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Manuel García-Ramos

ecos de Economía
A Latin American Journal of Applied Economics

ISSN 1657-4206 | e-ISSN 2462-8107 | Vol. 23 | No. 48 | PP. 4-15 | DOI: 10.17230/ecos.2019.48.1

Research Article

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El impacto de la brecha del producto sobre la tasa de desempleo: evidencia para México, 1987Q1-2018Q4

Manuel García-Ramos[a]

Keywords: Unemployment, Hysteresis, Output gap, Potential output, State-space model, Timevarying coefficients model, Okun's law

Palabras clave: Desempleo, Histéresis, Brecha del producto, Producto potencial, Modelo estado-espacio, Modelo de coeficientes variables , Ley de Okun

JEL Classification: C32, C52, E24, E32, O47

Received: 07/08/2018

Accepted: 08/08/2019

Published: 18/11/2019

a. Instituto de Investigaciones Económicas (UNAM), México
sauceverde@gmail.com
Orcid: 0000-0003-2397-4783
Funding: Programa de Becas Posdoctorales de la Universidad Nacional Autónoma de México.

Abstract

Using quarterly data for Mexico from 1987Q1 to 2018Q4, we measure the impact of output gap on the unemployment rate based on a State-Space model with time-varying coefficients. From an econometric modeling point of view, this model allows asymmetrical interactions between the output gap and unemployment rate. Our principal conclusions are: 1) The long-term equilibrium unemployment rate is equal to 3.06; 2) the unemployment rate does not exhibit hysteresis; 3) when GDP is lower than potential output, the impact of its growth on the unemployment rate is -0.43 percent points; and 4) when GDP is higher than potential output, the impact of its growth on the unemployment rate is close to zero. It implies that the reaction of the unemployment rate to output gap is different when the output gap is increasing from that when the output gap is decreasing; i.e., the output gap does not have the same effect on the unemployment rate over time.

Resumen

Usando datos trimestrales para México de 1988Q1 a 2018Q4, medimos el impacto de la brecha del producto sobre la tasa de desempleo con base en un modelo estado-espacio de coeficientes que varían en el tiempo. Desde el punto de vista de la modelación econométrica, este modelo permite interacciones asimétricas entre la brecha del producto y la tasa de desempleo. Nuestras principales conclusiones son: 1) la tasa de desempleo de largo plazo es igual a 3.06; 2) la

tasa de desempleo no exhibe histéresis; 3) cuando el PIB es menor que el producto potencial, el impacto de su crecimiento sobre la tasa de desempleo es de -0.43 puntos porcentuales; y 4) cuando el PIB es mayor que el producto potencial, el impacto de su crecimiento sobre la tasa de desempleo es cercano a cero. Esto implica que la reacción de la tasa de desempleo a la brecha del producto es diferente cuando la brecha del producto crece que cuando disminuye; es decir, la brecha del producto no tiene el mismo efecto sobre la tasa de desempleo a través del tiempo.

1. Introduction

The difference between the actual Gross Domestic Product (GDP) of an economy and its maximum sustainable output consistent over the medium-term with a stable inflation rate (*potential output*) is known as *output gap*. The output gap can be viewed as both a measure of economic fluctuations and as an indicator of economic efficiency. On the one hand, a positive output gap is typically accompanied by rising inflation because actual output is higher than the economy's maximum-efficiency output; on the other hand, a negative output gap is usually accompanied by falling inflation because actual output is below the economy's full capacity. In his seminal work, Arthur Okun (1962) reported a negative short-run relationship between the output gap and the unemployment rate, which became known as *Okun's law*. This empirical relationship can be written as:

$$u_t = \tilde{u}_t - \alpha u_{t-1} - \beta (y_t - \tilde{y}_t) \tag{1}$$

where u_t = unemployment rate; $\tilde{u}_t$ = long-term equilibrium unemployment rate; y_t = logarithm of actual GDP; and $\tilde{y}_t$ = logarithm of potential output.

From expression (1) we can deduce that if actual GDP is equal to the potential output, then the actual unemployment rate equals the long-term equilibrium unemployment rate; in other words, there is "full employment." Implicit in this is the notion that there is only one level of unemployment that is consistent with a zero output gap; that is to say, there is one level of *full-employment* GDP.

