

Unobserved effects of monetary policy in the Peru's departments output and unemployment

Efectos inobservables de la política monetaria en el producto y el empleo de los departamentos del Perú

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ABSTRACT

This is the first article in a series of two. A NAIRU-Keynesian model is developed for Peru's departments (regions) to analyse whether there is a stable relationship between inflation and unemployment, and inflation and the output gap as documented in the Peruvian literature. I applied GLS for model estimation. My results document a positive relationship between future inflation rates and the gap in departmental unemployment rates concerning national unemployment rates, I evidence the Phillips curve flattening at the departmental level when estimating with the output gap, which is consistent with the national aggregate models, but there is a more elastic relationship when estimating with departmental unemployment rates. This represents unobserved effects for the monetary policy maker and requires further research.

Keywords: Phillips curve, monetary policy, decentralised effects, inflation, unemployment.

JEL Code: E37, E52, E58.

RESUMEN

Este es el primer artículo de una serie de dos. Se desarrolla un modelo NAI-RU-Keynesiano al nivel de los departamentos (regiones) del Perú para analizar si existe una relación estable entre la inflación y el desempleo, y la inflación y la brecha del producto, tal como se documenta en la literatura peruana. Se aplicó MCG para la estimación del modelo. Los resultados documentan una relación positiva entre las tasas de inflación futura y la brecha de las tasas de desempleo departamentales con respecto a las tasas de desempleo nacionales, también se evidencia el aplanamiento de la curva de Phillips al nivel departamental cuando se estima la inflación con la brecha del producto, lo cual es consistente con los modelos agregados nacionales, pero hay una relación más elástica al estimarse con las tasas de desempleo departamentales. Esto representa efectos no observados para el responsable de la política monetaria y requiere mayor investigación.

Palabras clave: Curva de Phillips, política monetaria, efectos descentralizados, inflación, desempleo.

Código JEL: E37, E52, E58.

1. Introduction

Barrera (2019), following the conceptual guidelines developed by Fitzgerald & Nicolini (2014) for the USA case; but applied to the Peruvian case; demonstrated the existence of a relatively horizontal section in the Phillips' curve that would explain a low reaction of aggregate inflation with the output gap using a semi-structural linear model for the Phillips' curves at the departmental level in Peru, to identify the parameter associated with the output gap in the aggregate curve. He also extends his findings to a nonlinear model which makes it easier for inflation and the output gap to change continuously and finds evidence that the departmental Phillips' curve contains a relative horizontal span.

While Barrera (2019) conceptually develops his linear model according to Fitzgerald & Nicolini's (2014) methodology, his econometric strategy does not match the one proposed by these authors. Fitzgerald & Nicolini (2014) document the stability of the Phillips' curve for the USA case: First, the endogeneity of monetary policy implies that aggregated data are largely uninformative about the existence of a stable relationship between unemployment and future inflation. Second, using a non-accelerating unemployment inflation rate model or NAIRU, they identify a structural relationship between unemployment and future inflation.

Contrasting both investigations, the question arises: if we assumed a NAIRU model for the Peruvian case, is it possible to document a stable relationship between inflation and unemployment in Peru's departments? After the empirical evaluation of different Phillips' curves, counterproductive results are found in the sense that there would be a positive relationship between unemployment rates gaps and future inflation rates in the departments of Peru, at the same time I document a more elastic relationship between inflation and unemployment in comparison to the relationship between inflation and output gap. These conditions are not observed by the monetary policy maker, to the extent that its decisions are made considering a benchmark with the inflation and unemployment rates of Metropolitan Lima, as the main market and based on the relationship between inflation and output gap at national levels.

The document, apart from the introduction, is organized into four sections: In section 2 there is a description of the stylized facts for

inflation, unemployment, real interest rates and output gap at the departmental level of Peru, assuming the structural relations documented by Aquino (2019) and Barrera (2019). Section 3 describes the NAIRU-model development by Fitzgerald & Nicolini (2014). Section 4 describes the data sources, and the econometrics estimation strategy for the Peruvian case and presents the results of the estimates for the Phillips' curves using four linear models at the departmental level. Finally, section 5 proposes a discussion of future research opportunities that arise from this investigation findings to identify the monetary authority's not-observed impacts on unemployment rates and output gaps in Peru's departments.

2. Stylized facts on inflation, unemployment, real interest rates, and the output gap in Peru's departments

One of the most discussed aspects in the economic literature is the monetary policy effects on inflation and economic activity, which is represented by the Phillips' curve and its different specifications over time (Phillips, 1958; Lucas, 1972; Clarida, Galí and Gertler, 1999; Reifschneider, Tetlow and Williams, 1999; Atkeson and Ohanian, 2001; Aquino, 2019; Gao, Kulish & Nicolini, 2021)

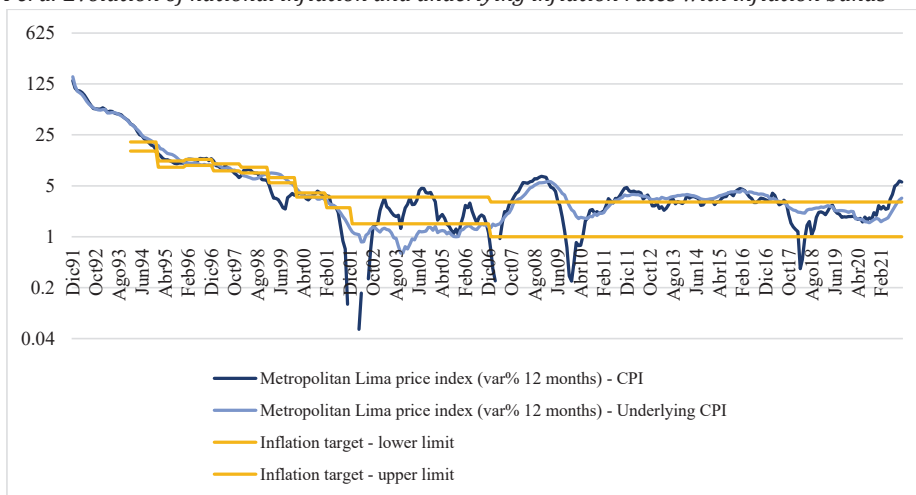
As a background, we must mention the explicit inflation targeting scheme, EIT, adopted by Peru in January 2002. However, referring to Armas *et al.* (2001), the Central Reserve Bank of Peru (Banco Central de Reserva del Perú, BCRP), before adopting the EIT scheme had used the announced quantitative inflation targets scheme, AQIT, since 1994 as part of commitments made with the International Monetary Fund, IMF. I summarize this information in Table 1.

The BCRP established both schemes, the AQIT and the EIT, which has contributed to the control of the hyperinflation that was generated as a result of the first APRA party government in the second five-year period of the '80s, highlighted in Figure 1 with a clear tendency to its reduction for the indicators of inflation and underlying inflation from December 1991 to December 2001 (Vega, 2018). Thereafter, the behaviour of inflation is stationary and oscillates within the target range, fulfilling the target for 64,9 % of the periods. The inflation target was not met from

December 2007 to October 2009, followed by short periods of instability in the years 2011, 2014, 2016 and the second part of 2021.

