent this trouble, all regressors are considered lagged by two years. This approach to deal with potential endogeneity is common in Okunian research (e.g. Jalles 2019; Maza 2022). However, under the same set-up, Jalles (2019) backshifted regressors only by one year, which is not sufficient in light of Eq. (3) where Okun coefficients are determined a year before they are observed. A lag of (at least) two years is needed. As a final point, since the estimation procedure embraced for the explanatory regression begins with demeaning variables at the country level, the resulting regression possesses a dual interpretation. For one thing, it helps reveal the determinants standing behind the cross-country heterogeneity in Okun coefficients. For another, it sheds light upon the factors behind the shape and volatility of trajectories of Okun coefficients, and thus their (a)synchronicity.

Assessment of the Nature of Flows Across and Outside the Labour Force

Instead of confronting the estimated trajectories of unemployment-based and employment-based Okun coefficients in a scatterplot, for each economy the comovement of their governing patterns is measured simply by the conventional Pearson correlation coefficient. Certainly, unemployment-output and employment-output sensitivities are expected to differ in magnitude, but they should yield a correlation coefficient in the vicinity of minus one provided that labour force flows are to be restricted mostly between the stocks of the unemployed and the employed. Other cases (negative correlation of smaller magnitude, positive correlation, or even an incomputable correlation coefficient) indicate the existence of stronger flows from or to the category of people outside the labour force. However, this evidence should instigate a deeper exploration of whether the reason is the DWE/EWE, AWE, trivial demographic shifts or population migration. In addition, for the panel of the 38 OECD countries, unem-

[5] Random effects are technically conceivable, but from the perspective of economic rationale are unsuitable.

ployment-based and employment-based Okun coefficients are compared visually in scatterplots in terms of their means and standard deviations to detect countries that deviate most from the dominant relation discernible between both versions of Okun coefficients. Such countries appear as outlying points distant from the straight line relation or its non-parametric alternative.

Clustering of the Time-Varying Trajectories of Okun Coefficients

Synchronicity in Okun's law amongst OECD countries is only explored for demeaned trajectories of both employment-based and unemployment-based Okun coefficients. The reason being, the chief interest lies in finding out which economies exhibit similar patterns of their business cycle fluctuations, to which end only shapes and volatility of trajectories of Okun coefficients need be studied. There are ample differences in the (un)employment-output elasticity amongst OECD countries, and these may be summarized *cum grano salis* by average trajectories of Okun coefficients and compared upon the real axis. Classification of countries with relatively synchronous trajectories of Okun coefficients is here based upon a time-series clustering algorithm proposed by Begum et al. (2015) and called TADPole (time-series anytime density peaks). Belonging to the class of density peaks methods (Wei et al. 2023), the algorithm performs clustering based on shapes, to which end it utilizes a time-series distance measure known as DTW (dynamic time warping), and applies it with a pruning strategy so as to optimize the clustering computations. Its distinctive feature is that it allows representing clusters by a particular observed trajectory (like a medoid), and not by a synthetic object (like a centroid). A restrictive feature is that TADPole is non-hierarchical and requires choosing the ultimate number of clusters in advance, which is determined here by consulting internal cluster validity indices.

Results

The analysis covers all 38 countries that in 2024 were members of the Organization for Economic Co-operation and Development (OECD) and spans a period of about three decades from 1991 to 2022, which is a time frame that allows all partial inquiries for each country. That being said, for some countries the available history of observations was shorter as is announced later in the captions of graphs in Appendix B. The data were available at an annual frequency and permitted estimation of mostly 32 Okun coefficients for the entire period, but in a few cases the trajectory was reduced up to 28 consecutive years. The analysis was conducted in program R, but the time-varying trajectories of Okun coefficients were estimated by dint of program gretl and its TVC package originated by E. Schlicht.

As outlined in "Details on the empirical set-up, and data" section, the analysis begins with the actually estimated trajectories of Okun coefficients, but in later stages it studies Okun coefficients adjusted for significance with the hope of better accommodating economic realities of countries with changing or unstable conditions. During the decades-long investigated period, many OECD economies underwent critical reforms, structural and sectoral changes, institutional or demographic shifts, which

might have temporarily thwarted or enfeebled stimuli between the labour market and real economy. In such a case, an observed non-zero Okun coefficient may simply be owing to estimation uncertainty, and not truly justified. This somewhat goes against conventional practice that implicitly expects—by estimating a single time-invariant Okun coefficient—that it is significant all time.

A good many results that appertain to original Okun coefficients unadjusted for significance are suppressed in the text and unreported in order to conserve space. Another point behind this decision is the similarity of the ultimate findings for original Okun coefficients and those adjusted for significance. Albeit the presented analysis is based on gap variables estimated by using the Christiano-Fitzgerald filtering methodology, as explained in "Details on the empirical set-up, and data" section, the analytical procedures were also repeated in full with the aid of the Hodrick-Prescott filter. Nonetheless, these dual results are postponed for the interested reader to Online Supplement and left non-commented.

Okun Coefficients and their Temporal Patterns

The primary results are the estimated trajectories of Okun coefficients for either version of Okun's law. They serve as an input for other analyses and are available in Appendix B that displays for each country separately trajectories of unemployment-based and employment-based Okun coefficients with approximate 95 percent confidence bands. Captions above the graphs state lengths of available history and R-squared values that serve as goodness-of-fit metrics for the varying-coefficient regression described by Eq. (3) or its employment-based reformulation. The heterogeneity of R-squared values suggests that Okun's law held in OECD countries with different degrees of regularity and that the comovement between (un)employment and output fluctuations was not tight everywhere.[6] It is immediately discernible whether Okun's law was constant over the period, manifested stable trends or revealed erratic features. It is also apparent that in a great many cases the confidence bands include zero and in those years (un)employment and output could simply be inelastic or noncosensitive. In other words, these graphs show that not only did Okun's law for most economies vary in strength over the period 1991–2022, but during some years it may have paused or temporarily ceased to hold.

The estimated temporal patterns of Okun's law in Appendix B exhibit too disparate a mosaic to afford a simple classification of trends, and confirm that Okun's law, be it the unemployment-based or the employment-based version, is unstable to the extent that it often varies over time. Only in a few OECD countries, Okun's law is found perfectly time-invariant with a constant Okun coefficient, and taking into account the confidence bands around estimated trajectories extends this list by

[6] For the unemployment-based Okun's law, R-squared values ranged from 0.153 to 0.960 with a median value of 0.458. The lowest regularity in the unemployment-output sensitivity was observed for PRT and FIN(R-squared 0.178 at most), whereas the greatest homogeneity was found for KOR, CAN and USA (R-squared 0.899 at least). Likewise, for the employment-based version, R-squared values varied from 0.032 to 0.924 with a median value of 0.423. The employment-output elasticity was found least regular in LUX, NLD and SVN (R-squared 0.129 at most) and most homogeneous in KOR, MEX and CAN (R-squared 0.877 at least).

other countries.[7] On these grounds, in as many as 33 OECD countries the unemployment-based Okun's law could be considered largely (or ideally) constant, and for the employment-based Okun's law it is in 31 OECD countries. The finding in fact implies that the (un)employment-output sensitivity in these countries is fairly robust to changes in labour force, labour market policies, structural compositions, populational make-up or can even withstand shocks mirrored in cyclical fluctuations. Another interpretation, perhaps less viable, might be that forces that affect the strength of Okun's law manifested themselves over the investigated period in such a feeble manner that Okun's law did not undergo a substantial change. This is not to say that Okun's law is short of any exposure to time variation, but that this variation is mostly subtle to all intents and purposes and that Okun's law is indeed a sturdy business cycle characteristic. Furthermore, the Okun coefficient was insignificant in one OECD country for the entire period with the unemployment-based version, and in four OECD countries with the employment-based version.

Focused on constancy and insignificance of Okun's law, Table 1 synthesizes some of the information communicated by the temporal patterns of Okun coefficients visualized in Appendix B as it identifies which OECD countries were found with an

Table 1 Constancy and insignificance of Okun's law

Trajectories	Unemployment-based Okun's law		Employment-based Okun's law	
	(Sometimes) significant	Insignificant all time	(Sometimes) significant	Insignificant all time
Possibly constant	AUS, AUT*, BEL*, CHE, CHL*, COL, CRI, CZE, DEU*, DNK, ESP, EST, FIN, FRA, GBR, GRC, HUN, ISL*, ISR*, IRL, ITA, JPN*, LTU*, LUX, LVA*, MEX, NLD*, NOR, NZL*, SVK, SVN*, SWE	PRT*	AUS, AUT*, BEL, CHL*, COL, CRI*, CZE, DEU*, DNK*, EST, FIN, GBR, GRC*, HUN*, IRL, ISL*, ISR*, ITA, JPN, LTU*, LVA, NOR, NZL*, PRT, SVK*, SWE, USA	FRA, LUX*, NLD*, SVN*
Time-varying	CAN, KOR, POL, TUR, USA		CAN, CHE, ESP, KOR, MEX, POL, TUR	

Note: The classification is based on approximate 95 percent confidence bands and respects whether they admit a constant value in the entire period or whether they include zero in the entire period.

Legend: The asterisk "*" in superscripts denotes cases when the trajectory was estimated as an ideal horizontal line. Boldface is used to highlight countries in the same category with both versions of Okun's law.

[7] A perfectly constant unemployment-based Okun coefficient with no or only petit statistical variation was identified for 13 countries (AUT, BEL, CHL, DEU, ISL, ISR, JPN, LTU, LVA, NLD, NZL, PRT, SVN), and with the employment-based version for 15 countries (AUT, CHL, CRI, DEU, DNK, GRC, HUN, ISL, ISR, LTU, LUX, NLD, NZL, SVK, SVN). Table 4 later catalogues the 10 countries for which the responses of both unemployment and employment to output across the business cycle were found constant in time. It might be argued that some variation should be present in the estimated trajectory, even if Okun's law were stable. Nonetheless, the optimization of the VC method seeks a trade-off between both the variability in the Okun coefficient and the goodness of fit. With this rationale, when there is little or no evidence observed in data, the variance of δ_{t-1} in model (3) is estimated at zero, and all values $\hat{\delta}_t$ are shrunk to zero. This occurs also in true state-space time series models (e.g. Harvey's local linear trend model) where the slope coefficient is fairly often estimated as a constant. Hence, here in these few cases, the variation observed in the estimated output and unemployment gaps does not substantiate time-varying patterns of Okun coefficients and constant trajectories are identified.

approximately constant Okun coefficient and where Okun's law was observed as insignificant for the period. These results accord roughly with other studies, even though their empirical designs and coverage of countries restrict comparability. For instance, like here, Sögner and Stiassny (2002), Jalles (2019) and Furceri et al. (2020) found an ideally constant trajectory for the unemployment-based Okun's law for AUT, and Furceri et al. (2020) for LUX. Likewise, Sögner and Stiassny (2002), too, observed a constant employment-based Okun's law for DNK. With confidence bands allowed for, also other countries might be pinpointed with a constant unemployment-based Okun's law or employment-based Okun's law.

The Okunian trajectories displayed with the greatest detail in Appendix B are further summarized in a tabular format. Table 2 replicates information on the estimated time-varying estimates through basic statistical summaries, but also confronts them with their traditional counterparts under a constant set-up. The constant set-up ensues from dropping the time subscript at the Okun coefficient in Eq. (3) or its employment-based reformulation and permits using OLS to estimate the parameters. Since the confidence bands of some Okunian trajectories exhibited in Appendix B indicate occasional insignificance, or likely zero (un)employment-output sensitivity, mean values of the time-varying trajectories in Table 2 are stated in two different forms: either by using the full time series of estimated Okun coefficients, or by using the estimated Okun coefficients only significant at a 0.05 level. Disregarding insignificant Okun coefficients may give a better indication of the entire strength of Okun's law for the period considered. Figures enclosed in parentheses and displayed in superscripts disclose the effective number of Okun coefficients entering the average. They provide information on the length of available history (column Average†) and the number of significant of Okun coefficients (column Average‡). The difference between these two count metrics captures the length of the period when Okun's law was insignificant. For convenience, as a measure of variability, Table 2 also reports minimum and maximum values observed in the trajectory of estimated Okun coefficients.

As reported in Table 2, traditional time-invariant estimates of Okun coefficients are not altogether different from their time-varying counterparts when these are represented by mean trajectories, which holds equally well for both versions of Okun's law (correlation 0.943 for the unemployment-based version, and correlation 0.954 for the employment-based version).[8] Except for four cases with the unemployment-based Okun's law and eight cases with the employment-based Okun's law, traditional estimates of the Okun coefficient are significant at a 0.05 level. Regardless of the version of Okun's law, traditional estimates are typically equal or almost identical to the mean trajectory estimated by Schlicht's method (column Average†). However, simple means of time-varying trajectories may be overstated in size by occasional insignificances. Apparently, neither traditional estimates nor simple means (column Average†) account for these frequently transitory insignificances, and mean trajectories adjusted by insignificance (column Average‡) are more trustworthy estimates of the (un)employment-output elasticity. With the unemployment-based version,

[8] With recession dummies as in equation (3), it is no longer true that which is claimed by Jalles (2019, p. 611) that Schlicht's estimator produces time-varying trajectories whose averages equal their time-invariant OLS counterparts.

these adjustments did not bring about any change in 17 cases, but the original Okun coefficients were deflated drastically to a 0% or 11% level for two economies (PRT and FRA, respectively). Likewise, with the employment-based version, the adjustment for significance did not affect the original Okun coefficients for 18 economies, but resulted in the zeroing-out of Okun coefficients for 4 economies (COL, DNK, ESP and MEX). Hence, adjustments for significance affected mean trajectories of unemployment-based and employment-based Okun coefficients for 21 and 20 OECD countries, respectively, and in some cases reduced notably the number of significant Okun coefficients. Only between 0 and 8 significant unemployment-based coefficients remained for FRA, GBR, LUX and PRT, and between 0 and 7 significant employment-based coefficients for CHE, COL, FRA, GBR, LUX, NLD, and SVN.[9]

This initial analysis is merely of a descriptive nature, and begs a thorough explanation of the observed time-varying patterns in Okun coefficients and as to why in a good many OECD economies Okun's law is possibly constant. This is the topic of the regression analysis to come that provides further insights.