The goal of expression (1) is to reflect, concisely and accurately, important interactions over the long-run between output gap and unemployment rate. However, from an econometric point of view, the estimation of this model presents the following challenges: First, if the variables are not stationary, the OLS estimators are inconsistent; second, the problem of measuring potential output and the long-term equilibrium unemployment rate; finally, the coefficient β assumes that the output gap has the same effect on the unemployment rate over time; in other words, Okun's law is symmetric.

Courtney (1991) and Palley (1993) are among the initial contributors to the idea that the relationship between the output gap and the unemployment rate is asymmetrical. Courtney concluded that imposing symmetry on Okun's law leads to "serious underestimates of unemployment rate increases in contractions and overestimates of decreases in the unemployment rate during expansions." Palley claims that Okun's law has become more cyclically sensitive. Viren (2001) says that asymmetry would explain the varying effectiveness of unemployment policies. Harris and Silverstone (2001) argue that ignoring asymmetry in Okun's law when it is present leads to misspecified econometric models and faulty policy conclusions.

Based on the above, the main purpose and contribution of this paper are to measure the relationship between the output gap and unemployment rate by estimating an SS model with time-varying coefficients. From an econometric modeling point of view, this model allows asymmetric interactions between the output gap and unemployment rate. Therefore, this paper contributes to the literature on asymmetry in Okun's law using quarterly data for Mexico from 1987Q1 to 2018Q4.

This paper is organized as follows: Section 2 presents our econometric approach of Okun's law; section 3 shows the econometric findings. Finally, conclusions are in section 4.

2. Methodology

The meaning of "asymmetry" is that the reaction of the unemployment rate to output gap is different when the output gap is increasing from that when the output gap is decreasing, i.e., the output gap does not have the same effect on the unemployment rate over time. Although model (1) let us interpret all the estimated coefficients, the assumption of linearity (i.e., there is a long-run relationship between the output gap and unemployment rate) can be too restrictive. Furthermore, from an economic point of view, model (1) is subject to the *Lucas critique* (Lucas 1976) and fails to take into account the inherent nonlinearities in Okun's law.

In this study, an SS model with time-varying coefficients or TVC model is adopted to estimate the asymmetric impacts of the output gap on the unemployment rate. Econometric inference always imposes some model assumptions, linearity being among the most important. Although linear models are useful, they are often unrealistic in economic applications (Durbin and Koopman 2001); moreover, misspecification of Data Generating Mechanism by a linear model could lead to a large bias (Fan and Zhang 2008). Many studies in the current international literature tend to pay more attention to the possibility of asymmetry in Okun's law (Lancaster and Tulip 2015; Cheng et al. 2015; Silvapulle et al. 2004; Harris and Silverstone 2001; Lee 2000).

2.1. State-Space models with time-varying coefficients

Potential output and the long-term equilibrium unemployment rate play a key role in expression (1). In practice, they are not directly observed, but they can be measured (International Monetary Fund 2015; Cui et al. 2015; Arnold 2009; Rodenburg 2007; Congressional Budget Office 2004 Weiner 1993). There are many techniques to estimate them, such as a Hodrick-Prescott filter, Baxter-King Band-Pass filter, Structural Vector Autoregression approach, and Production Function approach. *State-Space* (SS) models are particularly useful for structures involving unobserved or *hidden* variables.

In an SS model, we have an equation for determining the unknown *state* of the system which is driven by a stochastic process, and an equation for determining the observed *signal* of the system. The *Kalman filter* (Kalman 1960; Kalman and Bucy 1961) is an algorithm for *prediction* and *updating* equations for determining the optimal estimates of the state equations given the information available; i.e., given the observable signal, the Kalman filter provides estimates of the state signals and measures of the precision of these estimates.

SS models represent a generalization of the classic linear models: It relaxes stationarity assumptions and provides a simple interpretation of estimated coefficients. While linear regression models use exogenous variables to distinguish the explained variation from the unexplained variation, SS models depend on the dynamics of the state variables and the linkage between the observed variables and state variables to draw statistical inference about the unobserved states.