Figure 1

Peru: Evolution of national inflation and underlying inflation rates with inflation bands



Notes: Evolution of the indicators of Peru's general inflation and underlying inflation rates. The ordinate axis is in a logarithmic scale of base five.

Source: Central Reserve Bank of Peru (2021a)

In line with the latest Peruvian available inflation report, year-on-year inflation rose from 4,95 % in August 2021 to 5,66 % in November 2021; driven by the higher price of imported food and oil, as well as by the depreciation of the Peruvian Sol. Inflation without food and energy rose from 2,39 % to 2,91 % in the same period, remaining within the target range. The different trend indicators of inflation are above the target range and show an upward trend. On the other hand, a global phenomenon explains the recent upward trend in inflation, such as supply problems, and the rapid recovery of the world economy. Among these factors is the significant rise in international *commodity* prices, particularly oil and food such as wheat, maize, and soybean oil. To the increase in quotations and the higher cost of maritime freight, chemical fertilizers, and other inputs, as well as the local increase in the exchange rate (Central Reserve Bank of Peru, 2021b)

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In the case of Peru, according to Aquino (2019), there is a relationship between annualized underlying inflation and the cyclical component of gross domestic product, also known as the output gap from 1999 to the fourth quarter of 2018. This relationship also reflects the explicit EIT scheme adopted from 2002 onwards. There is an apparent deterioration of this relationship since 2014, which raises concern about the effectiveness of the monetary policy.

Table 1
Inflation targeting scheme adopted by Peru, in percentages

Year	Kind of Target	Inflation Target	Realized Inflation Rate	Underlying Inflation Rate
1994	AQIT	15,0 - 20,0	15,4	18,8
1995	AQIT	9,0 - 11,0	10,2	11,1
1996	AQIT	9,5 - 11,5	11,5	10,6
1997	AQIT	8,0 - 10,0	6,5	7,4
1998	AQIT	7,5 - 9,0	6,0	7,8
1999	AQIT	5,5 - 6,5	3,7	4,6
2000	AQIT	3,5 - 4,0	3,7	3,2
2001	AQIT	2,5 - 3,5	-0,1	1,3
2002	EIT	1,5 - 3,5	1,5	1,2
2003	EIT	1,5 - 3,5	2,5	0,7
2004	EIT	1,5 - 3,5	3,5	1,2
2005	EIT	1,5 - 3,5	1,5	1,2
2006	EIT	1,5 - 3,5	1,1	1,4
2007	EIT	1,0 - 3,0	3,9	3,1
2008	EIT	1,0 - 3,0	6,7	5,6
2009	EIT	1,0 - 3,0	0,2	2,3
2010	EIT	1,0 - 3,0	2,1	2,1
2011	EIT	1,0 - 3,0	4,3	3,6
2012	EIT	1,0 - 3,0	2,6	3,3
2013	EIT	1,0 - 3,0	2,9	3,7
2014	EIT	1,0 - 3,0	3,2	3,3
2015	EIT	1,0 - 3,0	4,4	4,1
2016	EIT	1,0 - 3,0	3,2	3,7
2017	EIT	1,0 - 3,0	1,4	2,3
2018	EIT	1,0 - 3,0	2,2	2,6
2019	EIT	1,0 - 3,0	1,9	2,2
2020	EIT	1,0 - 3,0	2,0	1,8
2021	EIT	1,0 - 3,0	5,7	3,4

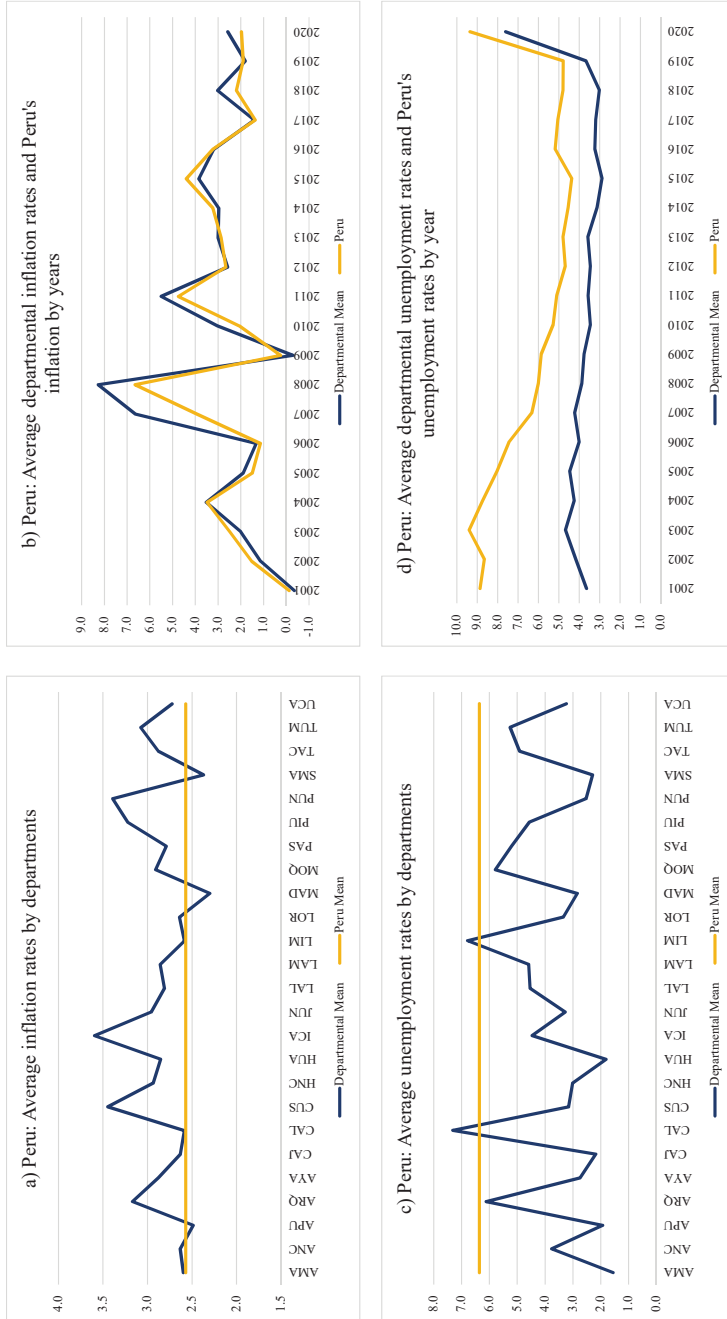
Notes:

+ AQIT: Announced quantitative inflation target.

+ EIT: Explicit inflation target.

