Real Wage Rigidity and the New Phillips Curve: the Brazilian Case

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RESUMO

A curva de Phillips Novo-Keynesiana tem sido criticada por não explicar o *trade-off* de curto prazo entre inflação e o hiato do produto. Blanchard e Galí (2007) introduziram a rigidez do salário real no modelo e derivaram um *trade-off* entre estabilizar a inflação ou estabilizar o hiato entre os produtos real-eficiente. Este artigo estima a nova curva de Phillips para a economia brasileira, estima o *trade-off* de curto prazo, analisa a rigidez do salário real e testa as restrições teóricas impostas pelo modelo. As estimações GMM adequam-se muito bem aos dados e todas as restrições teóricas são satisfeitas. Há forte rigidez do salário real e um alto custo do hiato do produto para estabilizar a inflação no curto prazo.

Palavras chave: Curva de Phillips; rigidez do salário real; desemprego; *trade-off*.

ABSTRACT

The new Keynesian Phillips curve has been criticized for not explaining the short run inflation-output gap trade-off. Blanchard and Galí (2007) introduced real wage rigidity in the model and derived a trade-off between stabilizing the inflation or the gap between actual-efficient outputs. This paper estimates the new Phillips curve for the Brazilian economy, computes short run trade-off, analyzes real wage rigidity, and tests theoretical restrictions imposed by the model. The GMM estimations fit the data very well and all theoretical restrictions are satisfied. There is strong real wage rigidity and a high output-gap cost to stabilize inflation in the short run.

Keywords: Phillips curve; Real wage rigidity; Unemployment; Trade-off.

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1. Introduction

The seminal work on the relationship between inflation and unemployment is due to Phillips (1958), who analyzed the case of United Kingdom from 1861 to 1957. The publication of Phillips' work has given rise to a debate on the existence of a trade-off between stabilizing inflation versus unemployment. Phelps (1967) and Friedman (1968) argued against a stable trade-off based on the definition of equilibrium unemployment rate, called *natural rate of unemployment,* and on the notion of inflation expectation. According to Friedman (1968), inflation expectation is an important variable to evaluate nominal wages and the traditional analysis by Phillips (1958) is misguided because he did not make a distinction between nominal and real wages. Both Phelps (1967) and Friedman (1968) recognized only the existence of a short run trade-off, which does not come from inflation itself, but from unexpected inflation.

This argument is reinforced by the Lucas (1972) incomplete information model. When there is an increase in price, the producer does not know whether there has been a change in relative prices or a rise motivated by inflation. The producer's rational response is to attribute one fraction of the increase to change in relative prices and another to aggregate inflation. Hence, his decision would be to raise production in some proportion in the short run, allowing for a positively sloped supply curve in the short run.

The New Keynesian literature argues that both prices and wages show some rigidity due to sluggishness of the adjustment toward new market conditions. The existence of price and wage contracts is among the reasons commonly used to explain rigidity. Even in the absence of such contracts, firms can face menu costs or fear the distaste of customers for frequent changes in prices. Thus, one should expect some sluggishness of price adjustment.

The implication of rigidity is that the short run supply curve is positively sloped, giving support to the hypothesis of short run trade-off admitted by Friedman (1968) and Phelps (1967). As a consequence, monetary disturbs might affect real activity in the short run.

In the theoretical vein of price rigidity, a widely used framework was proposed by Calvo (1983). In each period, only a fraction of firms change prices with some probability, which is independent over time and across firms. The Calvo's framework has become the workhorse for derivation of the so called New Keynesian Phillips curve (NKPC).

The standard version of the NKPC has been object of controversy because it generates no trade-off between stabilizing inflation versus output gap, when compared with the original Phillips curve[1]. A monetary authority that is able to commit itself to stabilize the output gap can, simultaneously, stabilize inflation. This result is in sharp contrast with the empirical evidence, as argued by Clarida, Galí and Gertler (1999), Woodford (2003), Galí, Gertler and Lopez-Salido (2001), among others.

A hybrid model, lacking from rigorous theoretical background, was proposed by Galí and Gertler (1999), who considered that some firms adopt a backward looking and others a forward looking behavior when adjusting prices. Their empirical evidence indicated that, besides statistically significant, price adjustment by the backward looking rule was not quantitatively important for the US economy in the period from 1960 to 1997.