The following SS model with time-varying coefficients is useful for exploring asymmetrical interactions between the output gap and unemployment rate. Expression (2) is the signal equation, while expression (3) is the state equation.

$$u_t = \tilde{u}_t + (\alpha_t - a)\, u_{t-1} + (\beta_t - b)\, \psi_t + \upsilon_t \qquad (2)$$

$$\begin{bmatrix} \tilde{u}_{t+1} \\ \varphi_{t+1} \\ \tilde{y}_{t+1} \\ \phi_{t+1} \\ (\alpha_{t+1}-a) \\ (\beta_{t+1}-b) \end{bmatrix} = \begin{bmatrix} 1 & 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & \theta_1 & 0 \\ 0 & 0 & 0 & 0 & 0 & \theta_2 \end{bmatrix} \begin{bmatrix} \tilde{u}_t \\ \varphi_t \\ \tilde{y}_t \\ \phi_t \\ (\alpha_t-a) \\ (\beta_t-b) \end{bmatrix} + \begin{bmatrix} 0 \\ \upsilon_t^{\varphi} \\ 0 \\ \upsilon_t^{\phi} \\ \upsilon_t^{\alpha} \\ \upsilon_t^{\beta} \end{bmatrix} \qquad (3)$$

where $\psi_t = y_t - \tilde{y}_t$, a and b are constants, $\upsilon_t \sim niid\,(0, \sigma_{\upsilon}^2)$, $\upsilon_t^{\varphi} \sim niid\,(0, \sigma_{\upsilon^{\varphi}}^2)$, $\upsilon_t^{\phi} \sim niid\,(0, \sigma_{\upsilon^{\phi}}^2)$, $\upsilon_t^{\alpha} \sim niid$ $(0, \sigma_{\upsilon^{\alpha}}^2)$ and $\upsilon_t^{\beta} \sim niid\,(0, \sigma_{\upsilon^{\beta}}^2)$. The noise processes are assumed to be uncorrelated, this implies that the covariance matrix of the disturbances is diagonal.

Expressions (2) and (3) show the asymmetrical response of the unemployment rate to the output gap. The time-varying coefficients $(\alpha_t - a)$ and $(\beta_t - b)$ captures both permanent and temporary responses of u_t to u_{t-1} (hysteresis in unemployment) and ψ_t (Okun's law) in a flexible and robust manner: When Θ_1 and Θ_2 are equal to zero, the state dynamics are given by $\alpha_t = a + \upsilon_t^{\alpha}$ and $\beta_t = b + \upsilon_t^{\beta}$, respectively; if $\sigma_{\upsilon^{\alpha}}^2$ and $\sigma_{\upsilon^{\beta}}^2$ are small relative to a and b, respectively, the system is nearly deterministic; i.e., $\alpha_t \approx b$ and $\beta_t \approx b$.

Under normality assumptions, the estimator of the state produced by the Kalman filter is the conditional expectations $E\,(\tilde{y}_t | y_1, \ldots, y_T)$ and $E\,(\tilde{u}_t | u_1, \ldots, u_T)$, also provides the conditional covariance matrixes $\text{cov}\,(\tilde{y}_t | y_1, \ldots, y_T)$ and $\text{cov}\,(\tilde{u}_t | u_1, \ldots, u_T)$. The computation of the estimators $E\,(\tilde{y}_t | y_1, \ldots, y_T)$ and $E\,(\tilde{u}_t | u_1, \ldots, u_T)$ is called *filtering*.

3. Results

This section presents the econometric findings. The time series used in this research, GDP and Harmonised Unemployment Rate are quarterly data for Mexico covering the period 1987Q1-2018Q4 (OECD, 2019a and 2019b). This paper contributes, alongside several works, to the Mexican literature on Okun's law; the list includes, inter alia, Loría, et al. (2015), Islas-Camargo and Cortez (2013), Loría, et al. (2012), De Jesús and Carbajal (2011), Islas-Camargo and Cortez (2011), Loría and De Jesús (2011), Loría and García-Ramos (2008), Rodríguez and de Jesús (2007), Liquitaya and Lizarazu (2004), and Chavarín (2001). However, model (2) allows nonlinearities in Okun's law and provides an updating of Okun's law coefficient.

