Economic Modelling 128 (2023) 106490

Contents lists available at ScienceDirect

Economic Modelling

journal homepage: www.journals.elsevier.com/economic-modelling

The heterogeneity of Okun's law: A metaregression analysis

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ARTICLE INFO

Handling editor: Sushanta Mallick

JEL classification:
C55
E23
E24
J60

Keywords:
Okun's law
Heterogeneity
Metaregression

ABSTRACT

Okun's law, a significant parameter in empirical research and policy analysis, faces considerable heterogeneity. This stems from its dual interpretation in the literature, with one implying unemployment's effects on output and the other suggesting output's effects on unemployment. Consequently, comparing results from these approaches is not straightforward. Even within each approach, variability persists. Through meta-analysis and correction for publication bias, we identified the primary factor contributing to heterogeneity in both approaches: labor market characteristics (e.g., self-employment, labor laws, productive structure), leading to varying reactions of unemployment to cyclical output changes across different labor markets. The second most influential factor was methodological issues (data type, frequency, spatial coverage, sample period, etc.), highlighting how researchers' decisions impact results. Lastly, the underlying theoretical model also accounted for some variability. Okun proposed three models to estimate the relationship, which yielded comparable results for the US economy, but for other economies this was less evident.

1. Introduction

Okun's law is an extremely influential concept in empirical research and policy analysis. Evidence of the relevance of this parameter for both academia and economic policy is reflected in the extensive body of literature analyzing this issue since Okun's original study (1962). Using this parameter, it is possible to determine the impact of cyclical variations in economic activity on unemployment or the effect of keeping human resources idle on output. From a policy perspective, it is imperative to know the "true" effect of the unemployment-output relationship for appropriate policy design and decision-making. However, the literature review reveals a high degree of heterogeneity in the Okun's coefficient, and it is not possible to extract from this review a single value for this relationship.

On one hand, the concept of "Okun's Law" is mentioned in the literature in studies that estimate the relationship from output to unemployment (Ball et al., 2015; Harris and Silverstone, 2001; Moosa, 1997; Palombi et al., 2017; among many others), while in others, the estimated effect is the opposite, i.e., the effects of unemployment on output (Attfield and Silverstone, 1998; Freeman, 2001; Guisinger et al., 2018; Lee, 2000, among others). The question is if it is possible to compare these two types of results and draw any conclusions about the "true value" of Okun's coefficient. This is one of the questions we will try to answer in this paper.

On the other hand, even within these approaches, heterogeneous results continue to be observed. For example, the Okun's coefficients estimated by Perman and Tavera (2005) for several European countries, using unemployment as a dependent variable, range between −0.8 and −0.05 (Spain and Luxembourg, respectively) for the period 1970–2002. This implies that the unemployment rate in Spain falls by 0.8 percentage points (pp) as output grows by 1%, while in Luxembourg, the fall is considerably lower at only 0.05 pp. This indicates that unemployment in Spain is highly sensitive to output, whereas the response of unemployment in Luxembourg is considerably lower. Why do these differences exist? There are some studies that try to find the factors that may explain the variations in Okun's coefficient between countries or regions. Some of the explanatory factors mentioned include employment protection legislation, the importance of self-employment, informality, social security coverage, and the production structure (Balakrishnan et al., 2010; Ball et al., 2019; Blanchard, 1997; Herwartz and Niebuhr, 2011; Porras-Arena and Martín-Román, 2019, 2023; Sögner and Stiassny, 2002; Villaverde and Maza, 2009). This suggests that there are country- or region-specific characteristics that lead to varying levels of sensitivity of unemployment to changes in economic activity in different economies.

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https://doi.org/10.1016/j.econmod.2023.106490
Received 11 February 2023; Received in revised form 25 July 2023; Accepted 19 August 2023
Available online 22 August 2023

In addition, heterogeneity is also evident between estimates for the same country or region. For example, estimates for the United Kingdom vary between −0.68 and −0.05 (Palombi et al., 2017; Perman and Tavera, 2005), which could be explained by the time period of estimations, if the relationship was unstable, or if there was a structural break, but it suggests that methodological approach used for estimation also matters. Indeed, Okun's coefficient has been estimated from different estimation methods, with data of different frequencies, using time series or panel data, etc.

There is a precedent in the literature that analyzes various primary studies on Okun's law (Perman et al., 2015) with the aim of determining whether a clear and common representative empirical coefficient of Okun's law emerged from previous work. They found that the estimated "true effects" are −0.40 for the subsample that has unemployment as the dependent variable and −1.02 for the subsample with output as the dependent variable. They conclude that it may be reasonable to argue that there are two underlying 'true values' for Okun's law, depending on the choice of the dependent variable. To make the two values comparable, they use the inverse value of Okun's estimates with output as the dependent variable. However, the question remains: Are the results of the two approaches truly comparable?

On the other hand, even correcting for strictly methodological factors, as do Perman et al. (2015), we question whether it is relevant to inquire about a single "true value" for all time and place. Instead, given the high observed heterogeneity of the estimates, we believe it is more appropriate to explore this heterogeneity. Thus, we assert that an analysis of the different dimensions of heterogeneity of Okun's law, providing empirical evidence regarding the variables that may be influencing the results, analyzing which factors contribute more to the disagreement of the previous studies, will offer a significant contribution to the literature.

Based on the literature discussed above, we distinguish between three main sources of heterogeneity of Okun's law: 1) the features of each labor market that make the relationship between unemployment and output more or less sensitive, 2) the underlying theoretical model of the relationship, and 3) the methodological approach used to estimate the law. We conducted tests using meta-analysis techniques to assess the significance of each of these factors as explanatory factors of heterogeneity.

The meta-regressions include 1213 estimates of Okun's coefficients collected from previously published studies. First, we studied the existence of publication bias in our data, which is a common problem in meta-analyses. Then, after presenting evidence of considerable heterogeneity between estimates of the law, we introduce the results of meta-regressions, considering that the studies' effect sizes may vary and that the collected studies represent a random sample of a larger number of studies.

As a primary result, we present evidence indicating that the most important factor explaining the heterogeneity is the diverse use of the concept "Okun's law" in the literature, which refers to both the relationship implying the effects of unemployment on output and the effects of output on unemployment. As a consequence, the results from these different approaches are not directly comparable. After conducting meta-analysis techniques and correcting for publication bias, we found that the most significant factor explaining the heterogeneity of Okun's relationship is the differences across labor markets. The second most important factor contributing to heterogeneity is methodological issues, including various decisions made by researchers in estimating Okun's coefficient, which also influence the variability of the results. The underlying theoretical model of the relationship was found to be the least important factor in explaining heterogeneity. Okun himself proposed three different models to estimate the relationship, and although his study for the U.S. economy yielded similar results, it was not evident that this held true for all economies.

The remainder of this paper is structured into six sections. Section 2 provides a brief overview of Okun's law. Section 3 presents the different sources of heterogeneity. Section 4 details methodological approach, including a description of the criteria adopted to create the metadataset, and the metaregression techniques applied, followed by a description of the variables used in our regressions and descriptive statistics. Section 5 presents the results and section 6 concludes.

2. Okun's law

The unemployment–output relationship has been a relevant issue of the economic research agenda since Okun (1962) applied the initial estimation to the United States to examine how much output the economy could produce under conditions of full employment. Full employment is a key goal of economic policy, and from a Keynesian economic perspective, Okun considered it relevant to ascertain how far the real economy was from achieving it, to aid the formulation of appropriate fiscal and monetary policies to stimulate aggregate demand, and consequently, employment.

Okun's research presented an empirical analysis of quarterly US data for the period 1947:2–1960:4, demonstrating an inverse and statistically significant relationship between unemployment and output in the US, and concluding that for every percentage point of output growth above normal or potential growth, the unemployment rate of the US would fall by about 0.3 pp.

Knowledge regarding the validity and the magnitude of Okun's law is essential for economic policy development, as these insights uncover details on the responsiveness of unemployment to economic growth, or the cost of maintaining idle labor resources. The usefulness of this parameter is reflected by the enormous number of studies devoted to its estimation. The economic literature on this subject has grown over time, verifying its validity for other countries and time periods, applying one or several of the original models, analyzing the relationship of output to unemployment or of unemployment to output, incorporating adjustments to the original versions or attempting to explain the differences.

3. Source of heterogeneity

The existing research findings have a high degree of heterogeneity, and there is considerable variance among studies that cannot be attributed to measured sampling error alone (Higgins and Thompson, 2002). We identify three likely sources of heterogeneity in applications of Okun's law. 1) The features of each labor market that make the relationship between unemployment and output more or less sensitive, 2) the underlying theoretical model of the relationship, and 3) methodological diversity.

3.1. Features of individual labor markets

As noted previously, an increasing amount of research has found that some characteristics that differentiate labor markets explain part of the heterogeneity of Okun's law.

Some authors find employment protection legislation (EPL) to prevent the rapid adjustment of employment to changes in GDP, as it generates hiring and/or firing costs for firms, with effects on the unemployment-output relationship (Balakrishnan et al., 2010; Blanchard, 1997; Sögner and Stiassny, 2002). With high costs, firms choose not to lay off staff in recessions, resulting in so-called labor hoarding, and the unemployment rate reacting weakly to changes in GDP. Given that the EPL differs across countries, this could be expected to explain at least part of the differences between researchers' Okun coefficients. Despite this logical assumption, other authors find that the variable used to measure the degree of EPL fails to explain the estimated differences in Okun's law across countries (Ball et al., 2019; Porras-Arena and Martín-Román, 2023).

Other features of labor markets include variables that researchers have found to be explanatory factors for differences in Okun's coefficients between countries or regions. Such variables include labor productivity, productive specialization of the economy (Herwartz and Niebuhr, 2011; Villaverde and Maza, 2009), and labor market characteristics that affect the quality of employment, such as work in the informal sector, the proportion of self-employment when it functions as "refuge employment," and occupations without social security (Porras-Arena and Martín-Román, 2019, 2023).

3.2. Theoretical model of the relationship

Okun (1962) used three different models to estimate the relationship between unemployment and economic growth, finding a strong statistical relationship between the two variables. While the researcher estimated the relationship from models using unemployment as the dependent variable, he also analyzed the relationship in the opposite direction. This led to Okun's relationship being estimated, in some cases, with the unemployment rate, and in others, with the output as the dependent variable in subsequent studies. Consequently, two critical questions emerge. 1) Does the relationship go from output to unemployment or from unemployment to output, and are the results from the two models comparable? 2) Is the estimated coefficient sensitive to the model specification?

Regarding the first question, on econometric grounds, Barreto and Howland (1993) criticize the use of the inverse value of the estimated coefficient to indicate effects in the opposite direction. They argue that the coefficient has only one reading corresponding to the estimated model, and independent of the "true" causal relationship, the researcher must choose between models, depending on the variable to be predicted from the past values of both variables. Based on this convincing argument, it is evident that comparing the results of the estimates arising from these two approaches is, at least, questionable. Consequently, the main source of heterogeneity is the use of the term "Okun's law" to refer to both types of results. Because of that, heterogeneity analyses of the law must be conducted separately; one for the results of models with unemployment as dependent variable (U_model), and another for those with output as dependent variable (Y_model).