Sources: Armas et al. (2001), Central Reserve Bank of Peru (2021b)

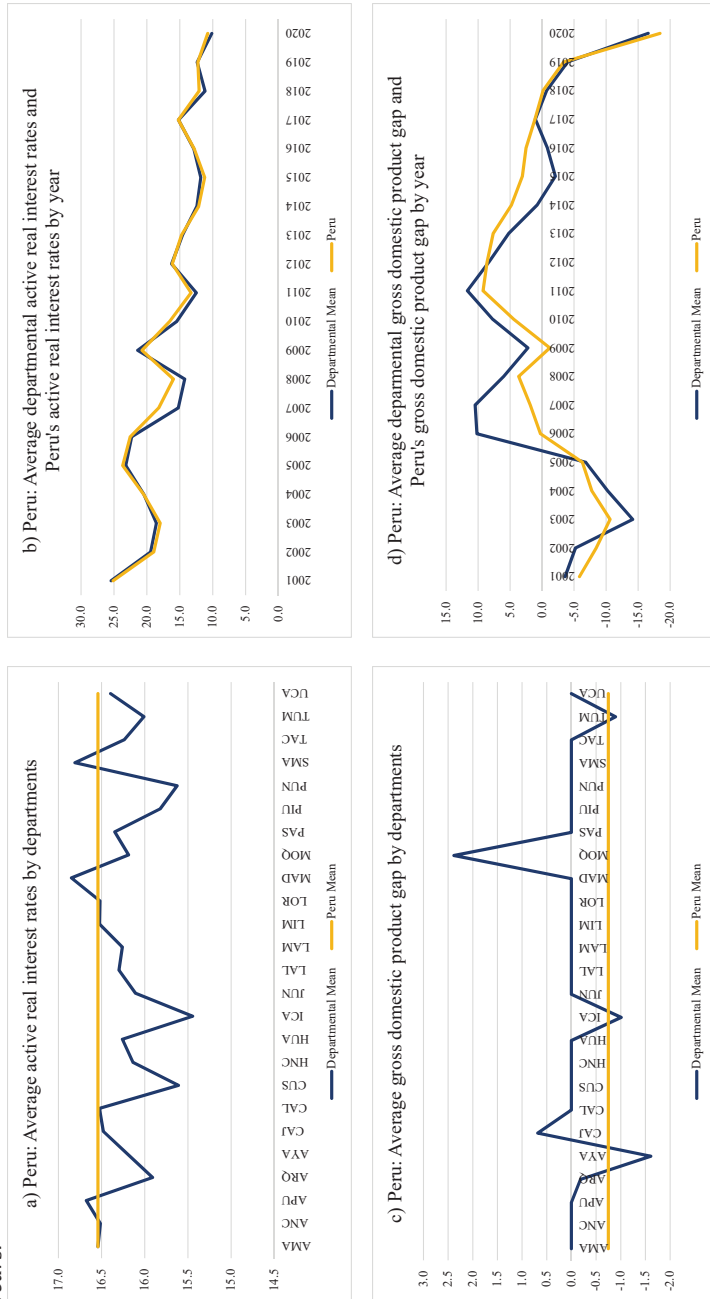
Figure 2
 Evolution of departmental averages and national means of inflation and unemployment rates by department and years.



Notes: Panel a) shows the average inflation rates by the department for the period 2001 – 2020 compared to the average inflation rate of the country for the same period. Panel b) highlights the evolution of departmental average inflation rates compared to the evolution of the country's inflation rate. Panel c) summarizes the average unemployment rates by the department for the period 2001 – 2020 compared to the country's average unemployment rate for the same period. Panel d) summarizes the evolution of departmental unemployment rates compared to the evolution of the national unemployment rate.
 Source: National Institute of Statistics and Informatics (2021d), Central Reserve Bank of Peru (2021a)

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Figure 3
Evolution of departmental averages and national means real-active rates and gross domestic product gap by department and years.



Notes: Panel a) summarizes the departmental active real interest rate for the period 2001 – 2020 compared to the national active real interest rate. Panel c) shows the evolution of the departmental active real interest rate and the evolution of the national active real interest rate. Panel c) shows the average GDP gaps by departments for the period 2001 – 2020 and Peru's average GDP gap for the same period. Panel d) highlights the evolution of the departmental GDP gap average about the evolution of the national GDP gap.

Source: National Institute of Statistics and Informatics (2021d), Central Reserve Bank of Peru (2021a)

Based on the information detailed in Figures 2 and 3 on inflation, unemployment, active interest rates and gross domestic product gap for Peru's departments, we can highlight the following:

- From an average perspective, it is evident that departmental inflation rates exceed the national average of 2,57 % for the period 2001 – 2020. In most cases, the departmental averages are within the inflation target range, apart from the cases of Arequipa (3,17 %), Cusco (3,45 %), Ica (3,60 %), Piura (3,22 %), Puno (3,39 %) and Tumbes (3,07 %)
- From a perspective of annual averages, it is evident the alignment of Peru departments' inflation rates with the national inflation rates, replicating their same behaviour. The reader should notice that, on nine occasions, the departmental averages exceeded the inflation rate made for the country, but only on five of those nine occasions, the departmental average exceeds the inflation target range: 2007 (6,64 %), 2008 (8,27 %), 2010 (3,03 %), 2011 (5,05 %) and 2018 (3,02 %).
- It is important to notice that the relationship of the departmental unemployment average rates with the national unemployment average rate for the period 2001 – 2005 is opposite to those described for the inflation case: The departmental averages are well below the national average (6,36 %) by more than one and a half percentage point, apart from the cases of Arequipa (6,12 %), Callao (7,32 %), Lima (6,79 %) and Moquegua (5,79 %) which are more aligned to the national averages.
- On the other hand, when comparing departmental averages per year, the gap between the national unemployment rate and departmental average unemployment rates is better evidence. This gap has been narrowing over time from more than five percentage points in 2001 to about 1,2 percentage points in 2013. Since then, the gap between national unemployment and departmental unemployment has hovered around 1,62 percentage points.
- When comparing the departmental average active real interest rates with the national active average real interest rates we found that Peru's departments performed below the national average, but in a

range that does not exceed one percentage point of difference. The geographical areas whose averages are close to the national average for the period 2001 – 2020 (16,54 %) are Amazonas, Ancash, Cajamarca, Lima, and Loreto.

- The behaviour of the departmental average active real interest rates for the analysis period is like the national active interest rate, which reflects the effect of the BCRP's monetary policy through its communication mechanism. The differences become perceptible in the period 2007 – 2008 of the international financial crises, where the departmental active interest rates were higher.
- In the case of the gross domestic product gap, the departmental averages are higher than the national average gap for the period 2001 – 2020 (– 0,75 %). Panel d) of Figure 3 highlights the cases of Ayacucho (– 1,61 %), Ica (– 1,01 %) and Tumbes (–0,82 %), whose averages are lower than the national average. Also noteworthy are the cases of Amazonas, Ancash, Apurímac, Callao, Cusco, Huancavelica, Huánuco, Junín, La Libertad, Lambayeque, Lima, Loreto, Madre de Dios, Pasco, Piura, Puno, San Martín, Tacna and Ucayali, whose departmental averages are close to zero, that is, the production carried out in these departments would be equivalent to their potential production for the indicated period. It contrasts the cases of Cajamarca (0,68 %) and Moquegua (2,38 %) which would have average production levels higher than the potential product.
- The performance of departmental average output gaps follows the same trend as the national output gap, where the years 2001, 2002, 2006 to 2011 and 2020 stand out where departmental averages outweigh the national output gap.