On the one hand, Figure 1 plots Harmonised Unemployment Rate (u) and long-term equilibrium unemployment rate ($\tilde{u}$), and on the other hand, Figure 2 plots actual GDP (y) and potential output ($\tilde{y}$). At final state 2018Q4, u and $\tilde{u}$ are equal to 3.31 and 3.17 percent quarterly, respectively; while the quarterly percentage growth rates of y and $\tilde{y}$ are equal to 0.25 (1 percent annually) and 0.61 (2.47 percent annually), respectively. At crisis state 1995Q1, u and $\tilde{u}$ are equal to 5.03 and 4.37 percent quarterly, respectively; while the quarterly percentage growth rates of y and $\tilde{y}$ are equal to -5.74 (-21.07 percent annually) and 0.62 (2.48 percent annually), respectively. At crisis state 2009Q1, u and $\tilde{u}$ are equal to 4.96 and 4.57 percent quarterly, respectively; while the quarterly percentage growth rates of y and $\tilde{y}$ are equal to -5.09 (-18.85 percent annually) and 0.31 (1.26 percent annually), respectively. On average, u and $\tilde{u}$ are equal to 3.84 and 3.8, respectively; while the quarterly percentage growth rates of y and $\tilde{y}$ are equal to 0.661 (2.76 percent annually) and 0.659 (2.66 percent annually). These results are consistent with previous studies.