Regarding the second question, Okun estimated the relationship using three different models: model in difference, gap-model and fitted trend and elasticity model (Table 1).

As θ_0 in gap-model in Table 1 is unobservable, later research applying this specification of the law used the following equation: $u_t - u_t^* = \gamma_0 + \gamma_1(y_t - y_t^*)$, where the variable y_t represents the logarithm of real GDP, and the asterisk indicates the potential level of GDP, while u_t^* is the natural unemployment rate resulting from frictional and structural unemployment.

The first-difference model and the gap-model have been the most commonly used methods of researchers studying Okun's law. This is unquestionably related to the evolution of the field of econometrics since Okun's original work. Based on current knowledge, it is problematic to estimate OKUN_III model without proper variable cointegration analysis, or to include a trend variable in the model that could be absorbing much of the variability. However, there are also a few estimates of the law using fitted trend and elasticity models.

Belmonte and Polo (2005) demonstrated that models proposed by Okun are similar under certain assumptions; therefore, it is not surprising the Okun's estimates made yielded similar results ($\beta_1 = -0.3$; $\theta_1 = 0.36$, and δ_1 ranging from 0.35 to 0.4). Some of these assumptions are that the natural rate of unemployment, potential GDP, and potential employment are constant. Indeed, Okun's gap-model assumed that the natural rate of unemployment for the US was 4% in that period, and the parameter of interest was estimated under that assumption.

The existence of a unique and invariant natural unemployment rate has been questioned in the economic literature. In addition, the natural unemployment rate is unobservable and difficult to estimate; thus, studies estimating this version of the law use filters to decompose time series into trends and cycles. Various filters are used, including Hodrick and Prescott (HP-filter) (Hodrick and Prescott, 1997), Bandpass-BP-filters, (Baxter and King, 1999), BN-filter (Beveridge and Nelson, 1981), linear trend (LTREND), and quadratic trend (QTREND), or from modeling such as the Kalman-filter (Kalman, 1960) or Harvey's method (Harvey, 1985, 1990). The question is, are the estimation results sensitive to the model or filter used? Studies that present estimates using more than one model or more than one filter remain inconclusive, and in cases wherein differences are evident, the sign of the bias is unclear.

Table 1
Estimation models of Okun's law.

MODEL	
First-difference model (OKUN_I):	$u_t - u_{t-1} = \beta_0 + \beta_1 g_{yt}$
Gap-model (OKUN_II):	$u_t = \theta_0 + \theta_1\left(\frac{Y_t^p - Y_t}{Y_t^p}\right)$
Fitted trend and elasticity model (OKUN_III):	$ln\ E_t = \delta_0 + \delta_1\ ln\ Y_t - \delta_2 t$

Note: u is unemployment, and g_{yt} is real GDP growth in time t, Y_t and Y_t^p are the current and potential real GDP, respectively, θ_0 the natural rate of unemployment, E_t the employment rate ($E_t = 1 - u_t$), and *t* a trend variable.

3.3. Methodological issues

In addition to determining the direction of the relationship between unemployment and output and the Okun's model to estimate, researchers must decide on other methodological issues that may also be sources of heterogeneity among the results. For example, are there omitted variables in the relationship? Prachowny (1993) argued that the estimates made by Okun (1962) and later by Gordon (1984) produce higher values than the "real" outcomes due to the omission of relevant variables, estimating a model that also included other variables, such as installed capacity, labor supply, and hours worked, and obtaining a significantly lower coefficient of the relationship (in absolute value) than that of Okun and Gordon. Based on this finding, other authors have also included these or other variables in the model (Folawewo and Adeboje, 2017; Freeman, 2001; Katos et al., 2004; Liu et al., 2018), and it is to be expected that the inclusion of additional variables in the estimated relationship would reduce the absolute value of Okun's coefficient, explaining part of the observed heterogeneity.

Researchers must also choose the type of data to use, time series or panel data? The literature review reveals that most studies use time series, but there are also several studies that use panel data. Estimations with panel data always include more observations, which affects the precision of the estimated parameters. In contrast, the econometric methodology for approaching such estimations differs according to the type of data used, which can also be a source of heterogeneity. In this case, there is no a priori idea of the sign of the effect of using one type of data or another on heterogeneity.

Is the relationship linear? Some authors estimate a nonlinear relationship between the variables, showing differential effects depending on the business cycle phase, i.e., the effect of output on unemployment would differ in recessions than in expansions (Cevik et al., 2013; Palombi et al., 2015; Valadkhani, 2015, among others). Such studies have not developed theoretical arguments to support the possible asymmetric relationship; thus, there is no specific expected result. Instead, they have focused on testing the nonlinearity of the relationship by highlighting the error of not including it in estimations (Harris and Silverstone, 2001; Liquitaya and Lizarazuy, 2003; Marinkov and Geldenhuys, 2007; Pérez et al., 2003; Virén, 2001).

Is the relationship static or dynamic? Okun's original formulations assume a static relationship between unemployment and output, but several authors have argued that this is too restrictive and does not allow for the capture of possible correlations with past values (Knotek, 2007). In this sense, various studies present dynamic estimates of the law, arguing that the inclusion of variable lags also solves problems of serial correlation in the error terms (Canarella and Miller, 2017; Moosa, 1997, among others). In these cases, the effect of GDP on unemployment (or of unemployment on GDP) is not measured by only the coefficient of the current explanatory variable, but also by the total effect, which also considers the effects of lagged variables.

Does the periodicity of the data used for the estimates have an effect on the results? Does it make a difference whether annual, semi-annual, or quarterly data are used? The Okun's coefficient of a model with annual data is, in general, larger than the coefficient of the current relationship between the variables of a model with quarterly data. The time it takes for variables to adjust to shocks is one of the factors behind this phenomenon. This is also related to the above, as, in many cases, dynamic models are also estimated using quarterly data (Ball et al., 2017). In these cases, only the total effect, which considers the effects of lagged variables, will be comparable with the coefficient estimated with annual data.

Econometrics has also made considerable advances since the time of Okun's (1962) estimations, which is reflected in the heterogeneity of econometric approaches used in subsequent Okun's law estimations (ordinary least squares [OLS], generalized least squares [GLS], seemingly unrelated regressions [SUR], fully modified ordinary least squares [FMOLS], dynamic ordinary least square [DOLS], maximum likelihood [ML]).

Is the relationship stable over time? Some empirical evidence suggests that Okun's law is unstable over time, and that in many cases, the relationship is stronger in more recent periods (Balakrishnan et al., 2010; Knotek, 2007; Moosa, 1997; Perman and Tavera, 2005; Porras-Arena and Martín-Román, 2019; Sögner and Stiassny, 2002). Consequently, some of the observed heterogeneity between Okun's coefficients may be due to estimates' corresponding to different time periods.

4. Meta-analysis

Per Glass (1976), meta-analysis refers to an analysis of analyses; a statistical analysis of the results of individual studies that address the same question for the purpose of comparing the results to elicit one unified conclusion to that question. Nevertheless, as noted by Deeks et al. (2021), if there is considerable variation between the studies included, it may be misleading to quote an average value for the effect, and the conclusions will be less clear. Instead, a meta-analysis is more appropriate for exploring the factors behind the variability.

As a background to our study, Perman et al. (2015) conducted a meta-analysis of Okun's law. The aim of the research was to determine whether an evident common representative empirical coefficient of Okun's law emerged from previous work. They used 269 observed estimates of the law to measure the size of the "true" effect, applying a specific methodological meta-analysis approach. In a second stage, Perman et al. (2015) also estimated a multivariate metaregression, but with the objective of eliminating factors that might be affecting the estimate of the common effect. Our meta-analysis endeavors to explore the factors that may explain the heterogeneity, as with the work of Aiello and Bonanno (2019), Churchill and Yew (2017), Huang et al. (2022), Lichter et al. (2015), Neves et al. (2021), among others, regarding other economic problems. We present previous empirical evidence of a high degree of heterogeneity among the estimates that render the estimation of a common effect irrelevant.

We follow most of the meta-analysis guidelines proposed by Stanley et al. (2013) and Havránek et al. (2020).

4.1. Data

A critical first stage of the work is searching for, reading, and selecting the relevant literature that will be part of the meta-analysis, and constructing the database to be used in metaregression analyses after coding the information collected from the chosen articles.

To this end, the criteria used to select the data that will be included in the database must be defined in advance. In our case, we reference Perman et al. (2015), using the same criteria.

- Source: Empirical studies on Okun's law published after 1980 in journals included in EconLit database of the American Economic Association.[1]
- Article selection criteria:

a) The words "Okun's law" must be present in the title or abstract. This article selection criterion may be somewhat restrictive, and some articles analyzing the unemployment-output relationship may have been left out of our study. Nevertheless, since the literature on unemployment is extensive, we decided to concentrate our analysis on those studies that strictly estimate a coefficient of the Okun's law (in these cases, the words "Okun's law" are usually mentioned at least in the abstract). With this criterion, we found a wide variety of studies in the literature, wide enough to perform a meta-analysis.[2]

b) The selected articles must clearly specify at least one estimate of Okun's law and apply a measure of the precision of the estimate (standard deviation or t-statistic).

c) Articles should also clearly detail the methodology used for estimation.

Applying the aforementioned selection criteria, a total of 163 articles were identified, and we selected 64 studies (see Appendix 1). Articles were excluded due to several factors, including the aim of the study not referencing the law and not presenting related estimations of the coefficient of interest to our research, or, although focusing on the law, they were theoretical works, did not clearly present the results obtained in a way that was comparable with the others, did not present standard deviation or t-statistics as a measure of the precision of the estimate(s), or did not clearly present the methodology used.

Using the selected studies, we constructed a database with 1213 estimates of the Okun's law, corresponding 683 observations to estimated models of unemployment rate as the dependent variable and 530 observations of output as dependent variable.

4.2. Empirical approach

Publication selection bias is a common problem in meta-analysis. Often, both researchers and journal reviewers look for statistically significant results in a range of values in line with what might be expected according to economic theory, causing larger effects to be overrepresented by the research record. Thus, the data used in meta-analyses are not all possible data but only those that pass these filters. This is a problem when the meta-analysis aims to know the true effect size. But it is also a problem when the objective is to know the determinants of the heterogeneity observed among the estimates, since the different magnitudes of the standard deviations of the estimates may also explain part of this heterogeneity.

Publication bias has been detected in many meta-analyses. In fact, Doucouliagos and Stanley (2013) analyzed the presence of publication bias in meta-analyses on economics and indicated that it is a widespread problem. Some examples: Neves et al. (2021) find evidence of publication bias in studies on the relationship between intellectual property

[1] As Perman et al. (2015) have pointed out, econometric methods have evolved, especially since the 1980s, and therefore they consider it reasonable to select papers published from that year onwards, to make them comparable.