Comparison of Okun Coefficients Across Countries

In order to facilitate a comparison of countries by the strength of Okun's law, Appendix C ranks countries by the mean value of estimated trajectories. Countries are ranked by the unemployment-output elasticity from the strongest to the smallest (i.e. from the "most negative" to the "least negative" Okun coefficient on average), and by the employment-output elasticity from the smallest to the strongest (i.e. from the lowest to the highest Okun coefficient on average). With the mean level of Okun coefficients, Appendix C also provides information on their variability both in the form of error bars in the size of ± one standard deviation and in the form of minimum-to-maximum ranges. For one thing, these metrics of variability equip the reported mean values of Okun coefficients with a gauge of uncertainty insomuch as the broader the error bars and/or ranges, the less regular is the time-varying pattern of trajectories. For another thing, cases with constant Okun coefficients are distinguishable as mere points with error bars and ranges shrunk to zero.

Amongst other things, Appendix C points to two remote categories of countries to be singled out: countries marked with comparably high unemployment and employment cosensitivity with output (ESP, USA and AUS), and those where both unemployment and employment comove tepidly with output (GBR, LUX, and SVN). Finally, error bars and ranges in Appendix C reveal comparatively the greatest level of variability in the Okun coefficient for POL, USA, CAN, FRA, and ESP (for the unemployment-based version), and CHE, COL, TUR, FRA, CAN, and USA (for the employment-based version). Consulting Appendices B and C, one may conclude that the business cycle dynamics is comparatively most unstable and erratic in POL, and FRA.

[9] It also must be noted that the frequency of years with insignificant Okun coefficients is not untowardly high as follows from a comparison with Jalles (2019, Figure 1) who, too, employed Schlicht's method to estimate the temporal patters of Okun's law. By extending one standard deviation bands shown about the estimated trajectories, in many cases these bands convincingly encompass zero and suggest insignificance of the Okun coefficient for one or more years.

Table 2 Okun coefficients for various set-ups

Country	Unemployment-based Okun's law					Employment-based Okun's law				
	Constant set-up	Time-varying set-up				Constant set-up	Time-varying set-up			
		Average†	Average‡	Minimum	Maximum		Average†	Average‡	Minimum	Maximum
AUS	− 0.401***	− 0.399(32)	− 0.399(32)	− 0.451	− 0.339	0.372***	0.357(32)	0.342(30)	0.239	0.498
AUT	− 0.239***	− 0.239(32)	− 0.239(32)	− 0.239c	− 0.239c	0.200*	0.200(32)	0.200(32)	0.199c	0.199c
BEL	− 0.257**	− 0.257(32)	− 0.257(32)	− 0.257c	− 0.257c	0.266***	0.268(32)	0.268(32)	0.260	0.275
CAN	− 0.364***	− 0.371(32)	− 0.367(29)	− 0.659	0.020	0.248***	0.244(32)	0.201(17)	− 0.039	0.499
CHE	− 0.210***	− 0.207(32)	− 0.180(26)	− 0.246	− 0.136	− 0.026	− 0.118(32)	− 0.151(7)	− 0.760	0.173
CHL	− 0.374***	− 0.374(32)	− 0.374(32)	− 0.374c	− 0.374c	0.337***	0.337(32)	0.337(32)	0.337c	0.337c
COL	− 0.566***	− 0.578(32)	− 0.578(32)	− 0.624	− 0.525	0.299*	0.322(32)	0.127(7)	− 0.070	0.622
CRI	− 0.342***	− 0.367(32)	− 0.367(32)	− 0.441	− 0.301	0.362**	0.362(32)	0.362(32)	0.362c	0.362c
CZE	− 0.170**	− 0.196(32)	− 0.131(17)	− 0.291	− 0.054	0.100**	0.103(32)	0.103(32)	0.083	0.112
DEU	− 0.286***	− 0.286(32)	− 0.286(32)	− 0.286c	− 0.286c	0.260***	0.260(32)	0.260(32)	0.259c	0.259c
DNK	− 0.300***	− 0.299(32)	− 0.299(32)	− 0.306	− 0.295	0.180**	0.180(32)	0.180(32)	0.180c	0.180c
ESP	− 0.411**	− 0.636(32)	− 0.569(24)	− 0.853	− 0.223	0.255***	0.350(32)	0.350(32)	0.163	0.479
EST	− 0.395***	− 0.380(28)	− 0.315(20)	− 0.568	− 0.187	0.259***	0.230(28)	0.151(13)	0.069	0.444
FIN	− 0.184*	− 0.177(32)	− 0.075(12)	− 0.212	− 0.120	0.169*	0.157(32)	0.105(16)	0.044	0.241
FRA	− 0.141•	− 0.157(32)	− 0.018(1)	− 0.571	0.116	0.050	0.048(32)	0.000(0)	− 0.232	0.263
GBR	− 0.104*	− 0.083(32)	− 0.037(8)	− 0.171	0.080	0.071•	0.045(32)	0.018(5)	− 0.117	0.120
GRC	− 0.366**	− 0.372(32)	− 0.350(30)	− 0.406	− 0.291	0.240***	0.240(32)	0.240(32)	0.240c	0.240c
HUN	− 0.150**	− 0.172(32)	− 0.164(30)	− 0.240	− 0.126	0.176**	0.176(32)	0.176(32)	0.176	0.176
IRL	− 0.079	− 0.234(32)	− 0.223(19)	− 0.447	0.014	0.127*	0.266(32)	0.174(14)	− 0.033	0.462
ISL	− 0.293***	− 0.293(28)	− 0.293(28)	− 0.293c	− 0.293c	0.295***	0.295(28)	0.295(28)	0.295c	0.295c
ISR	− 0.196*	− 0.196(28)	− 0.196(28)	− 0.196c	− 0.196c	0.237**	0.237(28)	0.237(28)	0.237c	0.237c
ITA	− 0.154**	− 0.152(32)	− 0.095(16)	− 0.213	− 0.090	0.107*	0.091(32)	0.059(15)	0.048	0.137
JPN	− 0.120***	− 0.120(32)	− 0.120(32)	− 0.120c	− 0.120c	0.125**	0.130(32)	0.130(32)	0.107	0.149
KOR	− 0.312***	− 0.233(32)	− 0.184(18)	− 0.469	− 0.035	0.335***	0.298(32)	0.293(31)	0.169	0.422
LTU	− 0.472***	− 0.472(28)	− 0.472(28)	− 0.472c	− 0.472c	0.275***	0.275(28)	0.275(28)	0.275c	0.275c
LUX	− 0.100*	− 0.094(32)	0.049(8)	− 0.226	0.010	0.053	0.050(32)	0.000(0)	0.053c	0.053c

Table 2 (continued)

Country	Unemployment-based Okun's law					Employment-based Okun's law				
	Constant set-up	Time-varying set-up				Constant set-up	Time-varying set-up			
		Average†	Average‡	Minimum	Maximum		Average†	Average‡	Minimum	Maximum
LVA	-0.433^{***}	$-0.433^{(28)}$	$-0.433^{(28)}$	-0.433^{c}	-0.433^{c}	0.337^{***}	$0.315^{(28)}$	$0.301^{(26)}$	0.204	0.372
MEX	-0.192^{***}	$-0.178^{(32)}$	$-0.178^{(32)}$	−0.263	−0.128	0.241^{***}	$0.270^{(32)}$	$0.272^{(32)}$	0.145	0.455
NLD	-0.188^{**}	$-0.188^{(32)}$	$-0.188^{(32)}$	-0.188^{c}	-0.188^{c}	0.135	$0.135^{(32)}$	$0.000^{(0)}$	0.135^{c}	0.135^{c}
NOR	-0.231^{**}	$-0.242^{(32)}$	$-0.190^{(22)}$	−0.314	−0.161	0.324^{***}	$0.326^{(32)}$	$0.326^{(32)}$	0.289	0.354
NZL	-0.291^{***}	$-0.291^{(32)}$	$-0.291^{(32)}$	-0.291^{c}	-0.291^{c}	0.326^{***}	$0.326^{(32)}$	$0.326^{(32)}$	0.326^{c}	0.326^{c}
POL	0.047	$0.046^{(32)}$	$0.030^{(21)}$	−0.692	0.811	0.016	$-0.037^{(32)}$	$-0.050^{(9)}$	−0.242	0.152
PRT	−0.099	$-0.099^{(32)}$	$0.000^{(0)}$	-0.099^{c}	-0.099^{c}	0.135^{*}	$0.118^{(32)}$	$0.045^{(10)}$	0.087	0.152
SVK	-0.366^{***}	$-0.382^{(31)}$	$-0.281^{(18)}$	−0.540	−0.200	0.310^{***}	$0.310^{(31)}$	$0.310^{(31)}$	0.309^{c}	0.309^{c}
SVN	-0.141^{*}	$-0.141^{(28)}$	$-0.141^{(28)}$	-0.140^{c}	-0.140^{c}	0.061	$0.061^{(32)}$	$0.000^{(0)}$	0.061^{c}	0.061^{c}
SWE	-0.376^{***}	$-0.357^{(32)}$	$-0.271^{(20)}$	−0.580	−0.223	0.280^{*}	$0.262^{(32)}$	$0.149^{(13)}$	0.153	0.452
TUR	-0.193^{***}	$-0.219^{(32)}$	$-0.200^{(23)}$	−0.344	−0.045	0.041	$0.095^{(32)}$	$0.113^{(16)}$	−0.192	0.360
USA	-0.499^{***}	$-0.560^{(32)}$	$-0.547^{(28)}$	−0.851	−0.022	0.377^{***}	$0.419^{(32)}$	$0.399^{(28)}$	0.129	0.628

Averages in the column indicated by "†" were computed from all available Okun coefficients regardless of their significance. Corresponding numbers in parentheses displayed in superscripts reveal the length of available history. By contrast, averages in the column marked by "‡" were computed from Okun coefficients adjusted for significance (with estimated time-varying coefficients insignificant at a 0.05 level considered as zeros). Corresponding numbers in parentheses displayed in superscripts reveal the number of significantly non-zero observations

Legend: The notation "c" in superscripts indicates that respective time-varying coefficients were constant over the period (not necessarily insignificant). Significance labels respect the notational convention: *** for p-values ≤ 0.001, ** for p-values ≤ 0.01, * for p-values ≤ 0.05, $^{\cdot}$ for p-values ≤ 0.1, and ^{ns} (non-significant) otherwise

Factors of the Cross-Country Heterogeneity in Okun Coefficients

The initial catalogue of factors considered in the explanation of Okun coefficients is submitted in Table 5 in Appendix A, and comprises variables depicting national labour market conditions, the structural make-up of the economy and general institutional conditions. Only some of these factors were credited with relevant explanatory power identified by the BIC and appeared in the final specification, which was estimated by WLS and EGLS integrated within a SUR framework with fixed effects. The two estimates of the model are reported in Table 3. As announced in "Details on the empirical set-up, and data" section, all explanatory factors were backshifted by two years to avoid the endogeneity issue. Trajectories of estimated Okun coefficients adjusted by their local insignificance were utilized in conjunction with weighted approaches (WLS and EGLS) to mirror more severely uncertainty of estimated trajectories communicated by their standard errors.

Both standalone equations as well as the entire system were estimated with a good level of explanatory power as follows from the R-squared values presented in Table 3. The improvement of these R-squared metrics by incorporating fixed effects confirms that there are non-negligible differences in the mean level of Okun trajectories between countries, or—simply put—that the OECD countries vary generally in the strength of Okun's law. Nonetheless, this is not news as it was already observed by perusing Appendix C. The residual correlation coefficients can be deemed as the partial correlation coefficients between (all stacked) unemployment-based and employment-based Okun coefficients after controlling for the effect of the most important explanatory factors, which lends credibility and robustness to the findings derived from Appendix E. One would naturally expect that if some factor affects the corresponsiveness of both unemployment and employment with output in the course of the business cycle, this effect would be reverse in the sense that its impact regression coefficient would be positive with one version of Okun's law and negative with the other. This is testified by the output in Table 3. There are no substantive differences between the bivariate model estimated by WLS and the model estimated by EGLS. The differences are numerical and manifest themselves in the size of estimated effects.

Six variables were found significant at a 0.05 level of significance in explaining the heterogeneity observed in the time-varying trajectories of Okun coefficients. Only two variables emerged as significant explanators for both versions of Okun's law: rgdp_pc and infsect2gdp. Whereas the initial level of economic activity tends to dampen the unemployment-output cosensitivity and magnify the employment-output cosensitivity, the size of the informal sector displays opposite effects. Albeit unemployment-based and employment-based Okun coefficients are not technically directly comparable, it is discernible that the effect of two factors is disproportionate.[10] The level of economic activity dampens the unemployment-output relationship more vigorously than it pronounces the employment-output relationship. To the

[10] By the adopted definition, unemployment and employment rates are complementary to unity up to a multiplicative factor "labour force / working-age population". This participation rate in OECD countries over the examined period typically exceeded 70%, which allows comfortable room for ballpark comparisons.