Figure 1. Mexico: Evolution of u and $\tilde{u}$, 1987Q1-2018Q4

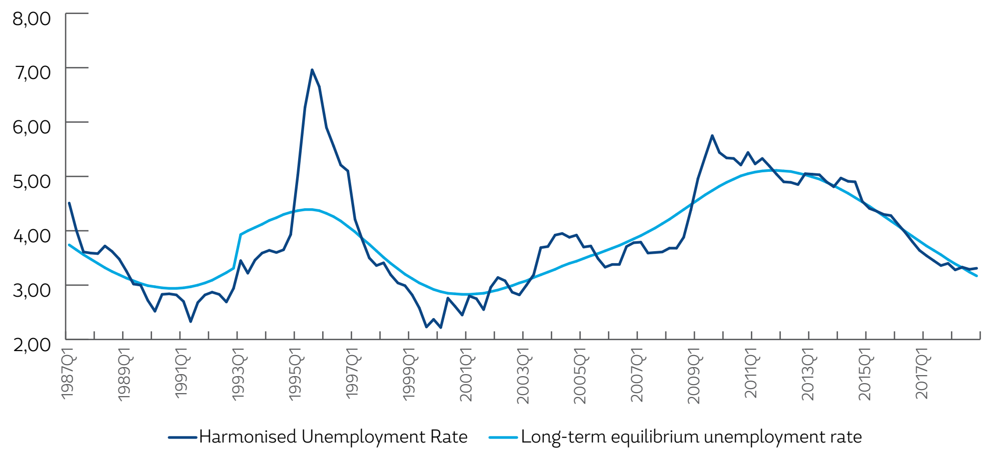


Figure 2. Mexico: Evolution of y and $\tilde{y}$, 1987Q1-2018Q4

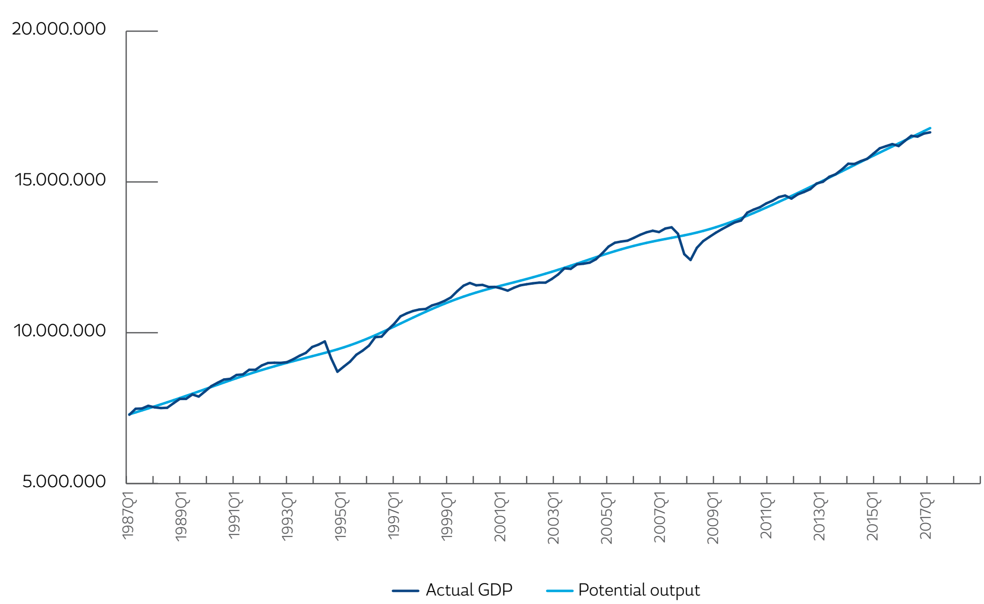


Figure 3 plots the evolution of the output gap and unemployment rate from 1987Q1 to 2018Q4. There is a pattern: A positive unemployment rate is related to a negative output gap; conversely, a negative unemployment rate is related to a positive output gap.

Figure 3. Mexico: Evolution of ψ and u , 1987Q1-2018Q4

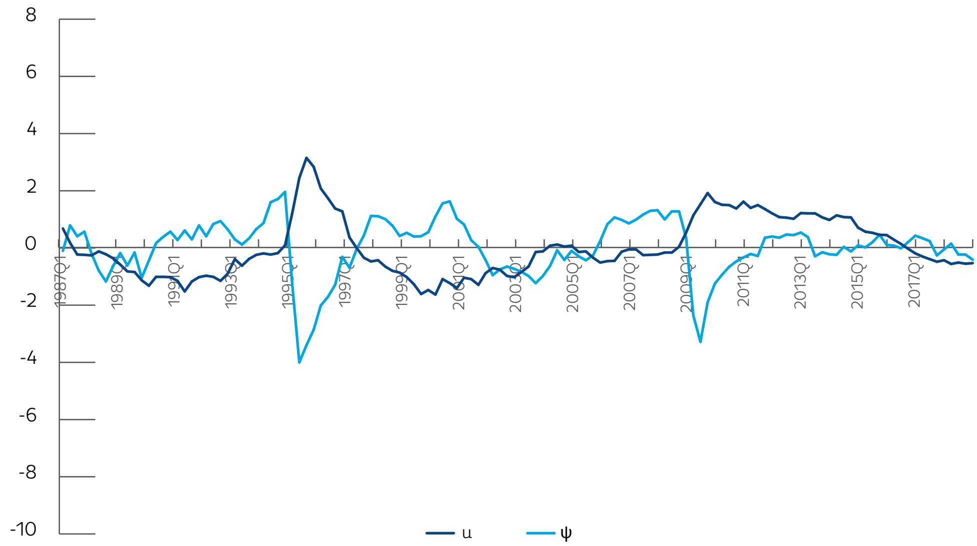


Figure 4 presents the cross-correlogram between the output gap and unemployment rate. All correlations are asymptotically consistent approximations; the dotted lines in the cross-correlogram is the approximate two standard error bounds. This figure provides a quantitative assessment of the likeness of output gap and unemployment rate at all possible statistically significant lags. Figure 4 shows the asymmetrical cyclical relationship of the variables: Positive correlation values indicate that as one variable rises so does the other, and negative correlation values indicate that as one variable rises the other decreases.