An alternative formulation uses the average real marginal cost, in percentage deviation from its steady state level, in substitution of the output gap. Galí, Gertler e Lopez-Salido (2001) found a better fit to the Europe and US data using this alternative version of the Phillips curve. However, under certain conditions, Woodford (2003) shows that it is equivalent to the standard one.

[1] The relationship between output gap and unemployment is given by the Okun's law, originally proposed by Okun (1962).

Mankiw and Reis (2002) introduced the concept of information rigidity instead of price rigidity in the derivation of the Phillips curve. This change was successful in generating inflation inertia. A criticism to this framework, however, argues that firms do not change prices continuously, as noted by Blanchard and Galí (2007).

A combination of both wage and price rigidity can be found in the model suggested by Erceg, Henderson and Levin (2000). However, they were not able to resolve the trade-off controversy. As stressed by Blanchard and Galí (2007), it just assumed a new format. In Erceg, Henderson and Levin (2000), to stabilize the gap between actual output and efficient output is equivalent to stabilize the weighted average of wage inflation and price inflation.

A recent contribution was offered by Blanchard and Galí (2007), who introduced real wage rigidity and supply shocks in the theoretical structure of the New Keynesian model. They defined welfare-relevant output gap as being the gap between actual output and efficient output – the output that would be produced under perfect competition in the goods and wage markets. From this framework, it has emerged a new Phillips curve, whose coefficients carry out different meanings compared to the traditional curve. Empirical evidence provided by the authors revealed that the new curve adjusted very well for the US economy in the period from 1960 to 2004.

The objective of this paper is to provide empirical evidence of the new Phillips curve for the Brazilian economy in the period from 1995 to 2008. This period is characterized by relative price stability, achieved after the edition of the Real Plan in June of 1994. In addition, the paper investigates the relationship between inflation, unemployment, and supply shocks. Estimated parameters from the new Phillips curve are used to analyze real wage rigidity and to compute the short run trade-off between inflation and output gap. This is an important issue because Brazil has historically experienced high levels of both inflation and unemployment.

By introducing real wage rigidity in the theoretical model, a trade-off between inflation and the gap between actual output and efficient output shows up in the resulting Phillips curve. The trade-off refers to choices that the monetary authority has to do in order to fight supply shocks. Thus, given any shock to the price of non-produced inputs, the monetary authority has to choose between stabilizing inflation, at a cost of higher output gap, or stabilizing output gap, allowing for higher inflation.

Given the rational expectations nature of the new Phillips curve, the parameters were estimated by GMM with robust standard errors. The results were consistent with the theory, revealing a good fit of the new curve to the Brazilian data. The estimated parameters presented expected signs and were statistically significant. Yet, they fulfilled a set of theoretical restrictions imposed by the model. Thus, our major contribution is to provide further empirical evidence on the new Phillips curve, estimate the short run trade-off between inflation and output gap, and measure the effects of real wage rigidity on inflation in the Brazilian economy.

The paper is organized as follows. Next section briefly describes the theoretical model proposed by Blanchard and Galí (2007) to derive the new Phillips curve. The third section discusses the econometric procedure and the data set. The results are reported and analyzed in the fourth section. Finally, the fifth section is dedicated to the concluding remarks.

2. Theoretical model

2.1 Firms and Households

The Blanchard and Galí (2007) model assumes that there is a continuum of firms acting in monopolistic competition to produce a differentiated good. Firms face an isoelastic demand curve and are subject to a Cobb-Douglas production function given by[2]:

$$Y = M^{\alpha} N^{1-\alpha} \tag{1}$$

where Y is output, M is a non-produced input, which is subject to supply shocks, and N is labor. There is constant returns to scale, so that $0<\alpha<1$.

There is a large number of identical households who own the firms. Their preferences are separable and represented by:

$$U(C,N) = \log(C) - \exp\{\xi\}\frac{N^{1+\phi}}{1+\phi} \tag{2}$$

where C is composite consumption, with elasticity of substitution between goods equal to ε, N is labor supply, ξ is a preference parameter, which might be time varying, and ϕ is the slope of the labor supply curve.

The marginal rate of substitution *(mrs)* between consumption and labor is derived from the solution of the household's problem. In logarithms, it is given by:

$$mrs = c + \phi n + \xi \tag{3}$$

2.2 First best level of output

The first best level of output (or efficient output) is defined as the optimal output of an economy working under perfect competition in all markets. There is efficient allocation of all production factors and no involuntary unemployment. From the production function (1), this level of output (in logarithms) is:

$$y_1 = \alpha m + (1-\alpha) n_1 \tag{4}$$

where y_1 and n_1 are efficient levels of output and employment, respectively.