The descriptive analysis that has been presented in the previous pages distinguishes different behaviours between unemployment rates and the output gap, which implies an important difference between estimating the departmental Phillips' curves with Fitzgerald & Nicolini's (2014) strategy using unemployment rates, or with Barrera's (2019) strategy using output gap. To this end, I produced a preliminary correlation analysis between future inflation, unemployment rates, output gap, and real

interest rates at departmental levels. In the case of unemployment, there is a low and significant correlation ($r = ,1554$; $p < ,001$; $N = 500$), the same for real interest rates ($r = - 0,1228$; $p < ,001$; $N = 500$); but not so for the case of the output gap ($r = ,0278$; $p > ,1$; $N = 500$)

As a corollary, the stylized facts that highlight the relationships between inflation, unemployment rates, real interest rates and output gap allow us to infer that the estimation of the departmental Phillips' curves with the Fitzgerald & Nicolini (2014) would be an appropriate mechanism to identify the relationship between inflation and productive activity for Peru's departments to identify non-observable effects of monetary policy.

3. Linear models of non-accelerated inflation rates of unemployment for peru's departments

With regards to the Phillips curve, it is important to make a special note about Fisher (1973), who documented for the first time a strong statistical correlation between the change in the volume of employment and the change in price levels for the US in 1926. Phillips (1958) subsequently highlighted a negative statistical correlation between unemployment and the exchange rate in nominal wages in the UK. For their part, Samuelson & Solow (1960) argued that a sloppy monetary policy that allows inflation to rise can reduce unemployment for several quarters. Lucas (1972) critically emphasised the non-structural relationship between unemployment and inflation, which is strengthened or weakened depending on the parameters that govern monetary policy; concluding that there is no trade-off between inflation and unemployment. After many years, Atkeson & Ohanian (2001), using a NAIRU model, demonstrated a negative relationship between unemployment and the growth of future inflation, controlling for changes in monetary policy, changes in the parameters of the Phillips' curve and external shocks that affect this curve.

With this background, Fitzgerald & Nicolini (2014), for the case of the USA, and Barrera (2019), for the Peruvian case, estimated regional Phillips' curves. The first one assumes NAIRU models and the second one assumes neo-Keynesian models. In this section, based on the findings in the stylized facts described in section 2, I estimate different linear models

of inflation rates for Peru's departments. To do this, we start with the following assumptions:

- An economy with a single good and input (work).
- The economy has N quite-similar geographical areas, with common characteristics:
 - ◊ Existence of price friction within each area.
 - ◊ The same currency.
 - ◊ The same legal system.
 - ◊ The same financial system.
 - ◊ There is no labour input mobility for all economies, that is, there is no migration.
- All geographical areas are subjected to the same monetary policy actions of the single monetary authority, reflected in changes in the real interest rate $r_{i,t}$ explained by changes in reference interest rates d_t .
- It follows that all geographical areas share the same parameters in the following structural equations that correspond to the solution of a NAIRU-Keynesian model without micro foundations (Sims, 1980; 1992; Clarida, Galí & Gertler, 1999; Atkeson & Ohanian, 2001) for the geographical scope j in terms of their inflation $\pi_{j,t}$, the unemployment rates $u_{j,t}$; and the real interest rate $r_{j,t}$:

$$(1) \quad \begin{aligned} \pi_{j,t+1} &= a^1 + b^1 \pi_{j,t} + c^1 u_{j,t} + d^1 d_t + \epsilon_{j,t+1}^\pi + \xi_{t+1}^\pi \\ u_{j,t+1} &= a^2 + b^2 \pi_{j,t} + c^2 u_{j,t} + d^2 d_t + \epsilon_{j,t+1}^u + \xi_{t+1}^u \\ r_{j,t+1} &= a^3 + b^3 \pi_{j,t} + c^3 u_{j,t} + d^3 d_t + \epsilon_{j,t+1}^r + \xi_{t+1}^r \end{aligned}$$

From the equations system (1) $\epsilon_{j,t+1}^m, m \in \{\pi, u, r\}$ represent, respectively, idiosyncratic shocks in the inflation expectations, unemployment, and real interest rate corresponding to each department. In turn, $\xi_{t+1}^m, m \in \{\pi, u, r\}$ represent, respectively, stochastic shocks that affect inflation expectations, unemployment, and real interest rates. The properties of the shocks to be white noises are the following:

- $\epsilon_{j,t+1}^m$ and $\xi_{j,t+1}^m$ are independent and identically distributed for $m \in \{\pi, u, r\}, \forall t$.
- $E_{t+1}[\epsilon_{j,t+1}^m] = E_{t+1}[\xi_{j,t+1}^m] = 0, m \in \{\pi, u, r\}$, i.e., they have zero conditional means.

It is also important to note that the parameter of interest in the Phillips' curve is $c^1 < 0$ (Atkeson & Ohanian, 2001; Fitzgerald & Nicolini, 2014). In turn, the monetary authority modifies its policy instrument d_t before observing the shocks of the following period $t + 1$, with immediate proportional effects on the three endogenous variables $\{d^1, d^2, d^3\}$ in each geographical area. In addition, I defined the following country-level aggregates (Fitzgerald & Nicolini, 2014; Barrera, 2019):

$$(2) \quad \begin{aligned} \pi_{t+1} &= \sum_{j=1}^N \pi_{j,t+1} \\ u_{t+1} &= \sum_{j=1}^N u_{j,t+1} \\ r_{t+1} &= \sum_{j=1}^N r_{j,t+1} \end{aligned}$$

Taking into consideration the levels of aggregation given by equation system (2), the solution for system (1) for each geographical area j implies the solution for the whole economy given the following aggregate equilibrium (Sims, 1992):

$$(3) \quad \begin{aligned} \pi_{t+1} &= a^1 + b^1 \pi_t + c^1 u_t + d^1 d_t + \xi_{t+1}^\pi \\ u_{t+1} &= a^2 + b^2 \pi_t + c^2 u_t + d^2 d_t + \xi_{t+1}^u \\ r_{t+1} &= a^3 + b^3 \pi_t + c^3 u_t + d^3 d_t + \xi_{t+1}^r \end{aligned}$$

The monetary authority can follow an **extremely suboptimal rule** (Barrera, 2019) of a constant interest rate $d_{t+k} = \tilde{d} > 0, \forall k > 0$. With this rule the levels of the aggregate equilibrium for π_{t+1}, u_{t+1} and r_{t+1} are:

$$(4) \quad \begin{aligned} \pi_{t+1} &= a^1 + b^1\pi_t + c^1u_t + d^1\tilde{d} + \xi_{t+1}^\pi \\ u_{t+1} &= a^2 + b^2\pi_t + c^2u_t + d^2\tilde{d} + \xi_{t+1}^u \\ r_{t+1} &= a^3 + b^3\pi_t + c^3u_t + d^3\tilde{d} + \xi_{t+1}^r \end{aligned}$$