Figure 4. Cross-correlogram of ψ and u

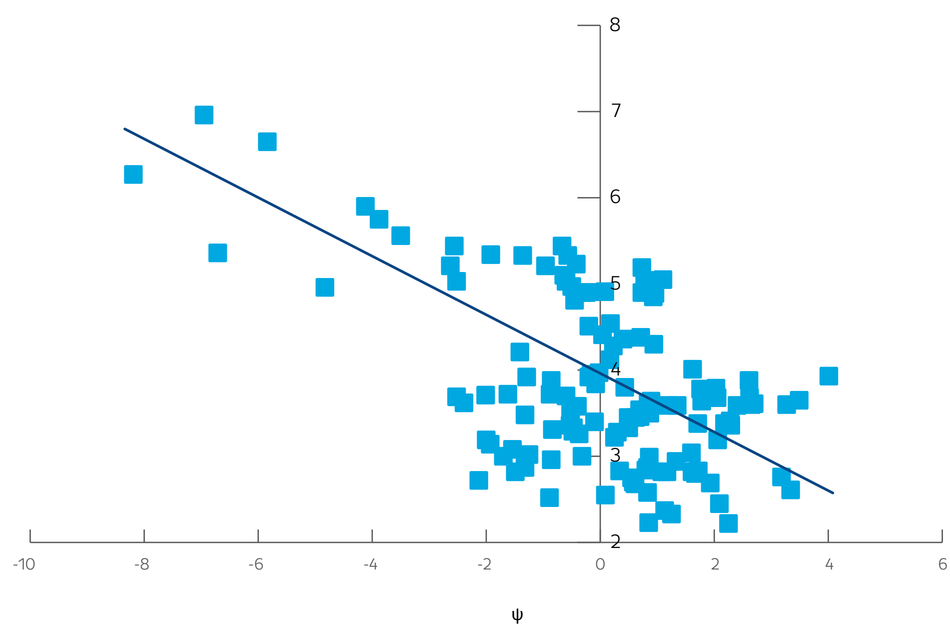
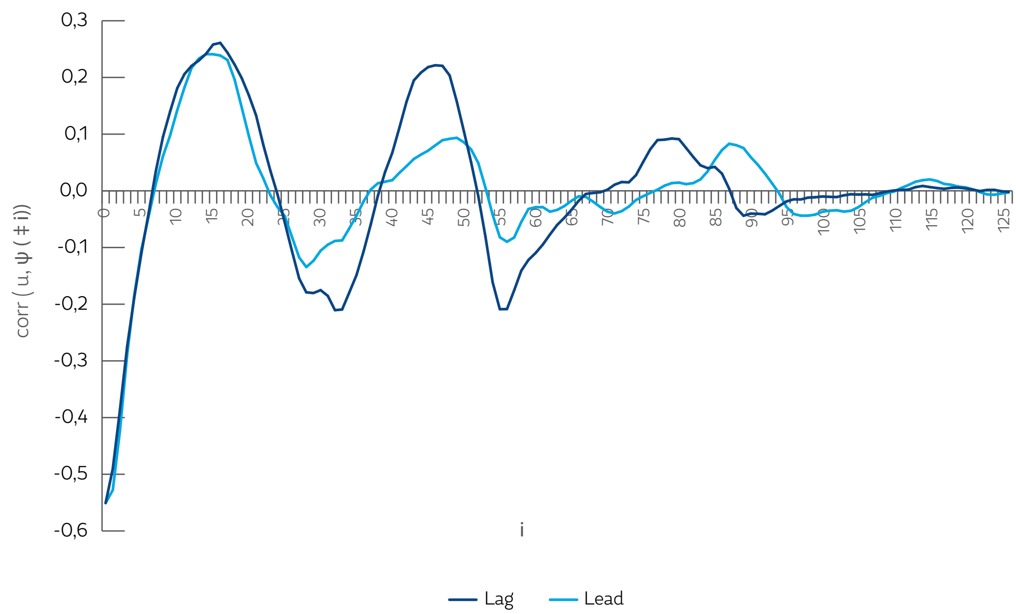


Figure 5 is the scatterplot of output gap and unemployment rate from 1987Q1 to 2018Q4. This figure displays a linear regression line (dotted line); its equation is u_t = 3.84 - 0.27 ψ_t (R^2 = 0.30), i.e., the long-term equilibrium unemployment rate is equal to 3.84 and the long-run response of unemployment rate to output gap is -0.27.

Figure 5. Scatterplot of ψ and u, 1987Q1-2018Q4



Certainly, correlation does not necessarily imply causation. Table 2 presents the pairwise Granger causality tests for the output gap and unemployment rate. We cannot reject the hypothesis that ψ_t *Granger cause* u_t. Therefore, it seems that Granger causality runs one-way from the output gap to the unemployment rate and not the other way.