2.3 Second best level of output

The second best level of output (or natural output) is defined by Blanchard and Galí (2007) as the optimal level of output under monopolistic competition. In this market structure, firms have market power and are able to set a mark up $\mu^p \equiv \log[\varepsilon/(\varepsilon-1)]$ over the marginal cost. From the production function (1), this level of output is:

$$y_2 = \alpha m + (1-\alpha) n_2 \tag{5}$$

[2] Unless otherwise noticed, the absence of subscript t means a current period variable.

where y_2 and n_2 are optimal levels of output and employment under monopolistic competition, but with flexible prices and wages. Notice that the difference between (4) and (5) is constant and equals to:

$$y_1 - y_2 = \delta = \frac{\mu^p(1-\alpha)}{(1+\phi)} \tag{6}$$

2.4 New Keynesian Phillips curve

The supply side of the standard New Keynesian model for a closed economy under monopolistic competition and flexible wages generates the well known NKPC:

$$\pi = \beta E\pi_{t+1} + \kappa(y - y_2) \tag{7}$$

where $\kappa \equiv \lambda\frac{(1+\phi)}{(1-\alpha)}$, y is the current period actual output, and y_2 is the natural output, obtained from equation (5).

Note that supply shocks and preference shocks do not directly appear in (7). Indirectly, however, they affect y_2. But, as seen before, the difference between y_1 and y_2 is constant and equals to δ. Thus, with flexible wages and price rigidity, it remains valid the result that stabilizing inflation is equivalent of stabilizing the gap between actual output and efficient output.

2.5 Real wage rigidity

In the previous framework, the real wage was always equal to the marginal rate of substitution. This might be changed by assuming that the (logarithm of) real wage, *w*, evolves according to the *ad-hoc* rule:

$$w = \gamma w_{t-1} + (1-\gamma)\cdot mrs \tag{8}$$

where γ is a coefficient that measures real wage rigidity.

Equation (8) assumes that there is no change in preferences. Therefore, real wage adjustments are due to imperfections in the labor market. The first best level of output is still defined by equation (4), given that it is derived for a frictionless economy under perfect competition. The second best level of output, however, will be affected by wage rigidity, as described in the following section.

2.6 Second best level of output under real wage rigidity

The second best level of output (or natural output) for an economy under monopolistic competition and real wage rigidity defines its feasible optimal output. Blanchard and Galí (2007) showed that it can be expressed as:

$$[y_2 - y_1 + \delta] = \Theta[(y_2)_{t-1} - (y_1)_{t-1} + \delta] + \Theta(1-\alpha)[\Delta m + (1+\phi)^{-1}\Delta\xi] \tag{9}$$

where $\Theta \equiv \dfrac{\gamma\alpha}{[\gamma\alpha + (1-\gamma)(1+\phi)]} \in [0,1]$.

Under real wage rigidity, the gap between the first and second optimal levels of output is no longer constant, but is affected by both supply (Δm) and preference $(\Delta\xi)$ shocks. One can show that Θ is increasing in γ, implying that the size and persistency of the gap between y_2 and y_1 increase with the degree of real wage rigidity.

An adverse supply shock (decrease in *m*) generates a negative variation in the gap of equation (9). Gradually, however, the size of the gap converges to its stationary level, δ, as the real wage is adjusted over time.

A preference shock that rises ξ is fully transmitted by reducing both n_1 and y_1, given that equation (4) does not depend on the preference parameter. The reduction is now smaller in y_2 because the wage rigidity, contained in Θ, imposes only a partial reduction in equation (9).

2.7 The new version of the Phillips curve

The framework proposed by Blanchard and Galí (2007) allows representing inflation as a function of the output gap as follows:

$$\pi = \beta E\pi_{t+1} + \frac{\lambda}{1-\gamma L}(x_2) \tag{10}$$

where $x_2 = (1-\alpha)^{-1}[(1-\gamma)(1+\phi)(y-y_2)+\gamma\alpha(\Delta y-\Delta y_2)]$, $\lambda = \theta^{-1}(1-\theta)(1-\beta\theta)$, and L is a lag operator, such that $LX_t = X_{t-1}$.