With this suboptimal rule, according to Fitzgerald & Nicolini (2014), and Barreda (2019), **there would be a linear relationship between current unemployment and future inflation** that allows the parameter c^1 to be identified using the aggregated data. We can rewrite equation system (4) in terms of the aggregate equilibrium change for both variables and their first differences, in terms of feasibility:

$$(5) \quad \begin{aligned} \pi_{t+1} - \pi_t &= b^1(\pi_t - \pi_{t-1}) + c^1(u_t - u_{t-1}) + (\xi_{t+1}^\pi - \xi_t^\pi) \\ u_{t+1} - u_t &= b^2(\pi_t - \pi_{t-1}) + c^2(u_t - u_{t-1}) + (\xi_{t+1}^u - \xi_t^u) \\ r_{t+1} - r_t &= b^3(\pi_t - \pi_{t-1}) + c^3(u_t - u_{t-1}) + (\xi_{t+1}^r - \xi_t^r) \end{aligned}$$

The solution of Peru's linear model considers that the monetary authority prioritizes the aggregate inflation objective in the future $\{\pi_{t+k}\}, \forall k \geq 1$ $\{\tilde{\pi}_{t+k}\}, \forall k \geq 1$, such that it is very close to the sequence of target aggregate inflation, then it must solve the following problem of minimisation of a welfare loss function in each period t :

$$(6) \quad \min_{\{d_t\}} \frac{1}{2} E_t [\pi_{t+1} - \tilde{\pi}_{t+1}]^2$$

Subjected to the constraint of equation system (3). Therefore, the optimal policy rule considers, both, the observed aggregate equilibrium $\{\pi_t, u_t, r_t\}$, and the inflation target $\tilde{\pi}_{t+1}$, such that:

$$(7) \quad d_t^* = \frac{1}{F} [\tilde{\pi}_{t+1} - (a^1 + b^1\pi_t + c^1u_t + E_t[\xi_{t+1}^\pi])]]$$

Consequently, the aggregate equilibrium for π_{t+1} and the inflation target $\tilde{\pi}_{t+1}$; results from the following expression:

$$(8) \quad \pi_{t+1}^* = \tilde{\pi}_{t+1} + \xi_{t+1}^\pi - E_t[\xi_{t+1}^\pi]$$

As a rule, the internal target is not observable by the private agents of each Peru department, apart from a monetary authority that opts for an explicit inflation targeting scheme. Therefore, given a **constant target**, it is

assumed that this is $\tilde{\pi}_{t+k} = \tilde{\pi}, \forall k > 0$, then the aggregate equilibrium has no relation to the unemployment rate, nor its change from the equilibrium value; and it is as follows:

$$(9) \quad \pi_{t+1}^* - \pi_t^* = (\xi_{t+1}^\pi - E_t[\xi_{t+1}^\pi]) - (\xi_t^\pi - E_{t-1}[\xi_t^\pi])$$

In the case of a **band goal**, it assumed that the target in each period t defined by $\tilde{\pi}_t$ according to the position of π_{t-1} , observable by the monetary authority, concerning a band: $[\underline{\pi}, \bar{\pi}]$ is given by:

$$(10) \quad \tilde{\pi}_t = \begin{cases} \pi_{t-1}, & \text{if } \pi_{t-1} \in [\underline{\pi}, \bar{\pi}] \\ \bar{\pi}, & \text{if } \pi_{t-1} > \bar{\pi} \\ \underline{\pi}, & \text{if } \pi_{t-1} < \underline{\pi} \end{cases}$$

To find the solution for the linear model of Peru's departments, since the **optimal policy rule** for the interest rate d_t responds only to the aggregate variables $\{\pi_t, u_t\}$, the deviations of the departmental variables for the corresponding aggregates $\{\pi_t, u_t\}$ are not significantly correlated with d_t . Unlike aggregate variables, the departmental deviations provide useful information for estimating the parameter c^1 . Like how equation (8), we substituted the **optimal policy rule** of equation (7) in the departmental solution of equation system (1) for $\pi_{j,t+1}$. Thus, we obtain the equilibrium inflation of the area j represented by:

$$(11) \quad \pi_{j,t+1} = \tilde{\pi}_{t+1} + b^1(\pi_{j,t} - \pi_t) + c^1(u_{j,t} - u_t) + \epsilon_{j,t+1}^\pi + (\xi_{t+1}^\pi - E_t[\xi_{t+1}^\pi])$$

From equation (11) we identify and estimate the parameter c^1 . By completeness, when you have a constant inflation target $\tilde{\pi}_{t+k} = \tilde{\pi}, \forall k > 0$, the equilibrium inflation in area j is:

$$(12) \quad \pi_{j,t+1} = \tilde{\pi} + b(\pi_{j,t} - \pi_t) + c(u_{j,t} - u_t) + \epsilon_{j,t+1}^\pi + (\xi_{t+1}^\pi - E_t[\xi_{t+1}^\pi])$$

If the observed inflation is always fluctuating within a band; and given the first case of equation system (10), we can estimate equilibrium inflation in the area j as follows:

$$(13) \quad \pi_{j,t+1} - \pi_t = b(\pi_{j,t} - \pi_t) + c(u_{j,t} - u_t) + \epsilon_{j,t+1}^\pi + (\xi_{t+1}^\pi - E_t[\xi_{t+1}^\pi])$$

A solution for Peru's departments, much more general, is to include in the specification the temporal effects of regression through binary variables for each year or a *temporary dummy* D_t (Barrera, 2019), which is an estimation of inflation targets for each period, as follows:

$$(14) \pi_{j,t+1} - \pi_t = D_t + b(\pi_{j,t} - \pi_t) + c(u_{j,t} - u_t) + \epsilon_{j,t+1}^\pi + (\xi_{t+1}^\pi - E_t[\xi_{t+1}^\pi])$$

4. Phillips' curves estimations for peru's departments

To explore the empirical implications of the estimation of departmental Phillips' curves, I used the following data sources:

- From the Regional Information System for Decision Making of the National Institute of Statistics and Informatics, INEI, (2021d) I retrieved the departmental unemployment rates for the period 2001 – 2018, departmental GDP for the period 2007 – 2020 at 2007 prices, the consumer price indices, CPI, with 2009 base for the period 2009 – 2020 and with 2007 base for the period 2001 – 2008, from which the series were standardized with base 2007 taking into account the annual variation of these indices for each department.
- The series of departmental unemployment rates for the period 2019 – 2020 was completed from Microdata-base (INEI, 2021c). The case of the GDP series for the period 2001 – 2006, was completed using the current values reported in the publication of national accounts at the departmental level (INEI, 2013) and converting it to real values of 2007 with the respective CPI.
- The information on active nominal interest rates comes from the National Superintendence of Bank, Insurance and Private Funds, SBS (2021), from which, the annual averages for the country were estimated and then transformed into real rates for each department discounting them with the corresponding CPI.
- Information on unemployment rates for the country comes from the INEI (2021b) for the period 2007 – 2020 and the BCRP (2021a) for the period 2001 – 2006. For its part, the information on the national GDP for the period 2001 – 2020 comes from the National Accounts (INEI, 2021a)

- It is also important to mention I estimated that departmental and national GDP gaps using the Hodrick & Prescott filter (1997).