[2] In addition, it should be noted that, using this article selection criterion, our database includes practically all the studies used in the previous meta-analysis of Okun's law (Perman et al., 2015), which used a less restrictive criterion than ours (key words used in the search were: 'Okun's law' and 'Output–unemployment relationship'). This leads us to conclude that a negligible number of papers analyzing our object of study would have been left out of our selection, and therefore, our results would be comparable to those of that study.

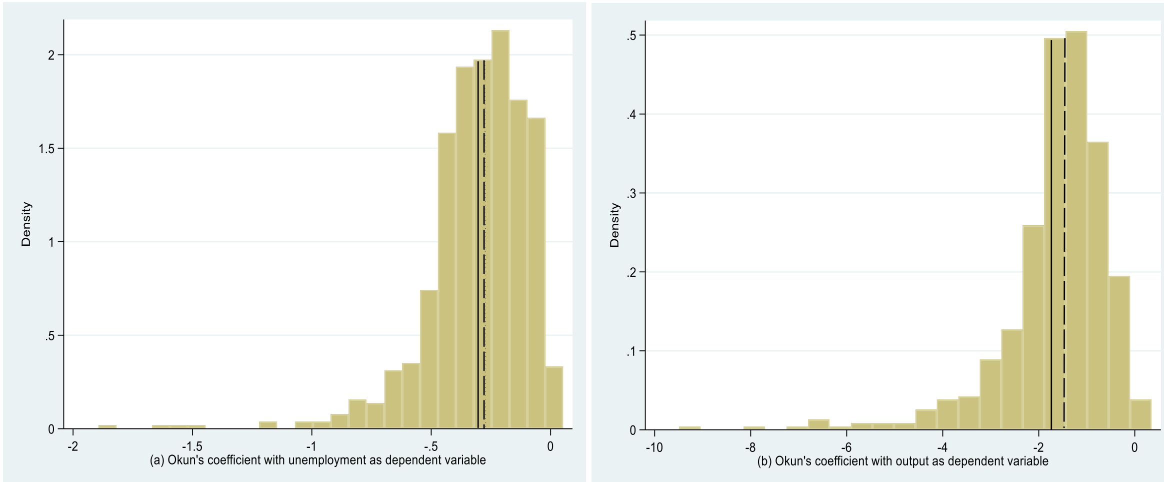

Fig. 1. Distribution of Okun's coefficient.
Notes: The figure on the left corresponds to the Okun's coefficients estimated with models using unemployment rate (U_dep) as the dependent variable and the one on the right with models using output (Y_dep) as dependent variable. The dotted line corresponds to the median of the distribution (−0.277 and −1.45 respectively) and the solid line to the mean value (−0.304 and −1.76 respectively). For illustrative purposes, estimates exceeding the absolute value of 10 were excluded from the plot on the right.

rights, innovation, and economic growth, Iamsiraroj and Ulubaşoğlu (2015) in studies analyzing the effect of foreign direct investment on economic growth, Valickova et al. (2015) in studies on the effects of financial system development on economic growth, among others, while in other cases, the presence of such bias is not found, as in Abdullah et al. (2015), which analyzes research on the effects of education on inequality.

On the other hand, as stated by (Valickova et al. (2015), publication bias can be particularly important in topics where there is little disagreement about the correct sign of the estimated parameter or the expected range of values according to the prevailing theory. This is the case with studies on Okun's law, where a negative relationship between unemployment and output is expected theoretically. However, Perman et al. (2015) do not find evidence of such bias in all cases in studies on Okun's law.

To analyze the presence of publication bias in our database, we used the most commonly used tools: funnel-plot graph and the so-called Funnel-Asymmetry Test (FAT), and Precision-Effect Testing (PET) (Abdullah et al., 2015; Churchill and Yew, 2017; Huang et al., 2022; Iamsiraroj and Ulubaşoğlu, 2015; Minasyan et al., 2019; Neves et al., 2021; Perman et al., 2015; Valickova et al., 2015, among others).

In economics, the analysis of publication bias starts with a simple meta-regression between the effect sizes observed and its standard errors (Stanley, 2005):

$$effect_{is} = \beta_0 + \beta_1 SE_{is} + \varepsilon_{is} \quad (1)$$

In our case, $effect_{is}$ is the *ith* estimate of Okun's law at the *sth* study, and SE_{is} is its standard error.[3] Observed effects should vary randomly around the 'true' effect size (β_0) in the absence of publication bias. But publication bias is proportional to the inverse of the square root of sample size and proportional to the standard error when only statistically significant results are published (Stanley, 2005). Thus, the FAT test consists in testing the significance of β_1. The problem is that Equation (1) is likely to be measured with heteroscedasticity and within-study dependence, so to solve the first problem, it is necessary to transform the model. Weighted least squares (WLS) become the method to obtain efficient estimates of Equation (1) with corrected standard errors:

$$t_{is} = \beta_1 + \beta_0 (1/SE_{is}) + \mu_{is} \quad (2)$$

t_{is} is the t-statistic of the effect size ($effect_{is}/SE_{is}$) and $1/SE_{is}$ the measure of the precision of the estimates. The within-study dependence problem is often observed in meta-analyses because multiple estimates of the study object are collected from the same primary study, and those multiple estimates can be correlated, resulting in potential biases to the standard error of the meta-regression. To address this problem with Equation (1), we apply the study-level clustered standard errors, like other meta-analysis in economics (Abdullah et al., 2015; Anderson et al., 2018; Churchill and Yew, 2017; Floridi et al., 2020; Huang et al., 2022; Lichter et al., 2015; Minasyan et al., 2019).[4]

When heterogeneity is high among the data collected, each observation may vary widely from the mean of the effects, rendering the estimated mean irrelevant. Thus, Stanley and Doucouliagos (2019) recommend that meta-analysis researchers refrain from reporting any overall summary of research findings or conduct multiple meta-regressions. In economics, the research variation responds to differences in models, methods, institutions, regions, populations, etc. Hence, the multiple metaregression, including all sensible moderator variables, can explain much of economics' high heterogeneity.

Therefore, metaregression offers an alternative to simple meta-analysis that aims to relate effect size to one or more characteristics of the studies involved (Thompson and Higgins, 2002). Metaregression is a linear regression of study effect sizes on study-level variables (moderators) to analyze whether heterogeneity between studies can be explained by one or more moderators.

[3] Some meta-analyses examine primary studies that use different measures of variables to estimate relationships. Therefore, they need to use a metric that makes the data comparable, such as the partial correlation coefficient (PCC), as the variable of analysis to explain (Anderson et al., 2018; Churchill and Yew, 2017; Huang et al., 2022; Iamsiraroj and Ulubaşoğlu, 2015; Minasyan et al., 2019; Neves et al., 2021; Valickova et al., 2015). However, in our case, it is not necessary to perform that transformation since the Okun coefficient estimates always express the change in percentage points in the unemployment rate for percentage changes in the output.

[4] Another way to address this problem could have been to estimate the model without considering this issue, and then re-estimate it by taking it into consideration and comparing the results as a way to analyze the robustness of the estimates. For example, Yang and Mallick (2014), in a second stage, re-estimate the model using the weight which is inversely proportional to the number of estimates from each paper used in their analysis and compare the results obtained with previous ones that did not take this problem into account.

To model heterogeneity, estimates were performed using unrestricted weighted least squares routines, which, according to Stanley and Doucouliagos (2017, 2015), is a better method than both random-effects and fixed-effect meta-analysis methods, and is used in many meta-analyses in economics (Abdullah et al., 2015; Anderson et al., 2018; Churchill and Yew, 2017; Floridi et al., 2020; Huang et al., 2022; Iamsiraroj and Ulubaşoğlu, 2015; Lichter et al., 2015; Minasyan et al., 2019; Neves et al., 2021; Valickova et al., 2015). However, in most meta-analyses in economics, estimates are presented using other methods as a way to check the robustness of the results. In our case, like Lichter et al. (2015) anda Minasyan et al. (2019), we test the sensitivity of our results by applying a random-effects meta-regressions method.

The equation to estimate corrected by publication bias is:

$$t_{is} = \beta_1 + \beta_0 \left(1/SE_{is}\right) + \sum_{k=1}^{K} \alpha_k \frac{Z_{isk}}{SE_{is}} + \varepsilon_{is} \tag{3}$$

using $(1/SE_{is})$ as a weighting factor, and Z_k includes K variables (moderators) that would explain the heterogeneity observed in the estimates, so Z_{isk} is the value of the variable k for the *ith* estimate at the *sth* study.

The study-level variables or moderators included in Z capture the sources of heterogeneity. For instance, the model used, type of data (time series or panel), level of data (country or region), frequency of data (quarterly or annual), and other relevant considerations, including country dummy variables capturing each labor market's differential features and time variables.

4.3. Descriptive statistics

Fig. 1 presents the distribution of Okun's coefficients in our database. The graph on the left shows the distribution of coefficients estimated with unemployment rate as the dependent variable. The simple mean is −0.30, with a standard deviation of 0.22 (Table 2). Notably, the vast majority of estimates lie within zero and −0.5 (87.6%), which is unsteady, as there are many observations that exceed the absolute value of 0.5. The right figure presents the coefficients estimated with output as the dependent variable. In this case, the data is more dispersed; the mean is −1.76, the standard deviation is 2.29, and the majority of the observation (73.4%) lies within zero and −2.

Table 2 describes all the variables used in the metaregressions, indicating the relative weight of each in the database constructed. Many countries are represented in our database, but estimates for developed countries predominate. The *fitted trend and elasticity model* (OKUN_III) is rarely used to estimate Okun's law. Most of the coefficients in both databases were estimated using the OLS method. For the rest of the variables, most of the estimates in both databases use static, symmetric, time series, bivariate, annual, and country-level models. Among those estimating the *gap-model* (OKUN_II), most use the HP-filter to decompose the series into trend and cycle components.

5. Results

In this section, we present graphs and tests of publication bias first, then empirical evidence of the high heterogeneity in the data, and finally, we detail our estimation results.

5.1. Publication bias

The most common way to check for publication bias in the data collected is to look at the dispersion of the data in the funnel plot. If there is no publication bias, the graph is expected to be funnel-shaped, i.e., low-precision estimates are widely dispersed, and the graph is expected to be symmetrical.

As can be seen in both graphs in Fig. 2, in neither case, the dispersion of the data looks like a funnel. In addition, it is also observed that, in almost all cases, the estimates take a negative value. This is an expected result, given that Okun's law indicates a negative and significant relationship between unemployment and output. However, this expected result may bias researchers and journal reviewers to publish only negative and significant results.

As a complement to the graphical visualization of publication bias, we also performed the FAT-PET test. The results are presented in Table 3. As the graphs indicated, the bias is negative in both cases ($\beta_1 < 0$) and also significant. Therefore, to correct for this bias, it is necessary to include a measure of the precision of the estimates as an explanatory variable in the metaregression.