According to equation (10), stabilizing inflation is still equivalent to stabilizing output gap, that is, to keep $(y-y_2)$ constant. But now, it is no longer desirable to stabilize $(y-y_2)$ because the welfare relevant measure of output gap is $(y-y_1)$. The distance between the first best and second best levels of output is affected by disturbances and so is no longer constant.

One can obtain a relation between inflation and the gap between actual output and the first best level of output expressed as:

$$\pi = \beta E\pi_{t+1} + \frac{\lambda}{1-\gamma L}x_1 - \frac{\lambda\gamma\alpha}{1-\gamma L}[\Delta m + (1+\phi)^{-1}\Delta\xi] \tag{11}$$

where $x_1 \equiv (1-\alpha)^{-1}[(1-\gamma)(1+\phi)(y-y_1+\delta)+\gamma\alpha(\Delta y-\Delta y_1)]$.

By equation (11), inflation depends on expected inflation, lagged distribution of the gap between actual output and first best level of output and lagged distribution of supply and preference shocks. It can be rewritten in terms of unemployment and change in the price of the non-produced input *M* $(\Delta\upsilon)$, yielding the new version of the Phillips curve:

$$\pi_t = \frac{1}{1+\beta}\pi_{t-1} + \frac{\beta}{1+\beta}E\pi_{t+1} - \frac{\lambda(1-\alpha)(1-\gamma)\phi}{\gamma(1+\beta)}u_t + \frac{\alpha\lambda}{1+\beta}\Delta\upsilon_t \tag{12}$$

where β is the discount factor, u_t is the deviation between labor supply and actual employment, and $\Delta\upsilon_t$ is the change in the real price of the non-produced input *M* at time *t*, or supply shock.

3. Empirical Evidence

3.1 Econometric model

The regression to be estimated for the Brazilian economy is directly derived from equation (12). It can be written as:

$$\pi_t = \frac{1}{1+\beta}\pi_{t-1} + \frac{\beta}{1+\beta}E\pi_{t+1} - \frac{\lambda(1-\alpha)(1-\gamma)\phi}{\gamma(1+\beta)}u_t + \frac{\alpha\lambda}{1+\beta}\Delta\upsilon_t + \zeta_t \qquad (13)$$

where all variables and parameters are defined as in (12) and ζ_t is the error term.

According to equation (13), inflation depends on the last period inflation, next period expected inflation based on time *t* information set, unemployment rate, and change in the real price of the non-produced input *M*. The expected signs for all variables but unemployment rate are positive.

Notice that it is not possible to identify all structural parameters from the estimated coefficients of equation (13). After exogenously setting 2 parameter values, a calibration exercise will be performed to analyze the sensitivity of inflation to the real wage rigidity (γ). Given that the discount factor is smaller than unit $[\beta \in (0,1)]$, the model place a restriction on the estimated coefficients for lagged and expected inflation, which must sum up to unit. This restriction will be tested in the estimated equation.

3.2 Data

The time series used in the estimation are quarterly for the period from 1995:1 to 2008:4. All variables were transformed by natural logarithm.

Inflation, π_t, is represented by the variation in the extended national consumer price index (IPCA), computed and published by IBGE. This is the official measure of inflation used by the Central Bank of Brazil to calibrate the inflation targeting regime.

Unemployment rate, u_t, is measured by the open unemployment rate at the metropolitan region of Sao Paulo, obtained from DIEESE and seasonally adjusted. It refers to individuals with 10 or more years of age that looking for employment. This series was used as *proxy* for the Brazilian unemployment because the national time series computed by IBGE, which refers to individuals with 15 or more years of age that were looking for a job, suffered a major methodological change in 2003 and has been interrupted.

Supply shocks, $\Delta\upsilon_t$, are measured by quarterly percentage change in the Brazilian real (R$) per US dollar (US$) nominal exchange rate, as published by the Central Bank of Brazil. It refers to the average exchange rate negotiated in the interbank exchange market. This measure of supply shocks is closely related to changes in the non-produced input prices, *M*, described in the equation (1), because changes in the US dollar exchange rate affect the input *M* prices as well as other prices in the economy due to transmission channels. Formally, one has that:

$$\Delta\upsilon_t = \ln\left(\frac{(R\$/US\$)_t}{(R\$/US\$)_{t-1}}\right) \qquad (14)$$

4. Results

4.1 Unit root tests

The empirical analysis starts by testing the time series for the presence of unit roots. A common criticism of traditional unit root tests, primarily those based on the classic methods of Dickey and Fuller (1979, 1981) and Phillips and Perron (1988), is that they suffer from low power and size distortions. However, these shortcomings have been overcome by modifications to the testing procedures, such as the methods proposed by Elliott, Rothenberg and Stock (1996), Perron and Ng (1996), and Ng and Perron (2001).