Table 3 Factors explanatory of the unemployment-output and employment-output sensitivity (adjusted for significance)

Regressors	WLS (Saxonhouse 1976)				EGLS (Hanushek 1974)			
	Unemployment sensitivity		Employment sensitivity		Unemployment sensitivity		Employment sensitivity	
	Estimate	Standard error	Estimate	Standard error	Estimate	Standard error	Estimate	Standard error
rgdp_pc(− 2)	0.008^{***}	0.002	-0.004^{**}	0.002	0.007^{**}	0.002	-0.002^{**}	0.001
ecomp_perc(− 2)	-0.004^{ns}	0.003	0.000^{ns}	0.002	-0.004^{ns}	0.003	0.000^{ns}	0.002
gdpsh_agri(− 2)	0.015^{ns}	0.011	0.014^{ns}	0.010	0.016^{ns}	0.011	0.014^{ns}	0.010
gdpsh_serv(− 2)	-0.020^{***}	0.004			-0.019^{***}	0.004		
gdpsh_ind(− 2)			-0.017^{***}	0.003			-0.017^{***}	0.003
infsect2gdp(− 2)	-0.038^{**}	0.012	0.029^{**}	0.011	-0.037^{***}	0.011	0.029^{*}	0.011
lf1524_t(− 2)	-0.006^{***}	0.002	$-0.003^{\cdot}$	0.001	-0.006^{***}	0.002	$-0.003^{\cdot}$	0.001
lf_m(− 2)			0.001^{ns}	0.004			0.001^{ns}	0.004
unemr_t(− 2)	-0.010^{***}	0.003			-0.011^{***}	0.003		
reg_bus(− 2)			-0.001^{ns}	0.006			-0.001^{ns}	0.006
$R^2_{rss.mar}$	− 0.076		− 0.262		− 0.062		− 0.346	
$R^2_{ess.mar}$	0.302		0.150		0.282		0.214	
$R^2_{rss.full}$	0.683		0.874		0.684		0.873	
$R^2_{ess.full}$	0.696		0.879		0.696		0.880	
Correlation	− 0.403 / − 0.348 (marginal / full residuals)				− 0.392 / − 0.349 (marginal / full residuals)			
# countries	37		33		37		33	
# years	1–30 (∅ = 20.351)		1–22 (∅ =16.788)		1–30 (∅ = 20.351)		1–22 (∅ =16.788)	
# observations	753		554		753		554	

Table 3 (continued)

System	Judge et al. (1985)	McElroy (1977)	Judge et al. (1985)	McElroy (1977)
R^2_{mar}	0.800	0.740	0.798	0.734
R^2_{full}	0.952	0.936	0.952	0.934

Only estimated time-varying Okun coefficients significant at a 0.05 level of significance were considered in the estimation. Hence, insignificant Okun coefficients were disregarded, which reduced the sample size. Both the unemployment-based and employment-based equations were estimated in a panel SUR framework with fixed effects. The original correlation between unemployment-based and employment-based Okun coefficients was –0.629 and the residual correlation is reported in the table. In order to assure robustness, the estimation was grounded in the WLS procedure described by Saxonhouse (1976) and the EGLS method proposed by Hanushek (1974). In superscripts at the estimated coefficients, the table reports significances derived from standard errors robust to heteroskedasticity reported in separate columns. The HC3 estimator advanced by MacKinnon and White (1985) and recommended by Long and Ervin (2000) was employed towards that end. The R-squared metrics differ in whether they derive from the residual sum of squares (rss) or the explained sum of squares (ess), and in whether they only include marginal residuals (ignoring fixed effects) or full residuals (considering fixed effects)

Legend: Significance labels respect the notational convention: *** for p-values ≤ 0.001, ** for p-values ≤ 0.01, * for p-values ≤ 0.05, $^{\bullet}$ for p-values ≤ 0.1, and ^{ns} (non-significant) otherwise

contrary, the relative size of the informal sector heightens the unemployment-output cosensitivity more than it lessens the employment-output cosensitivity.

Furthermore, three additional factors were significant for the unemployment-based Okun's law: gdpsh_serv, lf1524_t and unemr_t. On average, a higher relative share of services on output, a higher initial level of unemployment or a higher participation of the young cohort in the labour force bolsters the unemployment-output cosensitivity. Finally, one other factor was found significant for the employment based Okun's law: gdpsh_ind. With a higher share of services on output, the employment-based Okun's law becomes weaker.

Hence, the findings propose that the strength of Okun's law in OECD countries is chiefly determined not only by the initial conditions of the (un)employment-output relationship, but also by the structure of the economy, be it the share of services on output or the relative size of the informal sector. It seems that higher prosperity (operationalized through real per-capita output) attenuates effects of shocks sprouting from cyclical output fluctuations on the labour market, which becomes somewhat inelastic. Yet, higher unemployment levels appear to exert an exactly opposite effect upon unemployment and admit stronger elasticity in the unemployment-output relationship. With their level of development, OECD economies are dominated by services that take a sizeable share on both output and employment. Services are often reduced or insourced in times of unfavourable economic prospects, but the findings indicate that this response to cyclical fluctuations in output is manifested in unemployment rather than employment, which might be explained by another, here indirect effect of labour market flows between the formal and informal economy. Reduced demand for services leads to a lower demand for labour, but this decrease is not reflected in formal employment as firms prefer to retain their employees, but is seen in informal employment where adjustments are easier both in terms of hiring and laying-off. The depicted asymmetry can be ascribed to labour hoarding, which has always been to date discussed in terms of the formal sector only. The findings further indicate that the higher the involvement of young people in the labour force, the more elastic is unemployment with output across the business cycle. The noted role of age for the unemployment-based Okun's law tallies with the generally accepted a priori argument that unemployment behaves differently across different age cohorts where the youth cohort is often found most exposed to business cycle fluctuations (e.g. Hutengs and Stadmann 2014; Dunsch 2017). On the part of employment, industrial activity appears to be a factor that dampens cosensitivity of employment and output over the business cycle, which is to a great extent counter-intuitive as the industrial sector is generally viewed as more cyclical than other sectors (e.g. Furceri et al. 2020; Goto and Bürgi 2021). Nonetheless, this finding relates to formal employment and may be tainted by the existence of the informal sector and flows to or from the category of people outside the labour force. An increase of the share of industry on output may in some situations attract informal rather than formal employment.

These factors explain both the differences in the size of Okun coefficients between OECD economies, but also time-varying patterns. As these underlying factors varied in time, alongside changes in other factors non-reflected in Table 3, Okun coefficients varied with them. Nonetheless, these other factors contributed residually by a minor explanatory power of about 30% (for the unemployment-based Okun's law) or 12%

(for the employment-based Okun's law). In many cases, changes in the significant determinants interacted and resulted in almost constant trajectories of the Okun coefficient. In a typical OECD economy, real per-capita output was on the rise during the examined period with an offsetting effect of the declining informal sector, and much depended upon year-on-year variation of other factors. Yet, this variation emanated broadly not only from specific economic policy measures, but also adjustments in the legal and institutional environment, general and demographic changes, triggered by a number of primary causes. During the examined three decades, OECD economies were subjected to extensive labour market policies tailored to soften wage rigidity and to make their labour markets more flexible in general (Zambrano-Monserrate 2024, pp. 613–615). Case studies might be compiled for each specific OECD economy to reason out its particular pattern of both the unemployment-based and employment-based Okun coefficients.

Further, it is worth stressing that these are all in fact meta explanations that do not incorporate the semi-structural nature of the Okun coefficient. The Okun coefficient is substantiated under a strong *pari passu* assumption of Okun's that underutilization of labour varies proportionately with other idle resources (Okun 1962, p. 102). Following in Okun's footsteps, structural decompositions or extensions of Okun's law were considered by later authors who mainly highlight labour productivity, average hours worked, and labour force participation (e.g. Gordon 2010; Daly et al. 2013; Ismihan 2016). Nonetheless, these omitted structural components are equally moulded by the variables studied here as explanatory and their effect upon the Okun coefficient is skipped. In this manner, the explanation took a reduced-form route in place of a structural route.

To some degree, the results may be correlated with recent studies. For instance, An et al. (2022, Table 4) investigated factors associated with the employment-based Okun's law for low-income and lower-middle-income economies. They too found positive association between the informal sector and the employment-based Okun coefficient, on the occasion of which they noted that opportunities for informal employment may obscure the relationship between output and the labour market, yet without relating their findings to labour market flows. In contrast, Jalles (2019, Table 2), Ball et al. (2019, pp. 857–867) and Furceri et al. (2020, Table 8) scrutinized the unemployment-based Okun's law. Whereas the results of Jalles (2019) and Ball et al. (2019) as to the initial real per-capita output, the initial level of unemployment and

Table 4 Strength of Okun's law across the business cycle

With conjunctural variation based on temporal changes in output and unemployment		Employment-based Okun's law		
		Okun's law stronger in decline	Okun's law constant over the business cycle	Okun's law stronger in upswing
Unemployment-based Okun's law	Okun's law stronger in decline	FIN, GBR, ITA, KOR, NOR, SWE	CRI, GRC, HUN, LUX, SVK	
	Okun's law constant over the business cycle	LVA	AUT, CHL, DEU, ISL, ISR, JPN, LTU, NLD, NZL, SVN	BEL, PRT
	Okun's law stronger in uspwing		DNK, EST, FRA	IRL

the relative importance of services agree with those reported here in Table 3, their results in regard to the informal sector are not consistent. Interestingly, Furceri et al. (2020) for both advanced and developing economies established negative association for real per-capita output and absent association for initial unemployment. The portrayed palette of findings is much a consequence of the diverse depths of analytical techniques employed in the second-stage analysis. Whereas Ball et al. (2019) applied graphical methods, Jalles (2019) and Furceri et al. (2020) utilized regression methods analogous to those used here. Apparently, this second-stage analysis of Okun coefficients must be repeated by other studies in different contexts before a more authoritative synthesis may be ventured.

Evidence of Okun Coefficients for Labour Market flows

Appendices D and E give a better assessment of the informational match between unemployment-based and employment-based Okun coefficients. As argued in "Okun's Law, its interpretation and variant formulations" section, their confrontation may unveil the nature of labour force flows. Appendix D compares through two scatterplots means and standard deviations of estimated time-varying unemployment-based and employment-based Okun coefficients computed for individual OECD countries. Appendix E reports separately for each OECD country and the full pooled "OECD-38" sample correlation coefficients between unemployment-based and employment-based Okun coefficients. Nonetheless, there are numerous situations labelled as "NA" when the correlation coefficient could not be calculated owing to the constant trajectory (and zero standard deviation).

In step with the preceding considerations, these results suggest that in some countries labour force flux is not limited to flows between unemployment and employment, but actually oversteps the labour force. The scatterplot on the left-hand side of Appendix D uncovers an anticipable relatively tight negative association between the estimated unemployment-based and employment-based Okun coefficients averaged over the entire period. The conventional correlation coefficient between–0.680 indicates that labour force flows mostly go between unemployment and employment (and correlation measures that answer to the non-parametric and robust fits in Appendix D do not differ much). Two countries are visible in Appendix D that deviate notably from the prevailing relationship between the unemployment-based and employment-based output cosensitivity indicated by the two fits: CHE (comparatively high unemployment-output, but mild employment-output elasticity), COL (comparatively both modest unemployment-output and modest employment-output elasticity). A further few countries may be highlighted that somewhat outstands from the identified unemployment-output straight-line regularity or the curvilinear pattern: NOR, KOR, MEX and NLD. That said, this is not supported by the correlation report in Appendix E that—despite its limitations—identifies no consonance between the unemployment-based and employment-based versions of Okun's law for ITA or negligible consonance for CZE, and modest congruence for GBR and IRL. Moreover, in CHE and MEX with the only case of a positive correlation coefficient the pattern of Okun's law is counter-intuitive since unemployment and employment correact with output largely in the same manner: either they both rise or fall.

Asymmetry of Okun Coefficients Across the Business Cycle

A question associated with temporal patterns of Okun coefficients is to what extent they reflect the stylized fact often ascribed to Okun's law according to which the unemployment-output sensitivity is asymmetric over the business cycle, being heightened in downturns (Nebot et al. 2019; Boďa and Považanová 2021). The time-varying trajectories of Okun coefficients estimated here and portrayed in Appendix B follow from a statistical model that is not constrained by any parametric or non-parametric assumption of asymmetric features in downturns and upturns, and is thus suitable for this line of inquiry. If some business cycle asymmetry is present, it is absorbed in the estimated trajectories of Okun coefficients, and they should signal different levels of sensitivity across the business cycle. With two measures of cyclical behaviour of economic activity, Appendix F confronts averages of statistically significant Okun coefficients for either version of Okun's law. Guided by advice of one of the reviewers, cyclical activity is qualified here through the actually observed upswings and downswings in economic activity as it helps address ambiguities of definition and pro-cyclicality of output gap estimates, should the definition be based on output (and unemployment) gaps. A simpler classification uses only the criterion of output growth (Δy) to recognize favourable and unfavourable periods of cyclical variation, whereas a more elaborate classification hinges upon on the joint criterion of pro-cyclical output and counter-cyclical unemployment changes (Δy and Δu). Unpleasantly, Appendix F testifies against the stylized fact that Okun's law tends to be (almost universally) stronger during a decline in economic activity as the picture is in fact more varied. In several countries Okun's law is stronger in magnitude in an upswing stage, contingent sometimes on its version. Appendix F is simplified to Table 4 that organizes OECD countries by their sensitivity over the business cycle and for either version of Okun's law singles out three situations: "stronger in decline", "constant over the business cycle", and "stronger in upswing". For instance, Okun's law is classified as stronger in upswing if the Okun coefficient in Appendix F is detected larger in magnitude both in years with rising output ($\Delta y > 0$) and in years with rising output and falling unemployment ($\Delta y > 0$, $\Delta u < 0$). An analogy applies to the situation of decline. Yet, if there was a contradiction, such as a weaker Okun's law in years with rising output and a stronger Okun's law with rising output and rising unemployment, this is not reflected in Table 4. Likewise, the tabular classification omits three countries with counter-intuitive average Okun coefficients found for any stage of the business cycle with either the unemployment-based or employment-based version (e.g. CHE, POL and TUR). In consequence, there are only 28 OECD countries represented in Table 4. Okun's law is found to work stronger in decline for both unemployment and employment in a number of countries: FIN, GBR, ITA, KOR, NOR and SWE. Just one country, IRL, somewhat outstands since Okunian sensitivity is found to be higher for both unemployment and employment when the economy is in upswing. Interestingly, there are a total of 10 countries, AUT, CHL, DEU, ISL, ISR, JPN, LTU, NLD, NZL, and SVN, where both unemployment and employment are insensitive to output in different stages of cyclical fluctuations. Yet, Table 4 indicates that frequently an asymmetry may arise when Okun's law seems constant over the business cycle either for unemployment or for employment, but

varies across the business cycle for the other version (ten such economies). No case was observed where unemployment demonstrated stronger responsivity with output in decline, but employment during upswing, or where unemployment comoved with output more vehemently in upswing, and employment in decline. Unfortunately, owing to the discords in the cumulative condition for stages of the business cycle, Table 4 does not report the USA, albeit it is the country where this kind of asymmetries has been heavily studied and reconfirmed in empirical studies (e.g. Michail 2019; Donayre 2022).