On the other hand, as can be seen, the mean value of the estimates (β_0) is significant in all cases but suffers from large changes when correcting for heteroscedasticity.

5.2. Assessing heterogeneity

We first demonstrate evidence of high heterogeneity among Okun's estimates graphically, followed by some statistics that further confirm this extreme heterogeneity.

Fig. 3 presents the distribution of Okun's coefficient by country or group of countries. The white dots indicate the mean value of the coefficient per country, revealing that the mean values differ significantly, with wide heterogeneity of the Okun coefficients between countries. Indeed, in the U_dep database, the maximum mean value (in absolute value) is 0.81 (South Africa), and the minimum 0.006 (Belarus), and 10.15 (Japan) and 0.75 (Spain), respectively, in the Y_dep database. A high dispersion of coefficients within each country is also observed, particularly countries such as South Africa, the US, Spain, Denmark, and the Czech Republic, among others, in the U_dep database, and Japan, Austria, Switzerland, France, the US, and Greece in the Y_dep database.

The Galbraith plot (Fig. 4) is also used to detect heterogeneity among studies. On the *y*-axis are the standardized effect sizes, and on the *x*-axis, are the corresponding precision measures (inverse standard error). It offers an alternative to forest plots (the most used plot in meta-analyses) for summarizing results when there are many studies (Stata Meta-analysis Reference Manual -Release 17). Heterogeneity is assessed by observing the variation of the studies around the slope of the regression line that capture the overall effect size. For this purpose, the plot also draws a confidence interval (CI). High heterogeneity between studies will be evident if a sizable number of points occur outside the CI. We expect around 95% of the studies to lie within the shaded area (indicating 95% CI) in the absence of high heterogeneity. Studies with low precision are near the origin, and the precision of studies increases toward the right on the *x*-axis. In our case, there is a wide dispersion of points in both databases and a lot of them are outside the shaded area, indicating high heterogeneity between estimates of the Okun's law.

We also performed box plots to detect outliers (Fig. 5). As demonstrated, the values of Okun's coefficient lower than −0.8 are outliers in U_dep and lower than −4 in Y_dep. Outliers often hinder and distort analyses, and therefore, we will present the results of metaregressions with and without outliers, to visualize whether their inclusion modifies the conclusions.

A commonly used statistical test to indicate the extent of heterogeneity is Cochran's χ2 test or the Q-test (also known as a homogeneity test). The Q-test sums the weighted squared deviations of each study's estimate ($\widehat{\theta}_j$) from the estimated overall effect ($\widehat{\theta}$) (the weight $w_j = 1/\sigma_j^2$ and σ_j^2 is the variance of each study). The statistic then compares with a χ2 distribution (k−1 degrees of freedom, where k is the number of studies), obtaining a p-value.

The null hypothesis is, $H_0 : \theta_1 = \theta_2 = \ldots = \theta_K = \theta$ and the Q-test statistic is calculated as follows:

Table 2
Description of variables and descriptive statistics.

Variables	*Description of the variable*	U_dep (1)		Y_dep (2)	
		Proportion (%)			
Features of each labor market					
COUNTRY DUMMY VARIABLES	Dummy variables by country or group of countries				
Underlying model specification of the relationship					
OKUN_I	Dummy, 1 if the study uses first difference-model, 0 otherwise.	63.4		17.5	
OKUN_II	Dummy, 1 if the study uses gap-model, 0 otherwise.	36.2		80.0	
OKUN_III	Dummy, 1 if the study uses fitted trend and elasticity model, 0 otherwise.	0.4		2.5	
Methodological diversity of the estimates					
OTHER_OLS	Dummy, 1 if the study uses other than OLS, 0 otherwise.	39.1		17.2	
STAT_MOD	Dummy, 1 if the model is static, 0 otherwise.	67.7		91.1	
DYN_MOD	Dummy, 1 if the model is dynamicc, 0 otherwise.	30.0		4.0	
COINT_MOD	Dummy, 1 if the study uses cointegration model, 0 otherwise.	2.3		4.9	
SYM_MOD	Dummy, 1 if the model is symmetric, 0 otherwise.	88.0		74.3	
ASYM_MOD (3)	Dummy, 1 if the model is asymmetric, 0 otherwise.	12.0		25.7	
TIME_SERIES	Dummy, 1 if the study uses time series data, 0 otherwise.	81.7		83.0	
MORE_VAR	Dummy, 1 if the study uses more than two variables, 0 otherwise.	21.5		10.2	
YEARLY	Dummy, 1 if the study uses annual data, 0 otherwise.	53.0		97.5	
CTY_LEVEL	Dummy, 1 if the study is at country level, 0 otherwise.	67.4		48.7	
REG_LEVEL	Dummy, 1 if the study is at region level estimate, 0 otherwise.	9.4		45.5	
CTY_GR_LEVEL	Dummy, 1 if the study is at country group level, 0 otherwise.	17.2		5.8	
OTHER_LEVEL	Dummy, 1 if the study is at the population group level (e.g. age, sex), 0 otherwise.	6.0		0.0	
PERIOD<=1995	Dummy, 1 if the average year of the estimation period is less than or equal to 1995, 0 otherwise	30.8		74.3	
FILT_HP	Dummy, 1 if the gap-model uses HP filter, 0 otherwise.	75.3		40.3	
FILT_BN	Dummy, 1 if the gap-model uses Beveridge Nelson filter, 0 otherwise.	2.4		11.3	
FILT_BP	Dummy, 1 if the gap-model uses Band-Pass filter, 0 otherwise.	4.1		14.9	
FILT_LTREND	Dummy, 1 if the gap-model uses Linear Trend filter, 0 otherwise.	1.2		0.0	
FILT_Q	Dummy, 1 if the gap-model uses Quadartic Trend filter, 0 otherwise.	1.2		10.2	
FILT_OTHER	Dummy, 1 if the gap-model uses other type of filter or model, 0 otherwise.	15.8		23.3	
		Mean	***SE***	**Mean**	***SE***
OKUN	Observed Okun's coefficients	−0.30	0.22	−1.76	2.29
M_YEAR_OBS	Mean year of estimation period	1995	10.8	1987	10.7
M_YEAR_PUB	Mean year of publication	2013	8.3	2007	7.0
Number of observations		683		530	

(1) Database with Okun's coefficient estimated using unemployment as dependent variable.
(2) Database with Okun's coefficient estimated usign GDP as dependent variable.
(3) In meta-regression we distinguish between coefficient estimates for recessionary periods from estimates for expansionary periods (ASYM_MOD_REC and ASYM_MOD_EXP).

$$Q = \sum_{j=1}^{K} w_j\left(\widehat{\theta}_j - \widehat{\theta}\right)^2 = \sum_{j=1}^{K} w_j \widehat{\theta}_j^2 - \frac{\left(\sum_{j=1}^{K} w_j \widehat{\theta}_j\right)^2}{\sum_{j=1}^{K} w_j}$$

Nevertheless, this test does not provide relevant information regarding heterogeneity in all cases because it has poor power in a few studies circumstances, and excessive power to detect inconsequential heterogeneity when there are many studies (Higgins et al., 2003; Higgins and Thompson, 2002).

For this reason, Higgins and Thompson (2002) proposed two additional measures of heterogeneity, H^2 and I^2. For a random effect model the measures are:

$$H^2 = \frac{\widehat{\tau}^2 + s^2}{s^2}$$

$$I^2 = \frac{\widehat{\tau}^2}{\widehat{\tau}^2 + s^2} \times 100$$

where $s^2 = \frac{K-1}{\sum_{j=1}^{K} w_j - \sum_{j=1}^{K} w_j^2 / \sum_{j=1}^{K} w_j}$.

is the within-study variance, and $\widehat{\tau}^2$ is an estimator of the between-study variance. A value of H^2 close to unity indicates homogeneity between studies, meaning that $\widehat{\tau}^2$ is practically equal to zero and all the variance corresponds to the within-study variance. I^2 indicates the proportion of variation between the studies due to heterogeneity relative to the pure sampling variation, indicating what proportion of the observed variability would remain if each study in the meta-analysis had a large sample size and with the consequence of minimal sampling error. An I^2 percentage above 75% suggests considerable heterogeneity (Higgins et al., 2003). Among other advantages, the authors asserted that the I^2 statistic does not inherently depend on the number of studies in the meta-analysis as does the Q-test.

In Table 4, we present the statistics indicating the level of heterogeneity of the information contained in both databases (U_dep and Y_dep) for the databases with and without outliers, using the two previously introduced methods for estimating τ^2, REML, and DL. First, the results for the Q-test reject the homogeneity of the estimates of Okun's law in both databases; however, as already noted, this test may not be

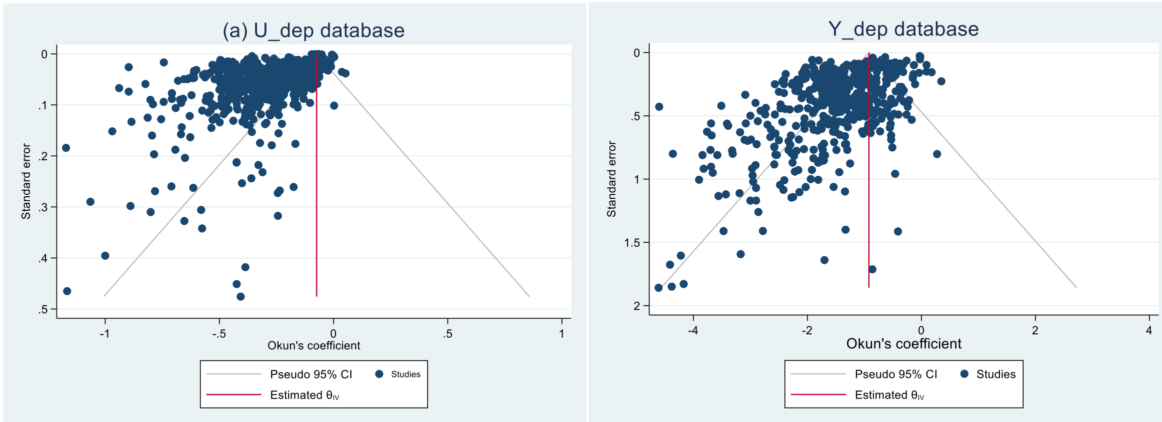

Fig. 2. Funnel plot.
Notes: The figure on the left corresponds to Okun's coefficients estimated with models using unemployment rate (U_dep) as the dependent variable and the one on the right with models using output (Y_dep) as the dependent variable. For illustrative purposes, high-precision estimates are excluded (SE < 0.5 and SE < 2, respectively).

Table 3
- Publication bias test (estimation of Eq. (2)).

	U_dep				Y_dep			
	No weights		Weights		No weights		Weights	
β_0	−0.225	***	−0.068	***	−1.303	***	−0.588	***
β_1	−1.16	***	−4.61	***	−0.791	***	−2.559	***
R^2	0.27		0.77		0.10		0.33	
Num. Obs.	683		683		560		530	
F_stat	256	***	2336	***	60	***	258	***

Notes: "No weights" corresponds to the estimation of Eq. (1) and "Weights" to Eq. (2). *p < 0.1, **p < 0.05, ***p < 0.01. If β_1 coefficient is significant there is statistical evidence of publication bias.