According to Sims' (1992) critique, the structural equation system (1) requires a joint solution, which is the subject of further research. For the present, I estimate the departmental Phillips' curves individually, following the strategy proposed by Fitzgerald & Nicolini (2014) as follows:

- The purpose is to identify the parameter c^1 by the econometrically estimating the Phillips' curves functional forms in systems (1), (12) and (13) for the period 2001 – 2020 for twenty-five geographical areas: twenty-four departments plus the Constitutional Province of Callao.
- For each of the cases, I generated binary variables to illustrate the change to the EIT scheme for the period 2002 – 2006, the reduction of the EIT target from 2007, and the external shocks that originated from the international crisis of 2008 and the COVID-19 pandemic of 2020. For this reason, in operational terms, it is not possible to estimate the equation (14), which Barrera (2019) did in his research.
- For all cases, econometric estimation includes the generalized least squares method, GLS, which is robust for heteroscedasticity, cross-sectional cross-dependence, and conditioned autocorrelation. All models successfully pass these tests.
- Following Wooldridge's (2021) recommendations I additionally estimate equation (1) by the method of the first differences.

Table 2 presents the results from the models I estimated. It is important to highlight the following aspects:

- From the set of specifications established for departmental Phillips' curves, equation (13) constitutes a model that performs better efficiently in terms of:
 - It better explains the behaviour of future inflation in terms of the explanatory variables ($R^2 = ,8587$). This effect is greater than that found in Barrera's (2019) models for the Peruvian case with a Neo-Keynesian Phillips curve; and that found by Fitzgerald & Nicolini (2014) for the USA case with a NAIRU-Keynesian Phillips curve.

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Table 2
Peru: Departmental Phillips' curves using unemployment, the result of the estimated models

	Lagged Inflation	Lagged Unemployment	Lagged Interest Rate	Nominal Depreciation	International Inflation Rate	EIT 1	EIT 2	Crisis
<i>Equation (1) estimated by GLS (R²=, 7145)</i>								
Coefficient	0.1035	0.1679	0.0459	-2.0102	0.1898	0.7496	1.9748	-1.6293
Std. Error	0.0100	0.0120	0.0050	0.1795	0.0091	0.1221	0.0915	0.1410
t-Statistic	10.3351	13.9399	9.2474	-11.2013	20.9443	6.1371	21.5835	-11.5552
Prob. t-Stat.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
<i>Equation (1) in first differences estimated by GLS (R²=, 7698)</i>								
Coefficient	-1.0020	0.4520	-0.6574	0.7417	0.0521	1.0023	-0.2614	-2.9136
Std. Error	0.0428	0.0200	0.0331	0.1988	0.0075	0.0715	0.0292	0.2062
t-Statistic	-23.4082	22.5486	-19.8719	3.7316	6.9835	14.0222	-8.9563	-14.1326
Prob. t-Stat.	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000
<i>Equation (12) estimated by GLS (R²=, 7828)</i>								
Coefficient	0.5522	0.0067	0.1712	0.2552	0.1638	4.9460	6.6952	-1.0225
Std. Error	0.0177	0.0109	0.0113	0.2696	0.0101	0.6109	0.6503	0.1487
t-Statistic	31.1703	0.6120	15.1617	0.9464	16.1972	8.0958	10.2956	-6.8772
Prob. t-Stat.	0.0000	0.5408	0.0000	0.3444	0.0000	0.0000	0.0000	0.0000
<i>Equation (13) estimated by GLS (R²=, 8486)</i>								
Coefficient	0.3654	0.0730	0.1514	-1.6741	0.3509	-2.1026	-0.7896	-3.1771
Std. Error	0.0169	0.0184	0.0069	0.2021	0.0107	0.1078	0.0691	0.1460
t-Statistic	21.5806	3.9663	21.9903	-8.2835	32.8365	-19.5105	-11.4278	-21.7616
Prob. t-Stat.	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Notes:

- EIT 1: Binary variable that takes 1 for the period 2002 - 2006, which corresponds to the first segment of the explicit inflation target.

- EIT 2: Binary variable that takes 1 for the period 2007 - 2020, which corresponds to the second segment of the explicit inflation target.

- Crisis: Binary variable that takes 1 for the years 2008 and 2020, representing the international economic crisis and the COVID-19 pandemic crisis.

- The signs for the binary variables representing the adoption of the BCRP's EITs are correct (negative), which implies that the adoption of the first scheme represented an approximate reduction of 2,1 percentage points in future inflation, while for the second scheme, the reduction was 0,8 percentage points.
- The models estimated found that the impact of the international crisis and the COVID-19 pandemic on future inflation involves a reduction of 3,2 percentage points.
- The coefficient for lagged inflation is three times higher than those estimated by Barrera (2019) with greater significance ($t=21,5806$; $p<,001$). The explanation of this difference is due to the greater number of degrees of freedom considered in the estimation of equation (13) compared to that of the referred author.
- The impact of nominal depreciation on future inflation in Peru's departments is about ten times greater than Barrera's (2019) estimate.
- The model has counterproductive findings for the case of the parameter of interest c^1 , which is positive (.073) and statistically significant ($t=3,9663$; $p<,001$). An explanation for this result needs to consider that the national unemployment rate, influenced by Metropolitan Lima, is higher than the unemployment rates in Peru's department, which represent negative gaps as inputs for the regression, which causes the coefficient to change sign.
- Another counterproductive outcome on departmental Phillips' curves is the sign of the lagged interest rate (positive), explained by the wide gap between departmental active real interest rates and the interest rate of reference. However, this finding requires further documentation and investigation.

With the purpose to contrast the results of the estimates for the NAIRU-Keynesian departmental Phillips' curves following Fitzgerald & Nicolini (2014), with the methodology of Barrera (2019), I produced estimations for the systems (1), (12) and (13), using the output gap instead of unemployment rates. Table 3 shows the results of this estimation. As the reader will notice, the estimation for the parameters is consistent with the findings detailed above for all control variables. The exception is the

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Table 3
Peru: Departmental Phillips' curves using the output gap, the result of the estimated models