Two points must be noted on account of the taxonomy in Table 4. First, it is not surprising that there is not a universal pattern in the group of OECD economies since each country has a specific mix of macroeconomic, structural, demographic and institutional factors. These were reconfigured at different paces in the examined period owing to policy measures, legal and societal changes, and entered differently into the interplay between unemployment and employment. Hence, these labour market characteristics may comove asymmetrically and multifariously with output across the business cycle. Second, Table 4 organizes in a 3 × 3 format situations that are not equally desirable.[11] For instance, cell [1,1] with both versions of Okun's law being stronger in decline indicates a problematic situation. When the economy is in a downswing phase as output wanes, both unemployment and employment suffer, with unemployment rising and employment falling, but these responses are more vehement than those in a period of recovery. In a recovery phase, rising output is unable to adequately make up for the problems of unemployment and employment that arose in downswing. Certainly, the most favourable situation is in cell [3,3] when both versions of Okun's law are stronger in upswing.

The classification derives from the cumulative fulfilment of the conjunctural conditions examined in Appendix F. Okun's law is qualified stronger in decline when the Okun coefficient is higher in magnitude for years with a negative output growth rate and simultaneously for years with a negative output growth rate and positive unemployment growth rate. Likewise, Okun's law is then stronger in upswing when the Okun coefficient is higher in magnitude for years with a positive output growth rate and simultaneously for years with a positive output growth rate and a negative unemployment growth rate. Neither mixed situations (e.g. Okun's law stronger in years with a positive output growth, but weaker in with a negative unemployment growth) nor the full insignificance of the Okunian trajectory are reflected in the classification. The classification also excludes three economies with counter-intuitive values of Okun coefficients (i.e. CHE, POL, and TUR).

The existence of asymmetries in Okun's law is not novel as it has been studied extensively for its unemployment-based version and several hypotheses have been put forth to reason it (e.g. Harris Silverstone and 2001; Silvapulle et al. 2004; Nebot et al. 2019; Boďa and Považanová 2021). A novelty here is the extension towards asymmetry in the employment-output relationship, and the explanation must address both studied features of labour markets. Silvapulle et al. (2004, pp. 356–357) were summarized three coherent hypotheses to explain asymmetry in the unemployment-

[11] To simplify the exposition, the nine cells of Table 4 are next designated as [r,c], where r refers to the row, and c to the column (with r, c taking values 1, 2 and 3 for decline, constancy and upswing, respectively).

based Okun's law that were coined by Nebot et al. (2019, p. 203) as institutional rigidity, labour hoarding, and risk aversion. Earlier, Palley (1993, p. 149) pointed out to labour spreading as a possible explanation.

- The institutional rigidity hypothesis maintains that stringent employee protection and other institutional constraints obstruct easiness with which firms may dismiss employees. Whereas taking on new employees is institutionally supported, reductions of employee counts face higher administrative burden and sizeable adjustment costs. By the original account, institutional rigidity makes unemployment less responsive to output in downturn than in upswing since in adverse times employers are reluctant to dismiss workers, whereas in upswing their demand for labour is as usual.[12] Of course, these explanations apply not only to unemployment, but also to employment, and fit ideally to cell [3,3]. However, the earlier literature does not consider labour market flows that miss the unemployment-output axis, either owing to the existence of the informal sector or prevalence of worker effects. Whereas employment may indeed be invigorated in upswing and reduced feebly in downswing, it need not be automatically seen in unemployment changes, and there may be no asymmetric response as in cell [2,3] or counter-intuitive response as in cell [1,3].
- The labour hoarding hypothesis argues that firms are disinclined to lay off skilled and qualified employees even when facing unfavourable economic conditions. They rather opt to optimize their working hours or reduce the number of shifts in order to retain human capital accumulated in their employees. Conversely, with improved circumstances, they adjust their demand for labour as usual. In consequence, the unemployment-output relationship becomes less elastic in downturn. In a vein similar to the institutional rigidity hypothesis, this hypothesis relates to both employment and unemployment and suits ideally cell [3,3], albeit its operability may be frustrated by the existence of flows outside the labour force.
- The labour spreading explanation builds on a strategy of firms to economize on hiring and training costs by higher utilization of existent employees in place of hiring new labour force. In upturn, firms force their employees work overtime or accept shift work, but in downturn they adjust their demand for labour more flexibly with a view to rationalizing labour force employed. This behaviour leads to lessened elasticity of employment and somewhat stagnant unemployment in upswing, but to otherwise standard response of both employment and unemployment in downswing provided that there are neither strong options nor incentives for informal employment or without strong worker effects. In addition, the explanation builds on labour spreading works under the assumption of no rigidities. However, in contrast to the previous two hypotheses, labour spreading answers to cell [1,1] with understandable overlaps with neighbouring cells [1,2] and [2,1].
- As with labour spreading, the risk-aversion hypothesis too construes both employment and unemployment being more responsive in decline, and explains cell

[12] Apparently, this traditional construal of behaviour under institutional constraints requires some irrationality on the part of firms as they are believed to take on employees in a propitious period whom they will find then difficult to dismiss in later unfavourable circumstances.

[1,1]. Here, however, the arguments revolve around unequal perceptions of firms to swings in output. Firms fear adverse scenarios and assign them more relevance in their decision making. Whilst downturns are greeted with utter pessimism, upturns are mistrusted as short-run and elusive, and are thus taken with light optimism only. They adjust their utilization of labour and employee counts accordingly and if there are no leaks outside the labour force, both versions of Okun's law are bound to be stronger in decline. Apparently, this risk aversion interpretation fits economic environments with specific and highly uncertain conditions.

For completeness, some of the earlier explanations relate asymmetry in Okun's law to asymmetry of the Phillips curve that might be explained through capacity constraints, signal extraction, costly adjustment and downward nominal wage rigidity (Harris and Silverstone 2001, p. 7). Yet, costly adjustment is the essence of the labour hoarding hypothesis and of its labour spreading counterpart.

As a matter of fact, these hypotheses inject piece-wise non-linearity into the Okun equation and are couched clear-cut and stated without a possibility of interaction. Yet, as noted by Nebot et al. (2019, p. 204), there is no reason why several hypotheses cannot hold at the same time. For instance, labour market rigidity combined with labour hoarding or spreading tendencies may purge asymmetry and result in an Okun coefficient that is (at least statistically) identical during different conjunctural periods. In this present context, firms may even modify their aggregate attitudes over a longer time frame and their behavioural weights assigned to different hypotheses may vary in time. For instance, firms in institutionally sound environments may juggle pessimism with optimism, possibly with the political cycle and global prospects, and may switch from risk aversion to labour spreading. A likely effect is then a time-varying pattern, perhaps statistically and substantively significant, in the Okun coefficient.

Synchronicity in the Temporal Patterns of Okun Coefficients

The preceding parts of the analysis pointed repetitively to a heterogeneity of temporal profiles exhibited by Okun coefficients and diverse dynamics of business cycles in OECD countries. It turns out difficult to give a simple unified categorization of the estimated trajectories of Okun coefficients displayed in Appendix B, and to assess their (a)synchronicity. There are three aspects by which the estimated trajectories differ: the overall degree of the (un)employment-output sensitivity (mean level), the uncertainty of temporal development (variability) and the overall shape (trends or erraticity). In comparisons of trajectories, their mean level may be rather decisive and is likely to override the other two aspects. In addition, variability in Okun coefficients should be considered relative to their mean level since larger Okun coefficients (in magnitude) may simply be prone to higher variability (in magnitude). Hence, in assessments of (a)synchronicity in Okun coefficients, it is necessary to consider these aspects in isolation.

To begin with, Figure 1 compares through scatterplots mean levels and standard deviations of unemployment-based and employment-based Okun coefficients to differentiate countries in terms of the first two aspects of Okun coefficients. The graphical display in Figure 1 reconfirms the findings that transpired in several circumstances

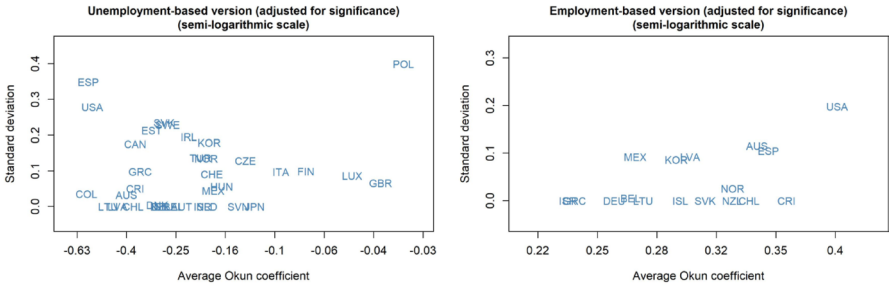


Figure 1 Similarity of countries in terms of the level and variability of Okun coefficients (adjusted for significance). *Note*: Means and standard deviations shown in the scatterplots were calculated by using Okun coefficients adjusted for significance with estimated time-varying coefficients insignificant at a 0.05 level considered as zeros. The scatterplots show positions of countries in the "mean / standard deviation" configuration in a usual manner, but the horizontal axis is drawn on a logarithmic scale and the plots are elongated to make the positions of countries better discernible.

of the previous analysis. The scatterplots evince that for either version of Okun's law there is a bunch of countries that are not very dissimilar in terms of their exposure to business cycles, and there are countries whose configuration is somewhat outlying in comparative terms. Some countries display cyclical corresponsiveness of unemployment and output that is stronger and more volatile (COL, ESP, USA), others are feebler and non-volatile in this regard (FIN, GBR, LUX) or feebler and volatile (POL). Concerning the employment-output sensitivity, a few countries are on average more sensitive with lower certainty of temporal patterns (USA) or with higher stability (AUS, CRI, ESP), other countries display comparatively small sensitivity with no volatility (ISR, GRC). Some of these countries invariably reappear as singular or distinct in their Okun's law in several analytical contexts.

Studying the second two aspects, Appendix G presents 10 clusters for unemployment-based trajectories and 10 clusters for employment-based trajectories of Okun coefficients. Demeaned trajectories of Okun coefficients adjusted for significance were utilized for each OECD country as an input to the TADPole algorithm whose particularities are expounded in "Details on the empirical set-up, and data" section. The graphs in Appendix G are elaborated with the same vertical axis, to say nothing about the adjustment for significance, which occasionally gives the drawn (demeaned) trajectories a fairly different impression than was conveyed by Appendix B (e.g. for FIN, GRC or LUX).[13]

Before anything else, there is no hiding that these clusters scarcely tally with general conceptions about economic and socio-cultural characteristics of OECD countries, and it must be bluntly conceded that it is very difficult to propound a synthesis of the clusters and to give some rationale to their membership. Whereas Okun's

[13] Of course, a comparison between the main text (with gap variables estimated by the Christiano-Fitzgerald filter) and the Online Supplement (with all results reproduced for gap variables estimated by the Christiano-Fitzgerald filter) evinces that many countries exhibit non-negligible sensitivity to the adoption of a particular filtering technique. There is no hiding that this is a critical choice in the entire analysis as the resulting trajectories of Okun coefficients differ. That said, the conclusions remain unaffected with the choice of either filter. Okun coefficients do not synchronize in the block of OECD economies.

law comes from conjoining the labour market with aggregate economic activity, its adjustments and variation over time are an outcome of the interaction between both key macroeconomic aspects. It seems that whilst there may be business cycle synchronization amongst OECD countries in terms of output (Kunroo 2024; Lee et al. 2024), as one actually descends into more nuanced aspect of this synchronization, it may disappear. Owing to the multifaceted and complex structure of labour markets, they themselves have not been—to the best knowledge of the authors—explored, as many other notable economic variables. What has been explored is the effect of labour market institutions on business cycle comovement (e.g. Fonseca et al. 2010), but synchronization of labour market performance or its properties not. OECD countries have implemented extensive labour market reforms aimed at enhancing labour flexibility, encouraging gender-balanced labour force participation and curbing youth unemployment, but each OECD country adopted its own policy program grounded in a different story (e.g. Martin 2015; Causa et al. 2021; Aumond et al. 2022; Wiese et al. 2025). This induces patterns that are not visible whilst studying output fluctuations only. The message is that even though OECD economies may be synchronized in output, the internal mechanisms with which macroeconomic production is achieved are far from being in comovement.