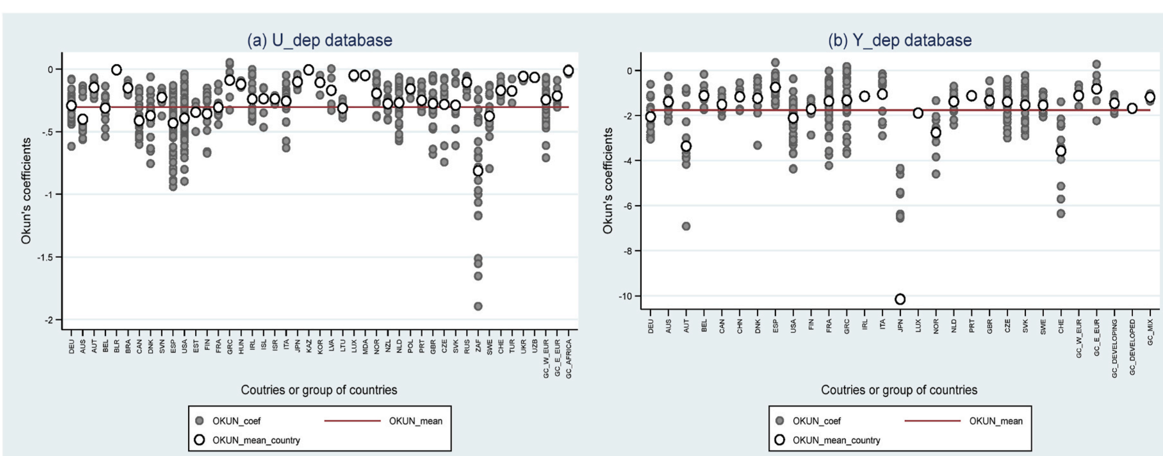

Fig. 3. Okun's coefficients by country.
Notes: The figure on the left corresponds to the Okun's coefficients estimated with models using unemployment rate (U_dep) as the dependent variable and the one on the right with models using output (Y_dep) as the dependent variable. For illustrative purposes, estimates exceeding the absolute value of 10 were excluded from the plot on the right. GC refers to group of countries.

reliable for databases with few or many studies (as in our case). Therefore, we add the results of H^2 and I^2 statistics, confirming the results of the Q tests. In both databases, H^2 is far from unity and I^2 indicates that most of the variance corresponds to between-study variability and to within-study variability to a much smaller extent.

With the graphical and statistical confirmation of the presence of high heterogeneity between the studies in both databases, it only remains to explore this heterogeneity by means of a metaregression, using explanatory variables of the study characteristics that may influence the estimated effect sizes.

5.3. Metaregression results

As shown in Table 5, several metaregressions using Equation (3) were estimated to test the significance of the variables under different criteria. All regressions include the measure of the precision of the estimates that corrects the problem of publication bias. Each database

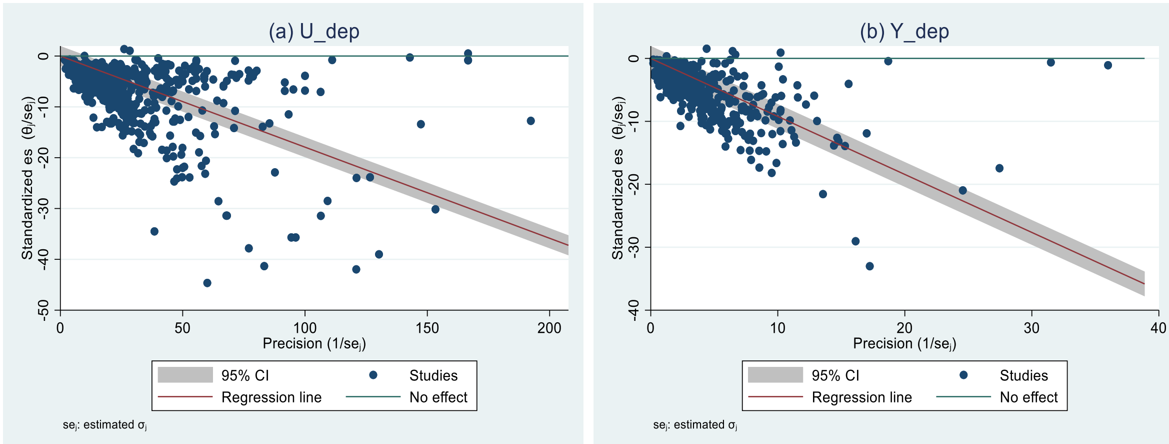

Fig. 4. Galbraith plots.
Notes: The figure on the left corresponds to the Okun's coefficients estimated with models using unemployment rate (U_dep) as the dependent variable, and the one on the right models using output (Y_dep) as the dependent variable. For illustrative purposes, estimates with $1/se_j > 200$ in the U_dep database were excluded from the plot.

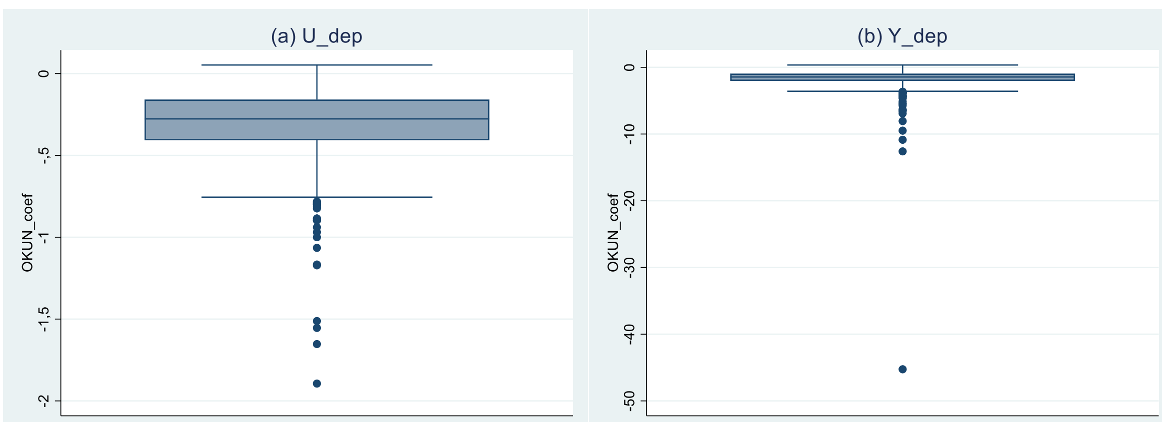

Fig. 5. Box plots.
Notes: The figure on the left corresponds to the Okun's coefficients estimated with models using unemployment rate (U_dep) as the dependent variable, and the one on the right models using output (Y_dep) as the dependent variable.

Table 4
Heterogeneity statistics.

		Estimation method of Test of homogeneity						
Database	(3)	τ^2(4)	**K-1**	**Q**	**p-value**	τ^2	H^2	I^2(%)
U_dep (1)	$\theta <$ |-0.8|	REML	664	44836.41	0.000	0.0229	743.76	99.87
		DL				0.0021	67.52	98.52
	θ without restrictions	REML	682	46553.17	0.000	0.0265	838.53	99.88
		DL				0.0021	68.26	98.54
Y_dep (2)	$\theta <$ |-4|	REML	507	6839.61	0.000	0.3542	11.66	91.43
		DL				0.4150	13.49	92.59
	θ without restrictions	REML	529	7240.29	0.000	0.4118	12.89	92.24
		DL				0.4394	13.69	92.69

(1) Database with Okun's coefficient estimated using unemployment as dependent variable.
(2) Database with Okun's coefficient estimated using GDP as dependent variable.
(3) Database without outliers and without restrictions.
(4) Estimation method of tau2: REML: restricted maximum likelihood and DL: DerSimoninan-Laird.

(U_dep and Y_dep) was estimated separately. Metaregressions were performed using unrestricted weighted least squares (Stanley and Doucouliagos, 2015, 2017) with study-level clustered standard errors. Afterwards, we tested the sensitivity of our results by applying the random-effects meta-regressions method. In addition, two estimations were performed for each database; one with all data and another without outliers (values greater than 0.8 and 4 in absolute value are considered outliers in the U_dep and Y_dep databases, respectively).

Table 5
Meta-regression of Okun's law.

Explanatory factor	VARIABLES (3)	U_dep (1)			Y_dep (2)		
		WLS (4)		Random Effect	WLS (4)		Random Effect
		(a)	(b)	(b)	(a)	(b)	(b)
Features of each labor market (Omitted variable is US country)	% of statistically significant country dummy variables (p < 0.05) (5)	90%	86%	65%	81%	73%	56%
Underlying model specification of the relationship (Omitted variable is OKUN_I)	OKUN_II	−0.106 ***	−0.104 ***	−0.102 ***	0.104 **	0.120 **	0.097
		(-4.88)	(-4.76)	(-8.77)	(2.24)	(2.3)	(1.26)
	OKUN_III	−0.405 ***	−0.075 **	−0.090	0.992 ***	1.017 ***	0.847 ***
		(-5.04)	(-2.44)	(-0.94)	(6.28)	(6.08)	(2.62)
Methodological diversity of the estimates (Omitted variables are DYN_MOD, SYM_MOD, CTY_LEVEL and the following characteristics of the studies: those that used OLS, panel data, two variables, data with quarterly or semiannual frequencies and with the average of the years of the estimation period greater than 1995).	OTHER_OLS	−0.041 *	−0.041 *	0.005	0.029	0.026	−0.044
		(-1.72)	(-1.71)	(0.37)	(0.40)	(0.34)	(-0.39)
	STAT_MOD	0.081 ***	0.079 ***	0.109 ***	−0.322 *	−0.345 *	−0.413 **
		(3.59)	(3.55)	(7.63)	(-1.85)	(-1.86)	(-2.38)
	COINT_MOD	−0.080 **	−0.073 **	−0.084 **	−0.298 **	−0.310 **	−0.369 **
		(-2.47)	(-2.14)	(-2.39)	(-2.52)	(-2.50)	(-1.99)
	ASYM_MOD_REC	−0.033	−0.034	−0.016	0.257 ***	0.267 ***	0.311 ***
		(-1.29)	(-1.35)	(-0.56)	(5.70)	(5.70)	(3.88)
	ASYM_MOD_EXP	−0.034	−0.035	0.032	−0.141	−0.134	0.014
		(-1.34)	(-1.40)	(1.26)	(-1.29)	(-1.19)	(-0.14)
	TIME_SERIES	−0.111 **	−0.106 **	−0.089 ***	0.092	0.092	−0.073
		(-3.43)	(-3.26)	(-3.82)	(1.02)	(1.00)	(0.38)
	MORE_VAR	0.011	0.012	0.006	0.042	0.043	0.090
		(0.95)	(1.00)	(0.42)	(0.56)	(0.57)	(0.72)
	YEARLY	−0.111 ***	−0.110 ***	−0.095 ***	−0.305 ***	−0.302 ***	−0.282 **
		(-5.40)	(-5.30)	(-6.56)	(-5.72)	(-5.27)	(-2.17)
	REG_LEVEL	0.268 ***	0.262 ***	0.190 ***	0.210 ***	0.209 ***	0.254 **
		(9.87)	(9.94)	(5.64)	(6.40)	(6.18)	(2.27)
	CTY_GR_LEVEL	0.087 ***	0.088 ***	0.051 ***	−0.278 *	1.178 ***	
		(3.37)	(3.45)	(2.82)	(-1.82)	(9.93)	
	OTHER_LEVEL	0.030	0.032	−0.047			
		(1.02)	(1.09)	(-1.57)			
	PERIOD<=1995	0.053 **	0.048 **	0.022	−0.737 ***	−0.743 ***	−0.504 ***
		(2.45)	(2.24)	(1.55)	(-7.17)	(-6.97)	(-3.07)
	Precision: β_0	−0.226 ***	−0.225 ***	−0.178 ***	−0.621 ***	−0.620 ***	−0.709 ***
		(-4.75)	(-4.74)	(-6.54)	(-3.31)	(-3.16)	(-2.80)
	Constant: β_1	−1.622 ***	−1.640 ***	−1.632 ***	−1.378 ***	−1.317 ***	−0.977 ***
		(-3.94)	(-3.90)	(-9.05)	(-3.54)	(-3.06)	(-7.32)
	N. obs.	683	665	665	530	508	508
	R^2	0.94	0.94	0.60	0.83	0.85	0.74