Elliott, Rothenberg and Stock (1996) demonstrate that OLS de-trending is inefficient if the data presents high persistence, and suggest using GLS de-trended data, which is efficient. Ng and Perron (2001) show that, in the presence of a strong negative moving average coefficient, the unit root estimate is strongly biased if the lag truncation, k, is small because the residuals of the test equation are serially correlated. In order to select the optimal value of k to account for the inverse non-linear dependence between the bias in the unit root coefficient and the selected value of k, Ng and Perron (2001) proposed a modified Akaike Information Criterion (MAIC). Thus, the modified ADF^{GLS} ($MADF^{GLS}$) test uses GLS de-trended data and the MAIC in order to choose the truncation lag.

The modified Phillips-Perron test (MPP^{GLS}), which also uses GLS de-trended data and the MAIC to select the optimal truncation lag, is due to Phillips and Perron (1988), Perron and Ng (1996) and Ng and Perron (2001). The asymptotic critical values for both the $MADF^{GLS}$ and MPP^{GLS} tests are given in Ng and Perron (2001).

The presence of structural breaks, a common feature among Brazilian time series, can severely bias unit root tests. One should be aware that distortions can go in both directions, reducing statistical power of the tests [Perron (1989)] or leading to spurious stationarity [Franses and Haldrup (1994)]. Thus, it is necessary to perform unit root tests that account for structural breaks. Perron (1989) proposes a test where the time of the break is exogenous and assumed to be known a priory. The break might affect both intercept and slope of the series.

A potential problem with Perron (1989) test is that it allows for just one break and assumes no structural break under the null hypothesis of unit root. Lee and Strazicich (2001) show that this assumption might result in spurious rejections. The two-break minimum LM unit root test, due to Lee and Strazicich (2003), is unaffected by whether or not there is a break under the null. Times of the breaks are endogenously chosen by points where t-statistic for the null of unit root is at a minimum. Critical values were tabulated by Lee and Strazicich (2003).

The results of the unit root tests are reported in Table 1. In the first panel of Table 1, one can see that only inflation rate, π, does not have unit root by the $MADF^{GLS}$ and MPP^{GLS} tests at the 10% significance level. The time series of unemployment, u, and supply shocks, $\Delta\upsilon$, have unit root according to both tests. This result, however, might be due to the presence of structural breaks.

The results for the Perron (1989) test, reported in the second panel of Table 1, confirm that inflation rate is stationary and find that the variable supply shocks is also I(0) once the change in monetary policy occurred in the beginning of 1999 is accounted for. The unemployment rate, however, remains as non-stationary. That might be because the series of unemployment has more than one structural break in the period.

The last panel of Table 1 shows that, in fact, unemployment rate is also stationary. This result was obtained after allowing for a second break in the time series, generated by economic instability following the electoral process and election of a left wing party candidate for the presidency of Brazil. Besides endogenously chosen, the time of the two breaks coincide with the change in the monetary policy regime to inflation targeting coupled with floating exchange rate in 1999 and the electoral process of 2002. Thus, based on the results of Table 1, one can conclude that inflation rate, unemployment rate, and supply shocks are stationary in the period under consideration.

Table 1: Unit root tests

Variables	*MADF^GLS* Z={1}	Z={1, t}	lags	*MPP^GLS* Z={1}	Z={1, t}	lags
π	-1.81*	-2.71*	2	-1.49	-2.27	2
u	-1.07	-1.04	0	-0.97	-0.85	0
$\Delta\upsilon$	-1.47	-1.23	8	1.11	1.12	8
Perron (1989)						
	Model 2	**lags**	**Break**	**5% cv**		
π	-4.77**	0	99:1	-3.87		
u	-1.92	0	99:1	-3.87		
$\Delta\upsilon$	-4.71**	0	99:1	-3.87		
Lee and Strazicich (2003)						
	Model 2	**lags**	**Break1**	**Break2**	**5% cv**	
π	-6.51**	1	1998:3	2003:2	-5.29	
u	-6.34**	9	1999:2	2002:4	-5.29	
$\Delta\upsilon$	-6.62**	0	2001:3	2002:3	-5.29	