To illustrate the heterogeneity of the clusters, an attempt at selective characterization of clusters that comprise Czechia is propounded. Appendix G identifies Czechia clustered with Italy and South Korea in terms of trends in the unemployment-output sensitivity ("ITA as the medoid"), but clustered with Norway and Japan in terms of trends in the employment-output sensitivity ("NOR as the medoid"). Czechia, as an integrated peripheral European economy, has not frequently been subject to large cross-country comparative Okunian studies, but this omission applies equally to South Korea and Norway (cf. Boďa and Považanová 2025, Figure 5). Two distinct patterns are detectable therewith.

- The trajectories of Okun coefficients over the period 1991–2022 drawn for the cluster tagged "ITA as the medoid" are characteristic by nil correponsiveness between unemployment and output at the beginning and the end of the period with a reverse bump-shaped pattern roughly between the mid-1990s and the mid-2010s. During the 1990s or their last years, unemployment in Czechia, Italy and South Korea began to respond to output fluctuations and this responsiveness persisted for about one and a half decades until it gradually vanished. This suggests that each of these economies was exposed during this period to a particular mix of labour market policies, structural changes, institutional adjustments or labour force development that activated the unemployment-output elasticity for a few years until it dissipated.
- By contrast, the trajectories for the employment-output sensitivity over the period 1991–2022 displayed for the cluster designated as "NOR as the medoid" were significant for the entire period and followed a slow upward trend, more recognizable from the graphs in Appendix B. Hence, the corresponsiveness of employment with output in Czechia, Japan and Norway gradually rose in strength. This indicates that the socioeconomic and institutional environment in these three OECD economies promoted more vivid adjustments of employment towards out-

put over the business cycle.

Only Czechia is part of both clusters. The observed dissonance in the estimated unemployment-output and employment-output trajectories of Okun's law evinces that cyclical variations in employment did not translate automatically into cyclical adjustment in unemployment, which is a finding that supports the existence of flows outside and into the labour force in the Czech economy over the investigated period.

The five economies assembled into the two clusters are fairly diverse in terms of their historical or structural development, size or geography. Czechia underwent throughout the 1990s post-Socialist transition to a market economy in order to eliminate artificial employment and activate the nonexistent unemployment-output and employment-output sensitivities. In contrast, South Korea emerged during the investigated period as a global manufacturing powerhouse, Italy is a mature advanced economy that suffers from regional disparities, Norway is famous for its oil-funded Nordic welfare model, and Japan had to navigate through its "lost decade" of stagnation. Figures compiled from the World Bank database indicate that four of these OECD economies are marked by generally low and resilient unemployment averaging over the period to 5.33% for Czechia, 3.72% for Japan, 3.37% for South Korea, 4.09% for Norway. These numbers somewhat overstate long-term unemployment levels to which all these OECD economies tended to converge, and are affected by cyclical responses to major crises followed by swift post-crisis recoveries (e.g. the 1997 Asian crisis, the 2007–09 global economic crisis, the 2020–21 COVID-19 pandemic). The only exception to this low-employment pattern is Italy with its average 9.87% and resolutely high unemployment over the full three decades. Nonetheless, all the five OECD economies modernised with agriculture shrinking dramatically and services expanding to become the dominant sector. Exceptions are Czechia and South Korea that both retained a strong industrial or manufacturing base. Whilst Czechia sustained one of the largest employment shares in industry across Europe, for South Korea the manufacturing sector maintained a robust pro-export orientation. Italy and South Korea are notable examples of countries with entrenched gender gaps, and Italy is also an example of a complicated youth labour market. Since the most critical labour market reforms in Czechia, Italy and South Korea—targeting labour market rigidities, and introducing a framework for temporary or flexible contracts—had been implemented by the 2010s, they might have been already effective at the end of the investigated period. Their success would be manifested in lessened or no sensitivity of unemployment to output, which explains the levelled-off pattern of the estimated unemployment-based Okun coefficients in the cluster labelled as "ITA as the medoid". All the five OECD countries faced demographic challenges of ageing societies constraining the labour force, but adopted different labour market policies to tackle them by promoting flexibility or female participation. For instance, Czechia responded by delaying retirement through increased retirement age, Japan pursued extensive reformist initiatives championed by Prime Minister Shinzō Abe designated to reshape the Japanese labour market, Norway balanced its welfare model with active labour policies to address skills mismatches and rising vacancies in some sectors. Albeit completely diverse in nature, these policies explain the progressively

increasing strength of the employment-based Okun's law in the low-unemployment environment of economies grouped in the cluster tagged as "NOR as the medoid".

In spite of the effort to pinpoint relevant characteristics of these clusters that would reveal their internal homogeneity, the summaries that might be compiled for each cluster would vary in analytical depth. One reason is that these OECD economies are almost all well-developed and service-driven, often with an advanced industrial base. As noted on several occasions, the patterns of Okun coefficients in these clusters are likely much affected also by reforms that were implemented with the intention to increase labour market flexibility in each of the countries during the three decades with different timing and success, to say nothing about wider sectoral changes and structural adjustments. On cataloguing these labour reforms, it became apparent that in most countries they were successive and gradual, and it is impossible to timeline them with certainty with the cluster membership to reason out the synchronous patterns organized by the clusters. There is no conceivable explanation for the presence of countries across differently populated clusters. The inevitable conclusion is clear. Whilst economies may be synchronous in terms of output, and in spite of the rising flexibility of labour markets, the internal mechanism which with (un)employment and output interact over the business cycle main resist synchronization.

Discussion

Save a handful of exceptions, Okunian studies elected to review either the unemployment-output sensitivity (the true Okun's law described here as "unemployment-based") or the employment-output sensitivity (an alternative Okun's law interpreted here as "employment-based") without providing a comparative perspective. To the best knowledge of the authors, no study has ever attempted to compare findings from the simultaneous study of both versions of Okun's law for a large panel of economies. This comparison is made here for 38 OECD economies over the period 1991–2022 with an eye to labour market flows that are not restricted to run between the employed and the unemployed. A substantially novel input to research on Okun's law is the effort to find patterns of synchronicity in Okun coefficients amongst the studied OECD countries as little is known whether and how Okun coefficients synchronize across economies. The agenda also comprises an inquiry into the asymmetry of Okun's law across the business cycle or a search for determinants of the cross-country and temporal heterogeneity observed in Okun coefficients. These tasks may look standard, but still come with unique features as is pointed out in the ensuing discussion of the novelties or novel findings of the present comparative analysis.

First, the fact that there is nothing to suggest in macroeconomic theory that the business cycle dynamics mapped through an Okun coefficient should be fixed over time invites a time-varying perspective in measuring and explaining Okun's law. The time-varying feature in Okun coefficients is handled by Schlicht's method that has lately become fairly popular in Okunian research (to wit, Jalles 2019; Furceri et al. 2020) since it treats Okun coefficients as slowly adjusting to changes in the environment (such as changes in productivity, the sectoral composition of the economy, skills mismatch, labour participation rates). This obviously is an advantage over other

methods common in research on Okun's law such as rolling regressions or splines since these leave the dynamics of Okun coefficients loose, and may identify arbitrary or abruptly changing temporal patterns. Owing to the flexibility of the method to accommodate possibly constant Okun coefficients, a surprisingly large number of countries are identified in the analysis with constant or statistically constant trajectories of the Okun coefficient, which is a finding that adds some justification to claims of its stability made by Ball et al. (2017), at least selectively for some countries.

Second, with the employment rate defined relative to the working-age population (and not only the labour force), a substantial mismatch between unemployment-based and employment-based Okun coefficients may indicate flows of workers affecting the category outside the labour force. This mismatch may be due to the substantive size of the informal sector alone or in combination with worker effects like the DWE, EWE, AWE, population changes, or migration flows, and may be used as a metric of the severity of flows from or outside the labour force. Whereas the available data do not permit isolating the role of worker effects or demographics as to how unemployment and employment respond to output fluctuations, at least the results provide evidence that labour market flows outside the labour force in the OECD countries have a strong impact upon Okun's law and are associated with the informal sector. In particular, in more prosperous times jobs in the informal sector tend to be preferred over formal employment, and unemployment serves as recourse when economic activity slacks. Of course, this pattern is unlikely to be equally manifested in all sectors, but is likely to be concentrated in services and often institutionally built-in. In such cases, the typical explanation built around discouraged or encouraged workers does not apply. For instance, many OECD countries are major tourist destinations or operate large resort areas, and tourism opens opportunities for seasonal unregistered work, with tourism demand being hugely counter-cyclical.

Third, it is unfortunate that the task of finding cross-country synchronicity in Okun's law as a descriptor of the business cycle dynamics may have seemingly produced results that are scarcely encouraging. The clusters identified by the TADPole time-series based algorithm are fed by trajectories that match in temporal traits, but they intermingle economies with different income statuses or differentiated levels of economic development making up the OECD and pointedly fail to correspond across the two version of Okun's law. Advanced and less developed countries may share similar business cycle dynamics, and despite the tendency in Okunian research to differentiate groups of countries by their economic development and compare features of Okun's law across such groups (e.g. Bartolucci et al. 2018; Ball et al. 2019; Furceri et al. 2020) calls for a more thorough justification. It is even worse that the clusters identified for the two versions of Okun's law are incompatible and without convincing overlaps. Hence, the 38 OECD economies have business cycle dynamics that make them difficult to synchronize when taking account both unemployment and

employment reactions to cyclical fluctuations in output.[14] Whereas there still may be some synchronicity in how unemployment or employment alone correacts with output across the business cycle, when both aspects are taken concurrently it becomes obvious that labour markets do not synchronize cyclically even for advanced economies. A practical consequence is that even in homogeneous economic blocks a unified stabilization policy that would seek a similar response of labour markets to cyclical variation in output is actually impossible.[15]

Fourth, a number of studies have highlighted a built-in proclivity of Okun's law for asymmetry across stages of the business cycle. A general consensus is that during recessions Okun's law manifests itself with greater intensity than during expansions (e.g. Knotek 2007; Michail 2019; Grant 2018; Boďa and Považanová 2021). Whilst the traditional technique is to posit some asymmetry-based econometric model and estimate specific Okun coefficients for different business cycle regimes, this asymmetry is verified here by applying a free time-varying coefficient model without any prejudice towards asymmetry and by categorizing Okun coefficients according as they are estimated for a decline stage or an upswing stage. The findings refute the stylized claim of an Okun's law universally stronger in decline as merely a handful of countries have both versions of Okun's law stronger in decline. As a matter of fact, the mosaic is richer and more colourful. Many countries display the same strength of Okun's law equally strong in decline and upswing irrespective of the version. Alternatively, a few countries have only one version of Okun's law stronger in decline. Furthermore, one country is with a stronger Okun's law in upswing for both unemployment and employment. Apparently, this observation ensues from considering as many as 38 countries in one comparative study. Usually, these investigations are conducted for less populous sets of countries. The observed mosaic may be justified by four coherent hypotheses formulated earlier in the literature (e.g. Palley 1993; Silvapulle et al. 2004), viz. institutional rigidity, labour hoarding, labour spreading, and risk aversion. An obvious drawback of these four propositions is that they are too polished and refined to hold credibly in pure form, which generates a polychromatic assortment of unemployment and output responses over the business cycle. Whereas the traditional account of institutional rigidity and labour hoarding justifies the pronounced sensitivity of the labour market in upswing, the labour spreading and risk aversion hypotheses substantiate the more vigorous response in downswing. Nonetheless, these pure state-

[14] As noted by one reviewer, the observed asynchronicity in Okun coefficients might an artifact of the changing patterns of business cycle synchronization that is documented by Antonakakis et al. (2016) for developed and developing countries over major globalization periods. However, OECD countries rank mostly amongst advanced economies, and many of them are euro area members for which business cycle synchronicity is becoming a stylized fact inasmuch as it has been repeatedly acknowledged by empirical research (e.g. Degiannakis et al. 2016; Campos et al. 2019; Arčabić et al. 2024). Yet, the cluster membership report at the time plots of Appendix G shows that euro area members are allocated to diverse clusters of Okun coefficients in spite of their strong business cycle patterns. Apparently, the detected asynchronicity in Okun coefficients incorporates also information on the asynchronicity in labour markets and their relationship towards the business cycle, and does not reflect merely business cycle synchronization derived from output gaps.

[15] Of course, the 38 OECD economies are not heterogeneous, and were chosen for this paper as a convenient political grouping promoting economic collaboration as in other studies (e.g. Sögner and Stiassny 2002; van Ours 2015; Dixon et al. 2017, Boďa and Považanová 2021).

ments with symmetric responses of unemployment and employment necessitate that there are no flows into and outside the labour force, which is in fact demonstrated for the OECD economies not to be true. Moreover, there is no reason to believe that firms tilt towards just one particular attitude and that their attitudes remain constant in time. For instance, with an economy with a strong tradition of the informal sector caused by long years of institutional rigidity, labour spreading may imply a lower degree of employment responsiveness to upswing, but otherwise constant and tepid unemployment across different stages of the business cycle. With the gradual flexibilization of the labour market, labour spreading may dissipate provided that there are no structural mismatches and the available labour force possesses required expertise. It should also be borne in mind that the analysis is performed on an aggregate national level, whereas firms in different sectors may have different inclinations.