Table 1. Pairwise *Granger* causality tests

	Lags				
	1-2	1-4	1-6	1-8	1-10
	F-Statistic (Probability)				
ψ_t does not Granger cause u_t	11.26 (0.00)	6.11 (0.00)	5.03 (0.00)	3.54 (0.00)	3.25 (0.00)
u_t does not Granger cause ψ_t	4.65 (0.01)	2.72 (0.04)	1.98 (0.08)	1.51 (0.16)	1.38 (0.19)

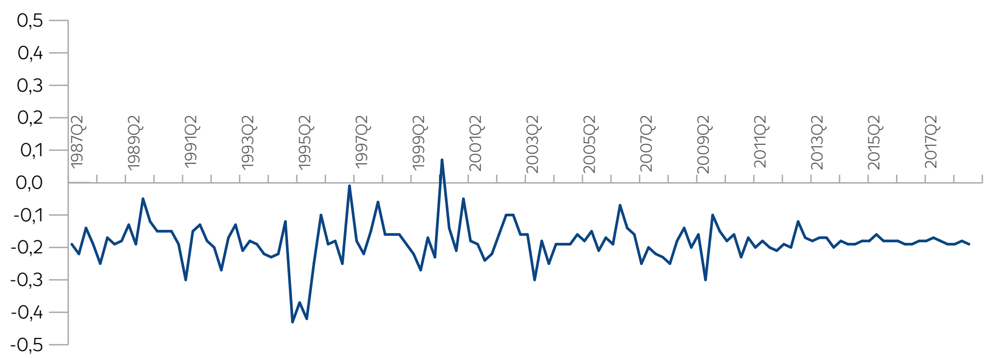
Expression (4) shows the estimated coefficients of model (2) at final state (2018Q4); root mean squared errors (RMSE) are reported. Table A1 of appendix A reports all goodness-of-fit and diagnostic statistics of this model; all its residual series are stationary (Table A2).

$$\underset{(RMSE)}{u_t} = 1.28\,\underset{(0.13)}{\tilde{u}_t} + 0.58\,\underset{(0.11)}{\tilde{u}_{t-1}} - \underset{(0.02)}{0.08\,\psi_t} \quad (4)$$

At final state (2018Q4): 1) the unemployment rate does not exhibit hysteresis; and 2) the long-run response of unemployment rate to output gap is -0.19, i.e., when actual GDP is greater than potential output, the unemployment rate falls by 0.19 percentage points. This result implies that a GDP growth of

5.24 percentage points is needed to reduce the unemployment rate by one percentage point. However, the reaction of the unemployment rate to output gap is different when the output gap is increasing from that when the output gap is decreasing; i.e., the output gap does not have the same effect on the unemployment rate over time. Figure 6 shows the impacts of the output gap on unemployment rate from 1987Q1 to 2018Q4.

Figure 6. Mexico: The impacts of ψ and u, 1987Q1-2018Q4



4. Conclusions

The main purpose of this paper was to measure the impact of output gap on the unemployment rate. Using quarterly data from 1987Q1 to 2018Q4, we estimated a TVC model. The econometric analysis suggests that: 1) The long-term equilibrium unemployment rate is equal to 3.17; 2) the unemployment rate does not exhibit hysteresis; 3) when GDP is lower than potential output, the impact of its growth on the unemployment rate is -0.43 percentage points; and 4) when GDP is higher than potential output, the impact of its growth on the unemployment rate is close to zero. It implies that, during economic recessions, a GDP growth of 2.33 percentage points is needed to reduce the unemployment rate by one percentage point; and, during economic expansions, further GDP growth may not generate additional reductions in the unemployment rate, because the unemployment rate equals the long-term equilibrium unemployment rate.