Notes: t-statistics in parentheses.*p < 0.1, **p < 0.05, p < 0.01 ***. (1) Database with Okun's coefficient estimated usign unemployment as dependent variable. (2) Database with Okun's coefficient estimated usign GDP as dependent variable. (3) For description of the variables see Table 2. (4) Weighted least squares (WLS) using the inverse of the standard error of the parameter estimate as weight and study-level clustered standard errors. (a) Estimated model with the complete database. (b) Estimated model without outliers: Okun's coefficient lower than −0.8 are outliers in U_dep and lower than −4 in Y_dep. (5) Percentage of dummy variables by country or group of countries that were statistically significant (p-value<0.05) over the total of these variables.

As noted previously, we identify three sources of heterogeneity among the estimates of Okun's law, which are confirmed by the results of metaregressions: 1) the features of each labor market that make the relationship between unemployment and output more or less sensitive, 2) the underlying theoretical model of the relationship, and 3) the methodological diversity of estimations. Our results regarding a group of variables coincide with some results obtained by Perman et al. (2015), but for other variables, we obtain contradictory results in terms of sign or level of significance, and we also included some variables that they did not include.

To capture the effects of the first source of heterogeneity, i.e., the features of each labor market, we introduced dummy variables by country or group of countries in metaregressions (Tables 5 and 6). The omitted variable was the US, and most of the country dummy variables were significant with a positive sign (with some exceptions). Indeed, in the models with the complete data base, 90% of the country dummy variables were significant (p-value≤0.05) in the U_dep base and 81% in the Y_dep base. Lichter et al. (2015) also used country dummy variables to capture cross-national differences in a metaregression analysis regarding the own-wage elasticity of labor demand, whereas Perman et al. (2015) did not include them. Instead, the authors only distinguished the degree of economic development, using the distinction between developed or developing countries. We contend that this distinction is not enough, as there are important distinctions in terms of labor market institutions or labor market features between countries at the same degree of economic development. Our results suggest that the relationship between unemployment and economic activity is weaker in most countries other than in the US. Some of the differential characteristics of country labor markets mentioned in section 2.3 may be factors that make the country dummy variables significant in the metaregressions, (e.g., EPL, the proportion of self-employment, informal employment, the sectoral distribution of employment, and other relevant considerations).

As a general comment, as can be seen in Table 5, some variables have effects with opposite signs depending on the database (U_dep or Y_dep). This is a logical result insofar as the Okun's coefficient of the unemployment-output relationship is approximately the inverse of the output-unemployment relationship, so that some of the variables that have a positive impact in one case have a negative impact in the other. Other variables were only significant in one of the two databases, which may be due to the fact that in the cases where they were not significant, there could be a problem of collinearity, which usually manifests itself in problems of significance of the variables. Finally, some variables were significant and of equal sign in both databases, also consistent results, which will be explained below.

Regarding the underlying theoretical model, the metaregressions

Table 6
Meta-regression of Okun's law gap-model (OKUN_II = 1).

Explanatory factor	VARIABLES (3)	U_dep (1)		Y_dep (2)	
		WLS (4)	Random Effect	WLS (4)	Random Effect
Features of each labor market (Omitted variable is US country)	% of statistically significant country dummy variables ($p < 0.05$) (5)	70%	82%	87%	61%
Methodological diversity of the estimates (Omitted variables are DYN_MOD, SYM_MOD, CTY_LEVEL, FILT_HP and the following characteristics of the studies: those that used OLS, panel data, two variables, data with quarterly or semiannual frequencies and with the average of the years of the estimation period greater than 1995).	OTHER_OLS	−0.049	−0.102 ***	−0.012	0.017
		(-0.97)	(-4.41)	(-0.16)	(-0.13)
	STAT_MOD	0.074 ***	0.104 **	−0.346 ***	−0.320
		(3.24)	(2.50)	(-4.88)	(-0.91)
	COINT_MOD			−0.294 *	−0.328
				(-2.16)	(-0.51)
	ASYM_MOD_REC	−0.004	−0.052	0.353 ***	0.417 ***
		(-0.14)	(-1.13)	(11.8)	(4.46)
	ASYM_MOD_EXP	0.124 ***	0.008	−0.075	−0.002
		(3.05)	(0.18)	(-1.10)	(-0.02)
	TIME_SERIES	−0.135 ***	−0.212 ***	0.017	−0.122
		(-3.38)	(-3.18)	(0.10)	(-0.29)
	MORE_VAR			0.018	−0.020
				(0.25)	(-0.13)
	YEARLY	−0.077 *	−0.121 ***	−0.402 ***	−0.376 **
		(-1.97)	(-3.04)	(-5.26)	(-2.10)
	REG_LEVEL			0.152 ***	0.182
				(3.35)	(1.29)
	CTY_GR_LEVEL	0.067	0.069 **	−0.375 **	
		(1.67)	(2.28)	(-2.73)	
	PERIOD<=1995	0.072 **	0.106 ***	−0.964 ***	−0.753 *
		(2.23)	(4.70)	(-11.57)	(-2.42)
	FILT_BN	−0.578 ***	−0.521 **	0.082	0.233 *
		(-4.76)	(-2.39)	(1.18)	(1.96)
	FILT_BP	−0.110 **	0.000	0.284 ***	0.255 ***
		(-2.15)	(0.01)	(7.84)	(2.90)
	FILT_LTREND	−0.565 ***	−0.488 ***		
		(-13.01)	(-3.24)		
	FILT_Q	0.115 ***	0.045	−0.002	−0.036
		(6.33)	(0.63)	(-0.04)	(-0.42)
	FILT_OTHER	0.020	0.022	0.251 **	0.219 **
		(0.71)	(0.80)	(2.74)	(2.20)
	Precision:β_0	−0.379 ***	−0.300 ***	−0.240 **	−0.397
		(-9.71)	(-4.60)	(-2.59)	(-0.96)
	Constant:β_1	−0.659	−0.639 *	−1.478 **	−1.514 ***
		(-1.03)	(-1.92)	(-3.06)	(-10.79)
	N. obs.	247	247	424	424
	R^2	0.91	0.70	0.86	0.77

Notes: t-statistic in parentheses. *p < 0.1, **p < 0.05, ***p < 0.01. (1) Database with Okun's coefficient estimated usign unemployment as dependent variable. (2) Database with Okun's coefficient estimated usign GDP as dependent variable. (3) For description of the variables see Table 2. (4) Weighted least squares (WLS) using the inverse of the standard error of the parameter estimate as weight and study-level clustered standard errors. (5) Percentage of dummy variables by country or group of countries that were statistically significant (p-value<0.05) over the total of these variables.

were initially performed separately between the estimations using the unemployment rate as the dependent variable (U_dep), and those using output (Y_dep) because the results are not comparable.[5] Second, as observed in the metaregression results (Table 5), the choice between OKUN_I, OKUN_II, or OKUN_III models yields significantly different results (the omitted variable was OKUN_I). This implies that not all cases estimating the Okun relationship with a *first-difference model* obtained the same result as with the *gap-model* or the *fitted-trend and elasticity* model. As noted, Okun obtained similar results with the three models for the US under the fulfillment of some assumptions, such as the natural unemployment rate of 4%; however, this assumption is not valid for any time period or location. Perman et al. (2015) obtained similar results. In their estimations, the variable LEVEL, which indicated that the variables were in levels as opposed to first differences, was found to be significant.

In addition, the estimates of Okun's law using the gap model have applied some kind of filter to decompose the series and obtain the gaps with respect to natural or trend values. As shown in Table 6, the choice of the filter to decompose the series between trend and cycle can also generate significant systematic differences between the results of the Okun's law estimates. Note that, to correctly capture the effect of the filter used in the Okun estimates, we have included the filter variables in metaregressions that only include estimates from the gap model. This is another difference with respect to Perman et al. (2015) and perhaps the reason why, for these authors, these variables were not significant. Indeed, the metaregression on the U_dep database indicates that the estimates using Beveridge and Nelson (FILT_BN) and linear trend filters (FILT_LTREND) differ from those that used the Hodrick and Prescott filter (FILT_HP) (the omitted variable). The meta-regression on the Y_dep database shows that using the Band-Pass filter (FILT_BP) or other

[5] Perman et al. (2015) estimated a metaregression with the entire database, and then separately; however, as the authors note in discussing some of the results, they retain the inverse of the estimated Okun's law for models with output as the endogenous variable to make them comparable to the Okun's law obtained when unemployment is endogenous. We contend that even keeping the inverse of the coefficient of one of the databases does not make these parameters comparable (Barreto and Howland, 1993).

methods (FILT_OTHER) can also yield different results.[6]

The third source of heterogeneity relates to the methodological diversity of the estimates. As shown in Table 5, many variables indicating methodological choices were significant in metaregressions in either or both databases. The results would be different if a static (STAT_MOD) or cointegrated (COINT_MOD) model were used instead of dynamic models, or if an asymmetric (ASYM_MOD_REC) ratio were used instead of a symmetric one, or if time series (TIME_SERIES) were used instead of panel data, or annual data (YEARLY) instead of quarterly or half-yearly, or if the estimation of the relationship is for a region within a country (REG_LEVEL) or for a group of countries (CTY_GR_LEVEL) instead of for countries, or if the estimates are for periods further back in time (PERIOD<1995).