Fifth, the explanation of the cross-country heterogeneity observed in Okun coefficients in this study turns out to be quite comprehensive given the fact that only one study in the past was engaged in a comparative explanation of both versions of Okun's law. The outcome is the reassertion of findings established in other Okunian studies, albeit some findings are in fact at odds. First of all, the (un)employment-output nexus is predetermined by initial business cycle conditions of the economy such as economic prosperity and unemployment. Obviously, more developed economies have better stabilized labour markets that are more resistant to fluctuations, resulting to a lower level of Okunian sensitivity. With higher unemployment, employment is typically tighter and vacant jobs are more scarce, which gives room for freer fluctuations in unemployment and modest or none in employment. Furthermore, the (un)employment-output relationship is also determined by the structural make-up of the economy: the relative size of the tertiary and industrial sectors as well as the informal sector. The existence of a sizeable informal sector is found to amplify both unemployment and employment fluctuations as it indicates that labour force may be more involved in informal activities whilst formally only switching between the categories of the unemployed and the employed. In this regard, relatively high services in output are found to heighten unemployment cyclical responsiveness, and relatively high industrial production is found to suppress cyclical coelasticity with employment. The ascertained pattern agrees with the comparative analysis of Goto and Bürgi (2021). OECD economies are all service-driven, which naturally brings about higher susceptibility of unemployment to economic fluctuations in services. The asymmetry with which the relative importance of the service sector is linked to unemployment and employment across the business cycle reveals that in good times people go to informal employment in services, but in troubled times they flee to unemployment for assistance and support. In OECD economies with advanced industrial bases and developed informal sectors, informal employment may be a strong competitor to formal employment.

Concluding Notes

With a focus upon economies of the 38 OECD member countries over the recent three decades, the present paper aims to contribute to research on Okun's law, which as an empirical regularity captures some crucial parts forming the anatomy of the

business cycle. Okun's law is deemed here as an internal characteristic of business cycle dynamics that measures through an Okun coefficient how (un)employment and output covary or comove over the business cycle.

The chief contributions to business cycle research may be briefly summarized in a list of four points: First, contrary to economic intuition, trajectories of the Okun coefficient for many OECD economies over the period 1991–2022 may not be time-varying, but constant or with statistically negligible variation. Second, the systematic comparison of unemployment-based and employment-based Okun coefficients solidifies evidence for the existence of labour market flows outside the labour force in OECD economies that are so sizeable that they exert an impact upon Okun's law. Third, Okun's law may not be universally stronger in decline, and there are many OECD countries for which Okun's law was identified equally strong across different stages or stronger in upswing. Fourth, Okun coefficients do not to synchronize across the block of OECD economies, and the analysis fails to provide any shred of satisfactory evidence that might indicate that the business cycles of OECD economies have internal structures that are similar beyond randomly correlated patterns. In consequence, economies may display comparable outer synchronicity in business cycles—which many OECD economies actually do—, but how the key variables of economic performance, that is, output, unemployment, and employment, *co*react over the business cycle may still remain specific for each economy.

It must also be emphasized at this instance that synchronicity in Okun coefficients is not to be mistaken for convergence in Okun coefficients. A somewhat older strand of literature occupied with testing convergence of Okun's law represented by Perman and Tavera (2005, 2007) and Yazgan and Yilmazkuday (2009) inquired whether in economies regulated by a coordinated monetary and fiscal policy Okun law coefficients tend to a common level of the (un)employment-output sensitivity. This makes sense for member states of a monetary union or federated states where (local) economies surrender more or less of their economic independence. In contrast, the present investigations of (a)synchronicity in Okun coefficients aspire to establish which economies are structurally similar in terms of their business cycle internal structure in the sense that their labour market and real economy comove in a similar fashion. The paper thus extends the bountiful literature on business cycle synchronization in OECD countries beyond bilateral trade or monetary and fiscal coordination (e.g. Inklaar et al. 2008; Kunroo 2024).

Of course, the present findings are partial in the sense that they do not establish the absolute absence of synchronicity in the labour markets of OECD economies. As noted by one reviewer, it is possible that some degree of synchronization exists in how either unemployment or employment alone responds to output fluctuations over the business cycle. Yet, this was not the focus of the present inquiry as it—as an Okunian study—rushed directly to studying the labour market sensitivity to output over the business cycle as an instrument of stabilization policy and macroeconomic forecasting.

The present analysis stands on the gap formulation of Okun's law with input gap variables estimated with the use of the Christiano-Fitzgerald filter for both versions of Okun's law. In spite of the esteem that this filtration technique receives amongst business cycle analysts, the Hodrick-Prescott filter is actually most favoured in research on Okun's law. It is thus worth noting that the key findings remain actually

unaltered and retain robustness when the Hodrick-Prescott filter is utilized instead of the Christiano-Fitzgerald filter.

Appendix A Data, their definition, sources and variables

See Tables 5 and 6.

Table 5 Declaration of input variables, their definition and sources

Notation or code	Definition and units of measurement	Source
Variables used in the first stage in estimating Okun coefficients		
rgdp	Gross domestic product (constant milliards of 2015 US$)	WB
unemr_t	Total unemployment rate (% of total labour force, age 15+, ILOSTAT)	WB
emplr_t	Total employment rate (% of total population, age 15+, ILOSTAT)	WB
Variables used in the second stage to explain Okun coefficients		
rgdp_pc	Gross domestic product per capita (PPP, thousands of constant 2017 international $)	WB
ecomp_perc	Compensation of employees (% of total expense)	WB
gdpsh_agri	Share of agriculture, forestry and fishing in value added (% of gross domestic product)	WB
gdpsh_serv	Share of services in value added (% of gross domestic product)	WB
gdpsh_ind	Share of industry in value added (% of gross domestic product)	WB
infsect2gdp	Dynamic general equilibrium model-based (DGE) estimates of the informal sector size (% of official gross domestic product)	WB
lfl524_t	Total labour force participation rate (% of total population, age 15–24, ILOSTAT)	WB
lf_m	Male labour force share (% of total labour force)	WB*
migrnetr_perc	Net migration (% of total population, all ages)	WB*
parttimer_t	Total part-time employment rate (% of total employment, age 15+)	WB
index_polstab	Political stability and absence of violence/terrorism index (Z-score)	WB
pop_urban	Urban population share (% of total population)	WB
schoolenrol_tert	Gross tertiary school enrolment rate (% of population in the typical age cohort)	WB
unemr_t	Total unemployment rate (% of total labour force, age 15+, ILOSTAT)	WB
negativeDrgdp	Binary variable indicating a negative year-on-year real gross domestic product growth (yes = 1)	WB*
negativeGrgdp	Binary variable indicating a negative real output gap (yes = 1)	WB*
reg_lab_mar	Labour market regulations index (scale 0 [strict] to 10 [flexible])	FI
reg_bus	Business regulations index (scale 0 [strict] to 10 [flexible])	FI

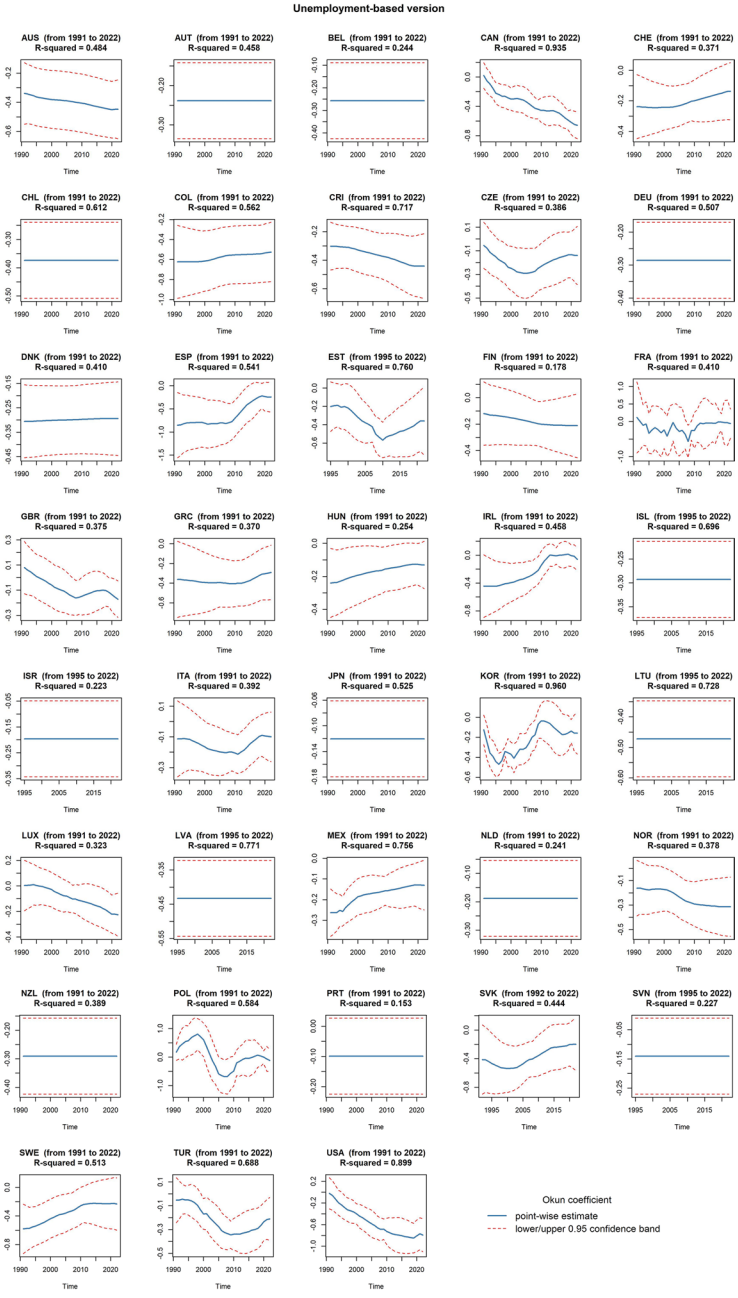
The data were downloaded throughout April and May 2024

Legend: Sources convey the following meaning: “WB” indicates the World Bank database (https://datacatalog.worldbank.org), "WB*" denotes additionally computed variables from those in the World Bank database, “FI” refers to the dataset accompanying *Economic freedom of the world: 2023 annual report* of the Fraser Institute (https://www.fraserinstitute.org). Some variables downloaded from the World Bank originate actually from the ILOSTAT database of the International Labour Organization (ILO) and are modelled ILO estimates

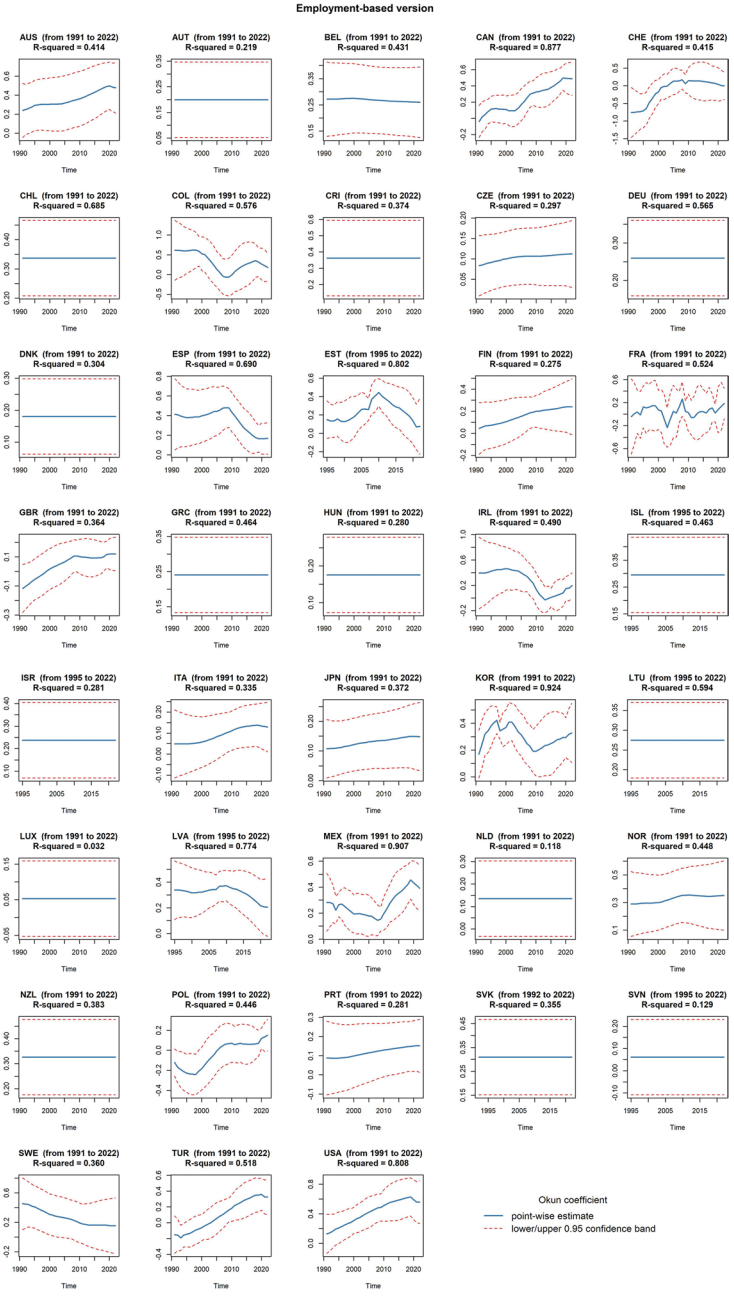
Table 6 Descriptive statistics of input variables