	Lagged Inflation	Lagged Output Gap	Lagged Interest Rate	Nominal Depreciation	International Inflation Rate	EIT 1	EIT 2	Crisis
<i>Equation (1) estimated by GLS (R²=.6632)</i>								
Coefficient	0.1169	0.0038	0.0666	-1.8110	0.2120	0.9983	2.2086	-1.2711
Std. Error	0.0086	0.0012	0.0050	0.1987	0.0094	0.0981	0.0707	0.1378
t-Statistic	13.6669	3.0243	13.3989	-9.1124	22.5866	10.1710	31.2491	-9.2237
Prob. t-Stat.	0.0000	0.0026	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
<i>Equation (1) in first differences estimated by GLS (R²=.7229)</i>								
Coefficient	-0.9492	-0.0010	-0.6355	1.7230	0.0893	1.0759	-0.2668	-2.2560
Std. Error	0.0365	0.0012	0.0282	0.2389	0.0062	0.0683	0.0234	0.1794
t-Statistic	-26.0339	-0.8830	-22.5340	7.2107	14.3330	15.7552	-11.4256	-12.5741
Prob. t-Stat.	0.0000	0.3777	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
<i>Equation (12) estimated by GLS (R²=.8077)</i>								
Coefficient	0.5426	0.0056	0.1663	0.2610	0.1656	4.8386	6.5797	-1.0461
Std. Error	0.0170	0.0011	0.0109	0.2662	0.0106	0.5826	0.6192	0.1465
t-Statistic	31.9884	5.1634	15.2857	0.9803	15.6822	8.3053	10.6265	-7.1395
Prob. t-Stat.	0.0000	0.0000	0.0000	0.3274	0.0000	0.0000	0.0000	0.0000
<i>Equation (13) estimated by GLS (R²=.8603)</i>								
Coefficient	0.3565	0.0087	0.1359	-1.6781	0.3566	-2.1359	-0.7305	-3.2578
Std. Error	0.0151	0.0013	0.0061	0.2184	0.0119	0.1015	0.0692	0.1412
t-Statistic	23.6273	6.8480	22.1750	-7.6851	30.0174	-21.0361	-10.5552	-23.0690
Prob. t-Stat.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Notes:

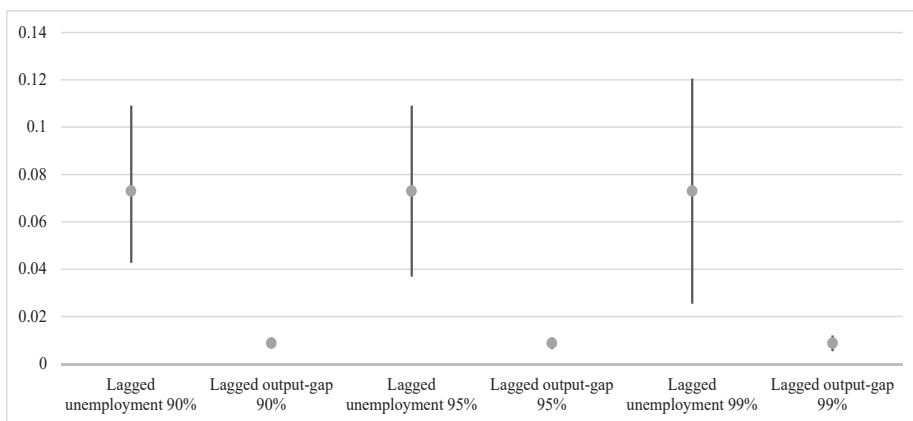
- EIT 1: Binary variable that takes 1 for the period 2002 - 2006, which corresponds to the first segment of the explicit inflation target.
- EIT 2: Binary variable that takes 1 for the period 2007 - 2020, which corresponds to the second segment of the explicit inflation target.
- Crisis: Binary variable that takes 1 for the years 2008 and 2020, representing the international economic crisis and the COVID-19 pandemic crisis.

parameter of interest c^1 , which is quite different if estimated by lagged unemployment or by lagged output gap.

Figure 4 shows coefficient intervals for 90 %, 95 % and 99 % confidence levels for c^1 , from which is obvious that departmental Phillips' curves estimated by output gap are flatter than those estimated by unemployment. Another deduction is that there is a stable relationship between expected inflation rates and the unemployment rate at the departmental level, as Fitzgerald & Nicolini (2014) demonstrated in the USA case.

Figure 4

Coefficient interval produced for Phillips' curves with unemployment and output gap.



Notes: Coefficient intervals produced for c^1 in equation (13) at 90 %, 95 % and 99 % confidence levels. Departmental Phillips' curve estimated by the output gap is flatter than those estimated by unemployment.

5. Discussion and final remarks

By way of conclusion, the stylized facts about inflation and unemployment highlight a negative gap between the unemployment rates of the Peru's departments with the country's reference unemployment rate, given by Metropolitan Lima. This characteristic implies that, given the negative sign of the rates obtained by difference in the case of the NAIRU-Keynesian model for Peru, the sign of the parameter of interest in the research c^1 must be positive to keep the theoretical relationship of Phillips curve.

Returning to the question that gives rise to the present research, we find that for the Peruvian case, the hypothesis of Fitzgerald & Nicolini (2014) is confirmed, that is, using a NAIRU-Keynesian model a stable relationship between inflation and unemployment in the departments of Peru is documented, which requires further investigation to find more consistent explanations. This finding, from the point of view of economic policy, exposes the opportunity for the national government to promote the improvement of employment conditions in the departments of Peru, which in proportional terms implies higher departmental levels of under-employment compared to those of the capital of the country.

On the other hand, the model estimated for the Phillips' curves in the Peru's departments also confirms the findings of Aquino (2019) and Barrera (2019) on the existence of a horizontal section that explains a low relationship between inflation and economic activity, when the estimations are produced by gross domestic product gap, as well as the importance of the expectations channel in determining future inflation. The findings described in this document show a greater flattening than that highlighted by the authors cited and would be in line with Lucas' (1972) findings on the neutrality of money in productive activity.

The article focuses on theoretical models and empirical methodologies provided in the literature. This implies that the macroeconomic variables provided therein were used. However, it is difficult to think that the reality of the labour and goods markets of the Peru's departments, including that of the Metropolitan Lima, follow the theoretical models invoked, since it should be expected that idiosyncratic variables, such as socio-cultural and structural techno-economic characteristics of that regions. The empirical strategy that I use in the article to estimate the parameter of interest in the Phillips curve coincides with what was proposed by Fitzgerald and Nicolini (2014) and Barrera (2019), with the purpose of eliminating idiosyncratic effects due to differences, as methodologically suggested by Wooldridge (2021) as a first research approach. Some critiques to the traditional macroeconomic approach should suggest that anomalies and counterintuitive results may not be resolved by other standard macroeconomic variables, but by variables of another type that were not considered in this article. Regarding this critique there is another way to identify the parameter of interest using the structural model of

equation system (1), where idiosyncratic variables are used for this purpose. This approach is documented in a second article.

As a line of future research, the solution to the structural system of equations (1) is available simultaneously, to confirm the findings described in this document, which involves:

Adequate identification of structural relationships within the meaning of what Sims (1992) proposed.

Improve information regarding real interest rates for Peru's departments, which represents a task for the SBS to collect information from banks and classify it at the departmental level.

An important advance is the publication of departmental series on inflation expectations through the BCRP Data (2021), to include this variable in the modelling of the monetary policy system considering departmental levels.

Identify a probable misalignment between the national economic cycles, marked by the department of Lima, and the economic cycles in each Peruvian department, with implications for monetary policy in terms of generating adverse effects on unemployment in Peru's departments, considering the greater elasticity of the Phillips' curves at this level, which required further research.

The measurement of economic activity considering the national averages for both inflation, employment, and the output gap, to the extent that the national analysis concentrated on the references of Metropolitan Lima's indicators do not represent properly the departmental averages.