In the case of studies using unemployment as a dependent variable, the Okun's coefficient estimated from a static model (STAT_MOD) would be lower in absolute value than that resulting from a dynamic relationship. This is because the dynamic model captures both the contemporaneous effect between variables and the total effect. Perman et al. (2015) obtained similar results in the same way, as such models will capture the total cumulated or long-run effect of the exogenous variable on the endogenous variable. In contrast, the variable STAT_MOD in the regression with Y_dep has the opposite sign but a lower level of significance. This may be related to the minimal number of dynamic estimates in this database, most of which are from a single study, which may not be representative of this problem. On the other hand, if the estimations are made from cointegrated models (COINT_MOD), the results would indicate stronger relationships. In many cases these estimates also involve dynamic relationships.

The variable ASYM_MOD_REC was significant only in Y_dep, which takes a positive sign. This implies that the estimated effects of unemployment on output during downturns and recessions will be smaller than those for the whole sample. This result is one of the contributions of this research, as Perman et al. (2015) did not differentiate between estimates with symmetric and asymmetric modeling.

Like us, Perman et al. (2015) distinguished between databases with time series or panel data used in Okun's law estimations, but they found no significant differences. In our case, the TIME_SERIES variable was significant in U_dep database, indicating that estimating Okun's law with time series variables yields systematically different results than those obtained with panel data.

In contradiction to Prachowny (1993), the results of Perman et al. (2015) indicate that including additional variables in the modeling of the Okun relationship may lead to larger estimated coefficients (in absolute values) than those including only unemployment and output. In our case, in none of our estimations was the MOR_VAR variable significant.

The periodicity of the data used for the estimates also has effects on the results. The variable YEARLY is significant in both databases, with negative sign, meaning that the Okun's coefficient of a model with annual data would be higher (in absolute value) than the one estimated with quarterly data. As noted, the time it takes for variables to adjust to shocks is one of the factors behind this phenomenon. Similar results were obtained by Perman et al. (2015).

The spatial level of the Okun's law estimation also affects the results and is confirmed as another source of heterogeneity. Indeed, while most of the estimates correspond to countries, others refer to regions within countries, groups of countries, or groups of people within countries (by gender). The omitted variable was CTY_LEVEL, and as demonstrated in Table 5, estimates of Okun's relationship for a region within a country or a set of countries would yield smaller coefficients in absolute value, meaning that the relationship is weaker in those cases. This is because there is greater diversity and heterogeneity at the regional level, and the relationship is influenced by the unique labor market characteristics. In some regions, the relationship is stronger, and in others, it is lower or even not verified (Porras-Arena and Martín-Román, 2019). These differences disappear in the aggregate when the relationship is estimated at national levels, or among groups of countries or groups of people at national level.

Finally, the effect of output on unemployment has been found to be stronger in more recent periods than in the past, but the number of estimates for developing countries with generally weak Okun's relationship has also increased recently. To detect the possible effect of the sample period on estimates of Okun's law, we used a dummy variable which takes the value one if the average year of the sample period is less than or equal to 1995 and zero if it is greater (PERIOD<1995).[7] As we can see in Table 5, this variable is significant in both databases, but positive in U_dep and negative in Y_dep. It seems that in more recent periods, the effects of output on unemployment are stronger than in the past. In the other database (Y_dep), with the inverse relationship, the effects of unemployment on output have been diminishing more recently; confirming this, the PERIOD<1995 variable is significant with a negative sign. The last result is the same as that obtained by Perman et al. (2015), who found that more recent databases lead to smaller Okun coefficients (in absolute values). On the other hand, in the database with unemployment as the dependent variable, the variable they used to indicate the estimation period (the central point of the sample period) turned out to be non-significant. Therefore, we can assert that some of the observed heterogeneity between Okun's coefficients may be due to estimates that correspond to different time periods.

5.4. *Contribution of each explanatory factor and the "true effect"*

According to the analysis carried out, we can say that one of the main factors explaining the heterogeneity of the estimates of Okun's law is the fact that, at a theoretical level, it is not clear which is the direction of the relationship between unemployment and output. Consequently, in the literature on this subject the "Okun coefficient" has been has been used to represent both the effects of economic activity on unemployment and the incidence of unemployment on economic activity. As a consequence, if unemployment is the variable to be explained in the estimation of the law, the results obtained are not comparable with those that arise from considering output as the dependent variable of the relationship (Barreto and Howland, 1993). This is the reason why we had to perform the meta-analysis separately, and were unable to quantify the effect on heterogeneity of one or the other model of Okun's relationship.

For the other source of heterogeneity, since the explanatory factors involve more than one variable in the regression model, to assess the contribution of each factor (group of variables), we first estimate the model with all the variables and then re-estimate the model by removing one explanatory factor (group of variables) at a time. After estimating the models, we compare the coefficient of determination (R^2) of the full model (which measures the proportion of variance in the dependent variable explained by the independent variables) with the R^2 of the model with one explanatory factor removed. In this way, we can observe which explanatory factor (group of variables) most significantly reduces the explained proportion of variance in the dependent variable and thus identify the relative importance of each factor in explaining the variability of Okun's coefficient.

As shown in Table 7, when the dummy variables by country or group of countries, which attempt to capture the differential characteristics of the labor markets, are excluded from the model, the coefficient of determination is reduced by 6.6 percentage points (pp) in the model with U_dep as the dependent variable and by 14.4 pp in the model with

[6] In Table 6, we show only the results without removing the outliers because by reducing the sample to only those estimated with the OKUN_II model, the estimates are very similar to those containing all the data.

[7] The year 1995 was chosen as the cut-off point because that year is the mean year of the sample periods of the base U_dep.

Y_dep. In other words, excluding these variables means that 6.6% of the variation of the dependent variable (Okun's law estimates) is no longer explained by the regression model with the U_dep database, and that percentage increases to 14.4% in the case of the Y_dep database. On the other hand, excluding the variables that indicate the specification of the estimated model (OKUN_I, OKUN_II, or OKUN_III) results in a much less significant reduction in the explained variation (0.8 pp and 0.5 pp, respectively). Finally, when removing from the model the variables that indicate some methodological aspect of the estimation (estimation method, static or dynamic, symmetric or asymmetric, with time series or panel data, with annual or quarterly data, with more than two variables, at regional, country, or other levels), the coefficient of determination is reduced by 2.1 pp in U_dep and 4.2 pp in Y_dep, meaning that 2.1% of the variation of the dependent variables is no longer explained by the regression model with the U_dep database and 4.2% with Y_dep.

With these results we can say that, leaving aside the main factor of heterogeneity of the results that makes the estimates not comparable, as mentioned above, the differential characteristics of the countries' labor markets are the main factor that explains the observed heterogeneity of the estimates of Okun's law, both when the unemployment rate or output is used as the dependent variable in the estimates. This was an expected result, since as mentioned above, the literature has detected evidence on the explanatory power of several variables that characterize labor markets on the heterogeneity of Okun's law. These variables are: employment protection legislation, labor productivity, productive specialization, as well as factors that influence the quality of jobs, such as employment in the informal sector, self-employment, occupations without social security, or unpaid occupations in family firms.

The second most important factor explaining heterogeneity is the methodological diversity of the estimates of Okun's law. Therefore, aspects related to the researcher's decisions on how to approach the estimation of Okun's relationship also contribute a certain degree of variability to the results. This was also an expected result when we began to observe the wide variety of methodological aspects involved in the estimations: data type, estimation method, data periodicity, etc.

Last in importance as an explanatory factor for heterogeneity is the underlying model specification of the relationship (OKUN_I, OKUN_II and OKUN_III) since removing these variables from the regression reduces the explanatory power of the model very slightly. That this was the factor that least explained the heterogeneity was also an expected result, given that, like Okun (1962), other authors also estimated the coefficient of the relationship with more than one specification of the model and also found no major differences in the results. However, as discussed in Section 3, the three models would yield similar results under certain assumptions (Belmonte and Polo, 2005), so it was also to be expected that the choice of the underlying model would provide some variability in the estimates.

Finally, can we speak of a "true effect" of the Okun relationship? We think not. First, because the effect depends on whether we believe that it is economic activity that influences unemployment or whether it is unemployment that influences economic activity, and as we have already mentioned, these results are not comparable. Secondly, if we analyze these two coefficients separately, does it make sense to speak of a "true effect" of economic activity on unemployment or of unemployment on economic activity? We believe that at, most, we can speak of an average value of the effect but that it does not provide much information when analyzing a particular economy.

The simple mean value of Okun's coefficient in the constructed databases was −0.31 in the U_dep database and −1.76 in Y_dep (Table 2). Once we estimated the simple meta-regression (Eq. (1)) correcting for publication bias, the summary values of the coefficients became −0.23 and −1.30, respectively. However, when correcting for the heteroscedasticity problem (Eq. (2)), the coefficients changed to −0.068 and −0.588, respectively (Table 2). Finally, when including in the meta-regressions the variables that explain heterogeneity, the corrected mean values would indicate that a 1% increase in economic activity above its potential level would reduce the unemployment rate by 0.23 percentage points (pp) on average while maintaining unemployment at 1pp above its natural level reduces economic activity by 0.62% also on average. These values are, in both cases, lower (in absolute value) than those estimated by Perman et al. (2015).

Table 7
Coefficient of determination (R^2) of meta-regression of Okun's law (1).

Model (1)		U_dep (2)		Y_dep (3)	
$t_{is} = \beta_1 + \beta_0\ (1/SE_{is}) + \sum \alpha_k\ (Z_{isk}/SE_{is}) + \varepsilon_{is}$		R^2	Change of R^2	R^2	Change of R^2
Model with all variables (4)		0.9442		0.8324	
Model without:	Dummy by country	0.8779	−0.066	0.6882	−0.144
	Model specification (5)	0.9365	−0.008	0.8276	−0.005
	Methodological issues (6)	0.9231	−0.021	0.7903	−0.042

(1) Estimation with weighted least squares (WLS) method of Equation (3), using the inverse of the standard error of the parameter estimate as weight and study-level clustered standard errors. Estimated model with the complete database. (2) Database with Okun's coefficient estimated using unemployment as dependent variable. (3) Database with Okun's coefficient estimated using GDP as dependent variable. (4) Model with all variables has the following omitted variables: US, OLS, OKUN_I, DYN_MOD, SYM_MOD, PANEL_DATA, TWO_VAR, NO_YEARLY, CTY_LEVEL and PERIOD>1995. (5) Model without the variables OKUN_II and OKUN_III (6) Model without the variables: OTHER_OLS, STAT_MOD, COINT_MOD, ASYM_MOD_REC, ASYM_MOD_EXP, TIME-SERIES, MORE_VAR, YEARLY, REG_LEVEL, CTY_CR_LEVEL, OTHER_LEVEL and PERIOD<1995.

6. Conclusions

Since the Okun's law allows a determination of the responsiveness of unemployment to output, or cost in terms of production of keeping labor resources idle, it is an extremely relevant knowledge for economic policy. The importance of this parameter is reflected by the enormous number of studies estimating Okun's coefficient.