Variable	# observations	Mean	Standard deviation	Median	Minimum	Maximum
Variables used in the first stage in estimating Okun coefficients						
rgdp	1191	1,100.352	2616.223	303.410	9.144	20,926.835
unemr_t	1191	7.712	4.078	6.880	1.480	27.690
emplr_t	1191	55.694	6.423	56.437	37.381	77.024
Variables used in the second stage to explain Okun coefficients						
rgdp_pc	1191	37.944	18.142	37.199	8.430	120.648
ecomp_perc	1071	15.479	8.166	14.052	2.171	51.566
gdpsh_agri	1133	3.089	2.556	2.311	0.191	17.455
gdpsh_serv	1133	61.736	6.477	61.671	41.790	80.383
gdpsh_ind	1133	25.565	5.329	25.619	10.397	49.124
infsect2gdp	1115	19.421	6.953	17.763	7.910	37.911
lf1524_t	1191	48.017	13.492	47.604	20.806	83.030
lf_m	1191	56.150	4.611	54.639	49.234	75.065
migrnetr_perc	1191	0.258	0.598	0.205	–1.505	9.142
parttimer_t	1010	31.627	10.872	29.800	4.450	61.730
index_polstab	1026	0.647	0.722	0.852	0.176	1.759
pop_urban	1191	75.832	11.071	77.170	48.469	98.153
schoolenrol_tert	1022	59.067	23.475	60.028	4.799	150.202
unemr_t	1191	7.712	4.078	6.880	1.480	27.690
negativeDrgdp	1183	0.136	0.343	0.000	0.000	1.000
negativeGrgdp	1191	0.543	0.498	1.000	0.000	1.000
reg_lab_mar	869	6.624	1.295	6.687	3.030	9.610
reg_bus	874	6.577	1.140	6.764	3.398	9.499

Appendix B Trajectories of Okun coefficients

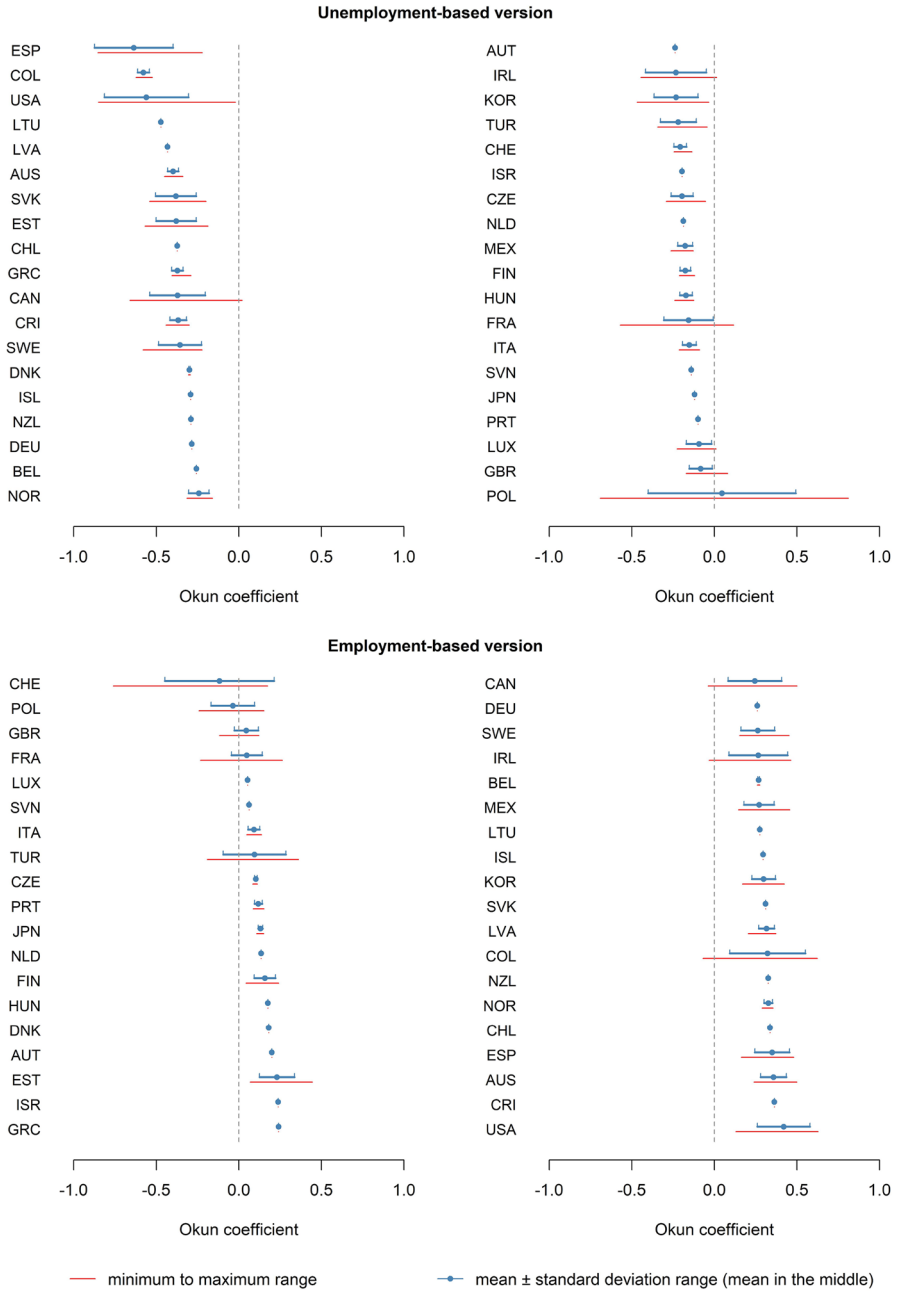


Note: Captions displayed above the charts provide information about the time availability of estimated Okun coefficients with R-squared values measuring the goodness-of-fit of first-stage regressions. These can roughly be construed as measures of the homogeneity of Okun's law over the period. The confidence band is displayed for a 0.95 level, and is only approximate (Gaussian).



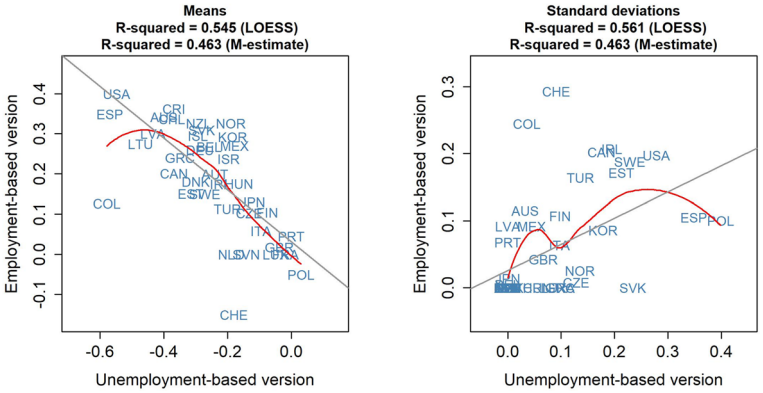
Note: Captions displayed above the charts provide information about the time availability of estimated Okun coefficients with R-squared values measuring the goodness-of-fit of first-stage regressions. These can roughly be construed as measures of the homogeneity of Okun's law over the period. The confidence band is displayed for a 0.95 level, and is only approximate (Gaussian).

Appendix C Economy-wide Okun coefficients ordered by size and their ranges



Note: Ranges shown in the charts were computed for all available estimated economy-wide Okun coefficients, hence mostly covering the period 1991 – 2022, except EST, ISL, ISR, LTU, LVA, SVK and SVN when a shorter history was available.

Appendix D Congruence of unemployment-based and employment-based Okun coefficients (adjusted for significance)



Note: Means and standard deviations shown in the scatterplots were calculated by using Okun coefficients adjusted for significance with estimated time-varying coefficients insignificant at a 0.05 level considered as zeros. Each scatterplot shows two regression fits through the cloud of points: a non-parametric fit by the traditional LOESS (locally estimated scatterplot smoothing) method indicated by a red curve, and a parametric straight-line fit by the robust M-estimator indicated by a gray line. Captions above the scatterplots display R-squared values measuring the goodness-of-fit for either case.

Appendix E Correlation of unemployment-based and employment-based Okun coefficients (adjusted for significance)

Country	Adjusted coefficients	Country	Adjusted coefficients	Country	Adjusted coefficients	Country	Adjusted coefficients
AUS	**− 0.905**	DNK	NA	ISR	NA	NZL	NA
AUT	NA	**ESP**	**− 0.949**	**ITA**	**− 0.001**	POL	− 0.622
BEL	NA	EST	− 0.736	JPN	NA	PRT	NA
CAN	**− 0.878**	FIN	− 0.706	KOR	− 0.733	SVK	NA
CHE	0.362	FRA	NA	LTU	NA	SVN	NA
CHL	NA	GBR	− 0.540	LUX	NA	SWE	− 0.842
COL	− 0.626	GRC	NA	LVA	NA	TUR	− 0.613
CRI	NA	HUN	NA	**MEX**	**0.370**	**USA**	**− 0.998**
CZE	− 0.074	IRL	− 0.582	NLD	NA	**OECD-38**	**− 0.591**
DEU	NA	ISL	NA	**NOR**	**− 0.962**		

Pearson correlation coefficients reported in the table were calculated by using Okun coefficients adjusted for significance with estimated time-varying coefficients insignificant at a 0.05 level considered as zeros. Country "OECD-38" indicates all 38 OECD members with their time-varying coefficients simplistically pooled. Symbol “NA” indicates cases where the correlation coefficient was not computable owing to a constant trajectory implying zero standard deviation

Legend: Boldface is used to highlight a high degree of match between correlation computed from Okun coefficients adjusted for significance and correlation computed from all Okun coefficients regardless of their significance. Whenever the difference is 0.08 at most, the informational similarity is signalled by bold font

Appendix F Average Okun coefficients over the business cycle (adjusted for significance)