The upcoming question is: Should the Mexican government wait for the self-correction of the economy? Ros (2013) suggests that the government has policies it can use to reduce output gaps: fiscal policy (expenditures and taxation) and monetary policy (money supply and interest rates). Both fiscal and monetary policy changes aggregate demand without waiting for the economy to adjust itself. However, on the one hand, a positive output gap is typically accompanied by rising inflation, because actual output is higher than the economy's maximum-efficiency output; on the other hand, Okun's law is a useful policy tool, but only if the potential output and the long-term equilibrium unemployment are well-defined and properly measured. Despite the used method, all estimates of potential output and long-term equilibrium unemployment rate have limitations: First, such estimates are purely statistical approximations of theoretical concepts and thus contain an element of randomness; and, second, such results can be interpreted, on the one hand, as *trend* output but not as *potential* output; on the other hand, as *trend* unemployment rate but not as *long-term equilibrium* unemployment rate. These affirmations remind us that Okun's law is just a *rule of thumb*, not a "law."

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APPENDIX A

A.1. Model (4): Goodness-of-fit and diagnostic statistics

Table A1 summarizes the following goodness-of-fit and diagnostic statistics: R-squared (R^2), Adjusted R-squared (R^2_A), Standard Error of the Regression (s), Bowman-Shenton statistic (BS), Box-Ljung statistic (BJ), and Heteroskedasticity test (H); p-values in parenthesis are reported. State vector analysis at period 2018(4).

Table A1. Model (4): Goodness-of-fit and diagnostic statistics, 1987Q1-2018Q4

$$u_t = 1.28\ \tilde{u}_t + 0.58\ \tilde{u}_{t-1} - 0.08\ \psi_t$$

(*RMSE*) (0.13) (0.11) (0.02)

$R^2 = 0.96$, $R^2_A = 0.96$, $s = 0.21$, $BS(\upsilon) = 0.35$ (0.84), $BS(\upsilon^{\varphi}) = 0.56$ (0.75), $BS(\upsilon^{\phi}) = 1.24$ (0.54), $BS(\upsilon^{a}) = 2.65$ (0.22), $BS(\upsilon^{\beta}) = 2.73$ (0.25), BJ (1-8) = 8.97 (0.18), BJ (1-12)) = 14.09 (0.17), H (29) = 0.58 (0.92)

A.2. Residuals: Unit root tests

Table A2 summarizes the following unit root tests: Augmented Dickey-Fuller (A-DF), Dickey-Fuller GLS (DF-GLS), Phillips-Perron (PP), and Kwiatkowski-Phillips-Schmidt-Shin (KPSS); t-statistic and p-values in parenthesis are reported. We reject the null hypothesis of unit root at the 95% level for all the residuals.

Table A2. Residuals: Unit root tests

	υ_t^{a}			υ_t^{φ}			υ_t^{ϕ}			υ_t^{a}			υ_t^{β}		
	Trend and intercept	Intercept	None	Trend and intercept	Intercept	None	Trend and intercept	Intercept	None	Trend and intercept	Intercept	None	Trend and intercept	Intercept	None
A-DF	-10.93 (0.02)	-10.98 (0.00)	-11.03 (0.00)	-10.82 (0.02)	-10.87 (0.00)	-10.98 (0.00)	-10.94 (0.02)	-11.00 (0.00)	-11.04 (0.00)	-10.91 (0.01)	-10.97 (0.00)	-11.02 (0.00)	-10.95 (0.01)	-11.01 (0.00)	-11.03 (0.00)
DF-GLS	-9.64 (0.00)	-3.63 (0.00)	-	-9.53 (0.00)	-3.52 (0.00)	-	-9.65 (0.00)	-3.64 (0.00)	-	-9.63 (0.00)	-3.62 (0.00)	-	-9.62 (0.00)	-3.64 (0.00)	-
PP	-13.94 (0.04)	-14.07 (0.00)	14.17 (0.00)	-13.83 (0.04)	-14.00 (0.00)	14.07 (0.00)	-13.95 (0.04)	-14.08 (0.00)	14.20 (0.00)	-13.93 (0.04)	-14.06 (0.00)	14.16 (0.00)	-13.92 (0.04)	-14.08 (0.00)	14.00 (0.00)
KPSS	0.10 (0.00)	0.10 (0.00)	-	0.09 (0.00)	0.10 (0.00)	-	0.15 (0.00)	0.16 (0.00)	-	0.95 (0.00)	0.97 (0.00)	-	0.98 (0.00)	0.0 (0.00)	-