In this article, we have shown graphical and statistical evidence of the existence of a high level of heterogeneity among the estimates of Okun's law. This observed heterogeneity is not only between countries or regions, but also within countries or regions; therefore, the usual meta-analysis procedure of estimating to find the "true common effect" is no longer logical and it is far more relevant to analyze the factors that may explain this heterogeneity.

Estimating metaregressions corrected for publication bias, we analyze the influence of three possible sources of heterogeneity: 1) labor market characteristics, 2) the theoretical specification of the underlying model of the relationship, and 3) methodological approaches.

Regarding the specification of the model, we first find that since the relationship has been estimated from output to unemployment and also in the opposite direction, the analysis of heterogeneity must be conducted separately since these parameters are not comparable (not even the inverse of one of the coefficients is comparable with the other). Second, while Okun estimated the relationship in the US, using three different models (in first differences, in gaps, and trend-adjusted and elasticity), and obtained similar results, this does not hold for all countries or regions. This implies that researchers should consider this finding when estimating the relationship, and the recommendation is to estimate the relationship with more than one specification, analyzing whether there are significant differences. Third, to estimate the model in gaps, it is necessary to apply some kind of filter on time-series prior to the estimation, and according to the results obtained in the metaregressions, the choice of filter can also be a source of heterogeneity. Again, the recommendation is to use more than one filter and compare the results.

As noted, although the literature has made progress in investigating the variables that refer to labor market characteristics that may explain the differences observed between the estimates of the Okun's law for countries or regions within the same country, some of these variables include the weight of self-employment, informal employment, sectoral distribution of employment, and EPL, among others. As a means of capturing these differences we included country dummy variables in the metaregressions, which were significant, in most cases. This confirms the existence of unobservable and idiosyncratic variables in each labor market in our database that also explain part of the observed heterogeneity.

Methodological approach also matters in explaining the differences between estimates of Okun's law, which has direct consequences for the choices the researcher must make in approaching the study of the law. We find the estimation period to be important; therefore, research estimating Okun's coefficient should include some kind of stability analysis of the law. The type of data used for the estimations, such as time-series or panel-data, or annual, quarterly, or semi-annual frequency, are also critical aspects of researcher consideration, bearing in mind that the choice of data may generate some level of bias in the estimations. The level of coverage for which the Okun's relationship is estimated has an effect on the results. Estimates at the country level generally indicate stronger relationships between unemployment and output than those at the level of regions within the same country. Consequently, if the objective is to obtain the Okun's relationship of a territory in depth, it is advisable to estimate it for the economy as a whole as well as for each region reflecting such diversity. Finally, it is also important to recognize that the dynamic or static specification of the model also has consequences on the results, as well as the specification of a symmetric or asymmetric relationship. It is therefore recommended to begin from a more general specification, such as the dynamic one, assessing the significance of variable lags as a way of capturing the "true" dynamics of the relationship, and not limiting the estimation to a static relationship, which is more restrictive. In contrast, the relationship between unemployment and output may be different in recessionary periods than when it is estimated without including this consideration; therefore, the linearity of the relationship should also be examined, not assuming a priori that it always holds.

Finally, considering the contribution of the three factors mentioned above to the heterogeneity of Okun's law, and setting aside the main factor that makes the results of the two approaches (U-dep or Y_dep) different and not comparable, we can conclude that the factor that most explains the heterogeneity in both approaches is the one that reflects the differential characteristics of the countries' labor markets. The second most important factor is that reflecting methodological differences in the estimates. Lastly, the factor that least explains the heterogeneity is the underlying model specification of the relationship, that is, the distinction between whether the model used in the estimation is the first differences model, the gap model, or the fitted trend and elasticity model.

Declaration of Competing interest

The authors declare that they have no affiliations with or involvement in any organization or entity with any financial interest , or non-financial interest in the subject matter or materials discussed in this manuscript.

Data availability

Data will be made available on request.

Acknowledgements

Both authors are grateful to the editor (Sushanta Mallick) and two anonymous reviewers for many helpful suggestions that improved the paper. They also thank the participants of the XIV *Jornadas de Economía Laboral* (Labor Economics Meeting) for their valuable comments. Finally, they are grateful for the comments of the members of the PhD Commission in Economics of the University of Valladolid. The second author was partially supported by the Government of Spain Ministry of Science and Innovation under project PID2020-112509 GB-I00.

Appendix 1

Table A.1
Selected primary studies on Okun's law

Author(s)	Impact on (1)	Estimates (2)	Okun's coefficient			Countries (3)
			Mean	Min.	Max.	
Abdel-Raouf (2014)	unemployment	6	−0.21	−0.30	−0.10	1
Apergis and Rezitis (2003)	GDP	16	−1.95	−3.69	−1.15	1 (*)
Arabaci and Arabaci (2018)	unemployment	1	−0.27			1
Attfield and Silverstone (1998)	GDP	1	−1.45	−1.45	−1.45	1
Ball et al. (2015)	unemployment	9	−0.29	−0.50	−0.08	9
Ball et al. (2017)	unemployment	90	−0.37	−0.94	−0.08	20
Basistha and Kuscevic (2017)	unemployment	2	−0.05	−0.07	−0.04	1 (*)
Binet and Facchini (2013)	GDP	44	−1.03	−1.95	−0.02	1 (*)
Brincikova and Darmo (2015)	unemployment	15	−0.30	−0.47	−0.12	group of countries
Busetta and Corso (2012)	unemployment	3	−0.42	−0.42	−0.42	1
Canarella and Miller (2017)	unemployment	10	−0.42	−0.67	−0.17	1
Cevik et al. (2013)	unemployment	32	−0.28	−0.74	0.00	8
Christl et al. (2017)	unemployment	8	−0.17	−0.24	−0.12	1
Christopoulos (2004)	GDP	13	−0.42	−1.70	0.18	1 (*)
Cuaresma (2003)	unemployment	6	−0.49	−0.71	−0.31	1
Doménech and Gómez (2006)	unemployment	1	−0.53			1
Durech et al. (2014)	GDP	66	−1.45	−3.00	−0.23	2 (*)
Economou and Psarianos (2016)	unemployment	24	−0.17	−0.32	−0.07	group of countries
Evans (1989)	unemployment	1	−0.44			1
Folawewo and Adeboje (2017)	unemployment	12	−0.01	−0.04	0.00	group of countries
Freeman (2000)	GDP	6	−1.96	−2.03	−1.82	1
Freeman (2001)	GDP	12	−1.39	−1.92	−1.00	group of countries
Gedek et al. (2017)	unemployment	10	−0.24	−0.36	−0.15	group of countries
Gil-Alana et al. (2020)	unemployment	76	−0.17	−0.69	0.05	24

(*continued on next page*)

Table A.1 (*continued*)

Author(s)	Impact on (1)	Estimates (2)	Okun's coefficient			Countries (3)
			Mean	Min.	Max.	
Guisinger et al. (2018)	GDP	51	−2.26	−4.38	−0.37	1 (*)
Harris and Silverstone (2001)	unemployment	7	−0.35	−0.50	−0.09	7
Herzog (2013)	unemployment	8	−0.27	−0.36	−0.16	1
Huang and Chang (2005)	unemployment	8	−0.45	−0.56	−0.28	1
Huang and Lin (2008)	unemployment	1	−0.39			1
Huang and Lin (2006)	unemployment	1	−0.45			1
Hutengs and Stadtmann (2014)	unemployment	30	−0.32	−0.80	−0.08	5
Ibragimov and Ibragimov (2017)	unemployment	19	−0.05	−0.09	0.00	6
Izyumov and Vahaly (2002)	GDP	8	−0.86	−2.23	0.28	group of countries
Karfakis et al. (2014)	unemployment	1	−0.33			1
Katos et al. (2004)	GDP	16	−0.97	−1.89	−0.46	16
Knoester (1986)	unemployment	36	−0.32	−0.55	−0.13	4
Kufenko and Geiger (2017)	unemployment	22	−0.25	−0.48	−0.07	22
Lee (2000)	GDP	204	−2.41	−45.26	−0.15	16
Liu et al. (2018)	GDP	21	−1.23	−1.79	−0.55	2
Lucchetta and Paradiso (2014)	unemployment	1	−0.90			1
Marinkov and Geldenhuys (2007)	unemployment	24	−0.81	−1.89	−0.17	1
McCallum (1990)	unemployment	2	−0.50	−0.56	−0.44	1
Melguizo Cháfer (2017)	unemployment	52	−0.35	−0.62	−0.13	1 (*)
Mielcová (2011)	unemployment	3	−0.22	−0.32	−0.07	3
Mitchell and Pearce (2010)	GDP	3	−1.58	−1.70	−1.35	1
Moosa (1997)	unemployment	7	−0.44	−0.62	−0.12	7
Nourzad and Almaghrbi (1996)	unemployment	2	−0.34	−0.36	−0.31	1
Novák and Darmo (2019)	unemployment	3	−0.41	−0.61	−0.22	group of countries
Palombi et al. (2015)	unemployment	8	−0.07	−0.10	−0.05	1 (*)
Palombi et al. (2017)	unemployment	1	−0.28			1 (*)
Pereira (2014)	unemployment	3	−0.45	−0.80	−0.19	1 (*)
Perman and Tavera (2005)	unemployment	17	−0.38	−0.79	−0.05	17
Perman and Tavera (2007)	unemployment	34	−0.26	−0.71	−0.02	17
Rigas et al. (2011)	GDP	6	−1.74	−2.54	−0.96	6
Silvapulle et al. (2004)	unemployment	4	−0.44	−0.61	−0.26	1
Soylu et al. (2018)	unemployment	1	−0.09			group of countries
Stockhammer and Sotiropoulos (2014)	unemployment	3	−0.27	−0.28	−0.26	group of countries
Tombolo and Hasegawa (2014)	unemployment	4	−0.15	−0.21	−0.09	1
Jalles (2019)	unemployment	60	−0.33	−0.90	0.00	20
Valadkhani (2015)	unemployment	4	−0.37	−0.44	−0.22	1
Valadkhani and Smyth (2015)	GDP	9	−1.66	−2.27	−0.93	1
Villaverde and Maza (2007)	GDP	36	−0.81	−1.55	−0.11	1 (*)
Villaverde and Maza (2009)	GDP	18	−0.56	−1.12	0.35	1 (*)
Hsing (1991)	unemployment	2	−0.41	−0.47	−0.35	1
Zanin and Marra (2012)	unemployment	9	−0.18	−0.34	−0.05	9
Total		**1213**				
U_dep database	unemployment	683	−0.30	−1.89	0.05	
Y_dep database	GDP	530	−1.76	−45.26	0.35	

(1) Unemployment: the estimated model has unemployment as dependent variable, y GDP: the estimated model has output as dependent variable.
(2) Total number of estimates.
(3) Number of countries. Asterisks correspond to studies with regional data.

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