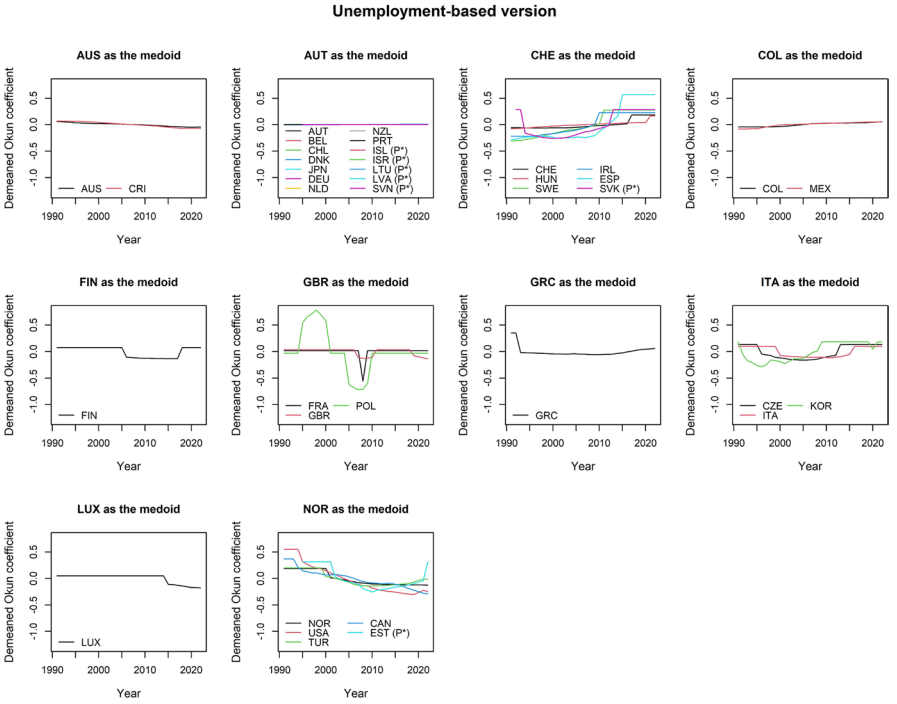
Country	Unemployment-based Okun's law				Employment-based Okun's law			
	Δy +	Δy –	Δy +, Δu –	Δy –, Δu +	Δy +	Δy –	Δy +, Δu –	Δy –, Δu +
AUS	– **0.399**$^{(30)}$	– 0.395$^{(2)}$	– 0.403$^{(22)}$	– **0.451**$^{(1)}$	**0.348**$^{(30)}$	0.249$^{(2)}$	0.365$^{(22)}$	**0.498**$^{(1)}$
AUT	– 0.239$^{(30)}$	– 0.239$^{(2)}$	– 0.239$^{(15)}$	– 0.239$^{(2)}$	0.199$^{(30)}$	0.199$^{(2)}$	0.199$^{(15)}$	0.199$^{(2)}$
BEL	– 0.257$^{(29)}$	– 0.257$^{(3)}$	– 0.257$^{(17)}$	– 0.257$^{(3)}$	**0.268**$^{(29)}$	0.266$^{(3)}$	**0.268**$^{(17)}$	0.266$^{(3)}$
CAN	– **0.369**$^{(29)}$	– 0.353$^{(3)}$	– 0.407$^{(22)}$	– **0.529**$^{(2)}$	0.194$^{(29)}$	**0.269**$^{(3)}$	0.224$^{(22)}$	**0.404**$^{(2)}$
CHE	– 0.174$^{(25)}$	– **0.200**$^{(7)}$	– 0.160$^{(14)}$	– **0.194**$^{(6)}$	– 0.103$^{(25)}$	– 0.322$^{(7)}$	– 0.051$^{(14)}$	– 0.249$^{(6)}$
CHL	– 0.374$^{(29)}$	– 0.374$^{(3)}$	– 0.374$^{(17)}$	– 0.374$^{(3)}$	0.337$^{(29)}$	0.337$^{(3)}$	0.337$^{(17)}$	0.337$^{(3)}$
COL	– **0.578**$^{(30)}$	– 0.577$^{(2)}$	– 0.574$^{(15)}$	– **0.577**$^{(2)}$	0.116$^{(30)}$	**0.295**$^{(2)}$	0.034$^{(15)}$	**0.295**$^{(2)}$
CRI	– 0.364$^{(30)}$	– **0.408**$^{(2)}$	– 0.378$^{(15)}$	– **0.408**$^{(2)}$	0.362$^{(30)}$	0.362$^{(2)}$	0.362$^{(15)}$	0.362$^{(2)}$
CZE	– **0.140**$^{(24)}$	– 0.106$^{(8)}$	– 0.121$^{(17)}$	– **0.141**$^{(6)}$	**0.104**$^{(24)}$	0.099$^{(8)}$	**0.105**$^{(17)}$	0.100$^{(6)}$
DEU	– 0.286$^{(27)}$	– 0.286$^{(5)}$	– 0.286$^{(19)}$	– 0.286$^{(5)}$	0.259$^{(27)}$	0.259$^{(5)}$	0.259$^{(19)}$	0.259$^{(5)}$
DNK	– **0.300**$^{(29)}$	– 0.297$^{(3)}$	– **0.299**$^{(20)}$	– 0.296$^{(2)}$	0.180$^{(29)}$	0.180$^{(3)}$	0.180$^{(20)}$	0.180$^{(2)}$
ESP	– **0.574**$^{(26)}$	– 0.546$^{(6)}$	– 0.488$^{(19)}$	– **0.546**$^{(6)}$	0.350$^{(26)}$	0.350$^{(6)}$	0.323$^{(19)}$	**0.350**$^{(6)}$
EST	– **0.336**$^{(22)}$	– 0.285$^{(5)}$	– **0.382**$^{(17)}$	– 0.356$^{(4)}$	0.156$^{(22)}$	0.156$^{(5)}$	0.176$^{(17)}$	**0.195**$^{(4)}$
FIN	– 0.066$^{(24)}$	– **0.102**$^{(8)}$	– 0.062$^{(19)}$	– **0.102**$^{(6)}$	0.095$^{(24)}$	**0.132**$^{(8)}$	0.099$^{(19)}$	**0.142**$^{(6)}$
FRA	– **0.020**$^{(29)}$	0.000$^{(3)}$	– **0.034**$^{(17)}$	0.000$^{(2)}$	0.000$^{(29)}$	0.000$^{(3)}$	0.000$^{(17)}$	0.000$^{(2)}$
GBR	– 0.026$^{(28)}$	– **0.114**$^{(4)}$	– 0.022$^{(20)}$	– **0.152**$^{(3)}$	0.016$^{(28)}$	**0.030**$^{(4)}$	0.017$^{(20)}$	**0.039**$^{(3)}$
GRC	– 0.336$^{(22)}$	– **0.381**$^{(10)}$	– 0.365$^{(15)}$	– **0.396**$^{(6)}$	0.240$^{(22)}$	0.240$^{(10)}$	0.240$^{(15)}$	0.240$^{(6)}$
HUN	– 0.158$^{(26)}$	– **0.181**$^{(5)}$	– 0.155$^{(20)}$	– **0.189**$^{(4)}$	0.176$^{(26)}$	0.176$^{(5)}$	0.176$^{(20)}$	0.176$^{(4)}$
IRL	– **0.229**$^{(29)}$	– 0.157$^{(3)}$	– **0.229**$^{(18)}$	– 0.157$^{(3)}$	**0.182**$^{(29)}$	0.095$^{(3)}$	**0.183**$^{(18)}$	0.095$^{(3)}$
ISL	– 0.293$^{(24)}$	– 0.293$^{(3)}$	– 0.293$^{(16)}$	– 0.293$^{(3)}$	0.295$^{(24)}$	0.295$^{(3)}$	0.295$^{(16)}$	0.295$^{(3)}$
ISR	– 0.196$^{(25)}$	– 0.196$^{(2)}$	– 0.196$^{(18)}$	– 0.196$^{(2)}$	0.237$^{(25)}$	0.237$^{(2)}$	0.237$^{(18)}$	0.237$^{(2)}$
ITA	– 0.083$^{(25)}$	– **0.136**$^{(7)}$	– 0.103$^{(16)}$	– **0.159**$^{(6)}$	0.047$^{(25)}$	**0.102**$^{(7)}$	0.050$^{(16)}$	**0.097**$^{(6)}$
JPN	– 0.120$^{(25)}$	– 0.120$^{(7)}$	– 0.120$^{(15)}$	– 0.120$^{(6)}$	0.130$^{(25)}$	0.130$^{(7)}$	**0.137**$^{(15)}$	0.127$^{(6)}$
KOR	– 0.180$^{(30)}$	– **0.239**$^{(2)}$	– 0.202$^{(17)}$	– **0.239**$^{(2)}$	0.291$^{(30)}$	**0.318**$^{(2)}$	0.306$^{(17)}$	**0.318**$^{(2)}$
LTU	– 0.472$^{(24)}$	– 0.472$^{(3)}$	– 0.472$^{(19)}$	– 0.472$^{(2)}$	0.275$^{(24)}$	0.275$^{(3)}$	0.275$^{(19)}$	0.275$^{(2)}$
LUX	– 0.046$^{(29)}$	– **0.074**$^{(3)}$	– 0.066$^{(12)}$	– **0.074**$^{(3)}$	0.000$^{(29)}$	0.000$^{(3)}$	0.000$^{(12)}$	0.000$^{(3)}$
LVA	– 0.433$^{(23)}$	– 0.433$^{(4)}$	– 0.433$^{(20)}$	– 0.433$^{(4)}$	0.294$^{(23)}$	**0.331**$^{(4)}$	0.289$^{(20)}$	**0.331**$^{(4)}$

Country	Unemployment-based Okun's law				Employment-based Okun's law			
	Δy +	Δy –	Δy +, Δu –	Δy –, Δu +	Δy +	Δy –	Δy +, Δu –	Δy –, Δu +
MEX	**− 0.179**$^{(26)}$	− 0.171$^{(6)}$	− 0.163$^{(14)}$	**− 0.169**$^{(5)}$	0.267$^{(26)}$	**0.283**$^{(6)}$	**0.309**$^{(14)}$	0.301$^{(5)}$
NLD	− 0.188$^{(28)}$	− 0.188$^{(4)}$	− 0.188$^{(17)}$	− 0.188$^{(4)}$	0.000$^{(28)}$	0.000$^{(4)}$	0.000$^{(17)}$	0.000$^{(4)}$
NOR	− 0.182$^{(30)}$	**− 0.298**$^{(2)}$	− 0.191$^{(14)}$	**− 0.298**$^{(2)}$	0.325$^{(30)}$	**0.350**$^{(2)}$	0.329$^{(14)}$	**0.352**$^{(2)}$
NZL	− 0.291$^{(28)}$	− 0.291$^{(4)}$	− 0.291$^{(22)}$	− 0.291$^{(3)}$	0.326$^{(28)}$	0.326$^{(4)}$	0.326$^{(22)}$	0.326$^{(3)}$
POL	0.032$^{(30)}$	0.000$^{(2)}$	0.012$^{(17)}$	NA	− 0.058$^{(30)}$	0.060$^{(2)}$	− 0.056$^{(17)}$	NA
PRT	0.000$^{(25)}$	0.000$^{(7)}$	0.000$^{(14)}$	0.000$^{(7)}$	**0.047**$^{(25)}$	0.041$^{(7)}$	**0.083**$^{(14)}$	0.041$^{(7)}$
SVK	− 0.288$^{(27)}$	**− 0.305**$^{(3)}$	− 0.240$^{(17)}$	**− 0.305**$^{(3)}$	0.309$^{(27)}$	0.309$^{(3)}$	0.309$^{(17)}$	0.309$^{(3)}$
SVN	− 0.140$^{(23)}$	− 0.140$^{(4)}$	− 0.140$^{(19)}$	− 0.140$^{(4)}$	0.000$^{(23)}$	0.000$^{(4)}$	0.000$^{(19)}$	0.000$^{(4)}$
SWE	− 0.254$^{(25)}$	**− 0.331**$^{(7)}$	− 0.215$^{(14)}$	**− 0.290**$^{(6)}$	0.137$^{(25)}$	**0.192**$^{(7)}$	0.121$^{(14)}$	**0.148**$^{(6)}$
TUR	**− 0.210**$^{(28)}$	− 0.127$^{(4)}$	**− 0.227**$^{(17)}$	− 0.055$^{(3)}$	**0.130**$^{(28)}$	0.000$^{(4)}$	0.137$^{(17)}$	− 0.052$^{(3)}$
USA	**− 0.552**$^{(29)}$	− 0.498$^{(3)}$	− 0.569$^{(22)}$	**− 0.748**$^{(2)}$	**0.404**$^{(29)}$	0.360$^{(3)}$	0.418$^{(22)}$	**0.539**$^{(2)}$

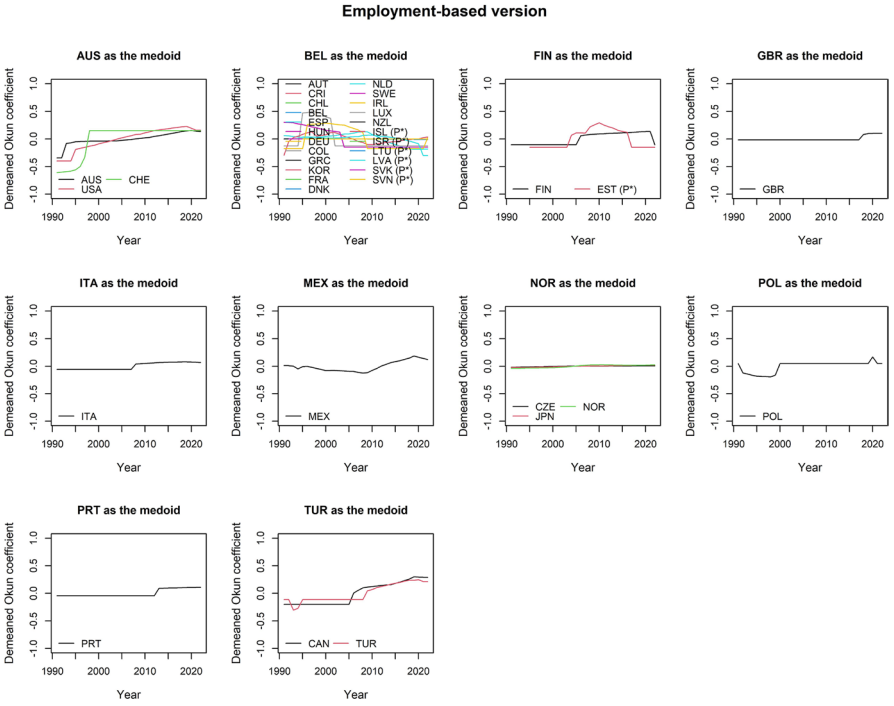
Averages presented in the table were computed from Okun coefficients adjusted for significance. Hence, estimated time-varying coefficients insignificant at a 0.05 level were treated as zeros prior to their averaging. Numbers in parentheses displayed in superscripts reveal the length of (not necessarily consecutive) business cycle stages over the investigated period

Legend: Symbols Δy and Δu denote year-on-year output and unemployment change, respectively. Information about the sign is communicated by + and – to indicate either a growth or positive case (+) or a decline or negative case (–). Symbol NA signals the absence of observations for the particular case in question. Boldface is used to highlight stages of the business cycle when the unemployment-output or employment-output sensitivity is greater ("more negative" and "more positive", respectively), but not counter-intuitive

Appendix G Clusters of countries by the shape of the trajectories of Okun coefficients (adjusted for significance)



Note: Trajectories of economy-wide Okun coefficients displayed in the charts were adjusted for significance, and estimated time-varying coefficients insignificant at a 0.05 level were treated as zeros. After being demeaned (to have zero mean) without any transformation to the same level of variability, they were entered into a time-series clustering procedure based on the TADPole (time-series anytime density peaks) algorithm developed by Begum et al. (2015), which is a non-hierarchical clustering algorithm based on the DTW (dynamic time warping) distance metric in essence similar to PAM (partitioning around medoids). The appropriate number of clusters was identified by consulting several internal cluster validity measures. The algorithm was first run with demeaned trajectories of economy-wide Okun coefficients for 27 countries where estimates were available for the full time frame over 1991–2022. Consequently, for the remaining 11 countries, the cluster membership was predicted *ad hoc* by respecting the shorter availability of estimated Okun coefficients. Again, of course, demeaned trajectories were utilized.
Legend: The notation "(P*)" after country codes indicates that the cluster membership of these countries was predicted additionally, and not determined within the TADPole clustering, as explained in the note.



Note: Trajectories of economy-wide Okun coefficients displayed in the charts were adjusted for significance, and estimated time-varying coefficients insignificant at a 0.05 level were treated as zeros. After being demeaned (to have zero mean) without any transformation to the same level of variability, they were entered into a time-series clustering procedure based on the TADPole (time-series anytime density peaks) algorithm developed by Begum et al. (2015), which is a non-hierarchical clustering algorithm based on the DTW (dynamic time warping) distance metric in essence similar to PAM (partitioning around medoids). The appropriate number of clusters was identified by consulting several internal cluster validity measures. The algorithm was first run with demeaned trajectories of economy-wide Okun coefficients for 31 countries where estimates were available for the full time frame over 1991–2022. Consequently, for the remaining 7 countries, the cluster membership was predicted *ad hoc* by respecting the shorter availability of estimated Okun coefficients. Again, of course, demeaned trajectories were utilized.
Legend: The notation "(P*)" after country codes indicates that the cluster membership of these countries was predicted additionally, and not determined within the TADPole clustering, as explained in the note.

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Availability of data and materials The data and R codes upon which this study draws are available from the corresponding author upon request.

Declarations

Conflict of interest The authors have no conflict of interest to declare.

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