References

- Aquino, J. C. (2019, diciembre). La curva de Phillips Neokeynesiana de una economía pequeña y abierta: Especificaciones, quiebres estructurales y robustez. *Revista de Estudios Económicos*(38), 43-59. Retrieved from www.bcrp.gob.pe/publicaciones/revista-estudios-economicos.html
- Armas, A., Grippa, F., Quispe Misaico, Z., & Valdivia, L. (2001). De metas monetarias a metas de inflación en una economía con dolarización: el caso peruano. *Estudios Económicos*(2), 1-50. Retrieved from <https://www.bcrp.gob.pe/publicaciones/revista-estudios-economicos.html>

gob.pe/docs/Publicaciones/Revista-Estudios-Economicos/07/Estudios-Economicos-7-2.pdf

- Atkeson, A., & Ohanian, L. E. (2001). Are Phillips Curves Useful for Forecasting Inflation? *Quarterly Review*, 25(1), 2-11. Retrieved from <https://www.minneapolisfed.org/research/quarterly-review/are-phillips-curves-useful-for-forecasting-inflation>
- Banco Central de Reserva del Perú. (2021, diciembre 16). *BCRP Data*. Retrieved from Banco Central de Reserva del Perú: <https://estadisticas.bcrp.gob.pe/estadisticas/series/>
- Banco Central de Reserva del Perú. (2021). *Reporte de Inflación Diciembre 2021*. Lima: Banco Central de Reserva del Perú. Retrieved from <https://www.bcrp.gob.pe/docs/Publicaciones/Reporte-Inflacion/2021/diciembre/report-de-inflacion-diciembre-2021.pdf>
- Barrera, C. (2019, Diciembre). ¿Existe un tramo horizontal en la curva de Phillips? Perú 2005-2017. *Estudios Económicos*(38), 61-80. Retrieved from www.bcrp.gob.pe/publicaciones/revista-estudios-economicos.html
- Clarida, R., Galí, J., & Gertler, M. (1999, December). The Science of Monetary Policy: A New Keynesian Perspective. *Journal of Economic Literature*, XXXVII, 1661-1707. Retrieved from <https://www.crei.cat/wp-content/uploads/users/pages/cggsci~1.pdf>
- Fisher, I. (1973, March-April). I Discover the Phillips Curve: A Statistical Relation between Unemployment and Price Changes. *Journal of Political Economy*, 81(2), 496-502. doi:<https://www.jstor.org/stable/1830534>
- Fitzgerald, T. J., & Nicolini, J. P. (2014). *Is There a Stable Relationship between Unemployment and Future Inflation? Evidence from U.S. Cities*. Minneapolis: Federal Reserve Bank of Minneapolis.
- Gao, H., Kulish, M., & Nicolini, J. P. (2021). Two Illustrations of the Quantity Theory of Money Reloaded. *Staff Report*(633), 1-49. Retrieved from <https://www.minneapolisfed.org/research/sr/sr633.pdf>
- Hodrick, R. J., & Prescott, E. C. (1997, February). Postwar U.S. Business Cycles: An Empirical Investigation. *Journal of Money, Credit and Banking*, 29(1), 1-16. Retrieved from <http://www.jstor.org/stable/2953682>
- Instituto Nacional de Estadística e Informática. (2013). *Producto Bruto Interno por Departamentos 2001 - 2012*. Jesús María: Instituto Nacional de Estadística e Informática.

- Instituto Nacional de Estadística e Informática. (2020, Septiembre 28). *Producto Bruto Interno por Departamentos*. Retrieved from Instituto Nacional de Estadística e Informática: <https://www.inei.gov.pe/estadisticas/indice-tematico/producto-bruto-interno-por-departamentos-9089/>
- Instituto Nacional de Estadística e Informática. (2021, octubre 15). *Cuentas Nacionales*. Retrieved from Instituto Nacional de Estadística e Informática: <https://www.inei.gov.pe/estadisticas/indice-tematico/national-accounts/>
- Instituto Nacional de Estadística e Informática. (2021, diciembre 15). *Empleo*. Retrieved from Instituto Nacional de Estadística e Informática: <https://www.inei.gov.pe/estadisticas/indice-tematico/ocupacion-y-vivienda/>
- Instituto Nacional de Estadística e Informática. (2021, Abril 19). *Microdatos: Base de datos*. Retrieved Abril 5, 2020, from Encuesta Nacional de Hogares y Condiciones de Vida: <http://inei.inei.gov.pe/microdatos/>
- Instituto Nacional de Estadística e Informática. (2021, octubre 15). *Sistema de Información Regional para la Toma de Decisiones*. Retrieved from Instituto Nacional de Estadística e Informática: <https://systems.inei.gov.pe/SIRTOD/>
- Lucas, R. E. (1972, April). Expectations and the neutrality of money. *Journal of Economic Theory*, 4(2), 103-124. doi: [https://doi.org/10.1016/0022-0531\(72\)90142-1](https://doi.org/10.1016/0022-0531(72)90142-1)
- Phillips, A. W. (1958, November). The relation between the unemployment rate and the change of money wage rates in the United Kingdom, 1961 - 1957. *Economica*, 283-299. doi: <https://doi.org/10.1111/j.1468-0335.1958.tb00003.x>
- Reifschneider, D., Tetlow, R., & Williams, J. (1999, January). Aggregative Disturbances, Monetary Policy and the Macroeconomy. *Federal Reserve Bulletin*, 1-19. Retrieved from <https://www.federalreserve.gov/pubs/bulletin/1999/0199lead.pdf>
- Samuelson, P. A., & Solow, R. M. (1960, May). Analytical Aspects of Anti-Inflation Policy. *American Economic Review*, 50(2), 177-194. Retrieved from <https://www.jstor.org/stable/1815021>
- Sims, C. A. (1980, January). Macroeconomics and Reality. *Econometrica*, 48(1), 1-48. Retrieved from <http://links.jstor.org/sici?sici=0012-9682%28198001%2948%3A1%3C1%3AMAR%3E2.0.CO%3B2-A>
- Sims, C. A. (1992). Interpreting the macroeconomic time series facts: The effects of monetary policy. *European Economic Review*(36), 975-1011.

- Superintendencia de Banca, Seguros y AFP. (2021, setiembre 15). *Estadísticas del Sistema Financiero*. Retrieved from Superintendencia de Banca, Seguros y AFP: https://www.sbs.gob.pe/estadisticas-y-publicaciones/estadisticas-sistema-financiero_
- Vega, M. (2018, marzo). El esquema de metas de inflación y la inflación peruana. *Moneda*(173), 4-8. Retrieved from <https://www.bcrp.gob.pe/docs/Publicaciones/Revista-Moneda/moneda-173/moneda-173-01.pdf>
- Wooldridge, J. M. (2021, August 16). Two-Way Fixed Effects, the Two-Way Mundlak Regression, and Difference in Difference Estimators. *Research Gate*(353938385), 1-77. Retrieved from <https://www.researchgate.net/publication/353938385>