Notes: *,**,*** the null hypothesis of unit root is rejected at the 10, 5, and 1% significance level, respectively. Critical values at the 5% level for the $MADF^{GLS}$ and MPP^{GLS} tests are -1.98 and -2.91 for the models with constant, Z={1}, and constant and trend, Z={1, t}, respectively. Model 2 of Perron (1989) is the "changing in growth model", which includes dummy for change in the slope of the time series. Model 2 of Lee and Strazicich (2003) includes two changes in intercept and trend slope of the time series.

4.2 GMM estimation of the new Phillips curve

Initially, it was estimated the original equation (13) by GMM using quarterly time series for the Brazilian economy. Given that the theoretical model assumes that agents are rational, a natural way to form current expectations of future inflation is based on lagged variables included as instruments in the regression. As in Blanchard and Galí (2007), who used a naive instrumental variables estimator, the instrument list was composed by lagged variables (up to three lags) of inflation, unemployment, and supply shocks. The validity of the instruments was tested by the Hansen (1982) over-identifying restrictions test. The results are reported in equation (18). In parenthesis are the estimated standard deviations, which are robust to heteroskedasticity and autocorrelation of unknown form.

$$\pi_t = \underset{(0.0047)}{0.0106} + \underset{(0.0512)}{0.5999}\,\pi_{t-1} + \underset{(0.0795)}{0.4415}\,E_t\pi_{t+1} - \underset{(0.0522)}{0.1365}\,u_t + \underset{(0.0084)}{0.0662}\,\Delta\upsilon_t + \underset{(0,0012)}{0.0029}\,D_t + \zeta_t \qquad (18)$$
$$H-test = 5.5848\ \ [0.586]$$

Given the results of the unit root tests from section 4.1, equation (18) has included a dummy variable, D_t, for the change in monetary policy occurred in the first quarter of 1999[3]. One can see that all estimated coefficients present signs according to the expected from

[3] A second dummy variable, for the pre- and post-electoral period of 2002, was also included in the model but was not statistically significant.

equation (13). Robust standard deviations, in parenthesis, indicate that all coefficients are statistically significant at 5% significance level. The Hansen's test (H-test) does not reject the null hypothesis that the over-identifying restrictions are satisfied[4]. In addition, the theoretical restriction imposed by the model on the coefficients of π_{t-1} and $E_t\pi_{t+1}$, which should sum up to unity, was not rejected according to the Wald test[5].

The restricted regression was, then, estimated and the results reported in Table 2. It is remarkable the stability of all estimated coefficients between these two models, with and without restrictions. For comparisons purposes, Table 2 also includes the restricted estimation obtained by Blanchard and Galí (2007) for the US economy using an instrumental variables technique.

One can see that the estimated coefficients for lagged inflation (*A₁*) and expected inflation (*A₂*) are very similar between the two economies. The effect of unemployment on current inflation (*A₃*) is, in absolute value, higher for Brazil than for US. The same is true for the coefficient of supply shocks (*A₄*). All coefficients are highly significant in the Brazilian case. As in the unrestricted model, the *H-test* does not reject the over-identifying restrictions. Thus, the new Phillips curve has fitted very well the Brazilian data. For the US economy, the adjustment was not as good given that the estimated coefficients of unemployment and supply shocks were not statistically significant at the standard 5% level of significance. In addition, the authors did not provide any information on the model's over-identifying restrictions. A discussion on the estimated coefficients vis-à-vis the theory for the Brazilian case is left to the next section.

Table 2: Restricted new Phillips curves for Brazil and USA

Coefficients	A_0	A_1	A_2	A_3	A_4	*Dummy*	*H-test*
Brazil (This study: GMM)	0.13 (0.04)	0.59 (0.05)	0.41 (0.05)	−0.12 (0.04)	0.07 (0.01)	0.0031 (0.0011)	5.61 [0.691]
USA (Blanchard-Galí: IV)	not reported	0.52 (0.05)	0.48 (0.05)	−0.08 (0.05)	0.014 (0.009)	–	–

Note: Blanchard and Galí (2007) used quarterly data for the US economy from 1960 to 2004. This study used quarterly data for the Brazilian economy from 1995 to 2008. Robust standard errors are in parenthesis. The critical value of $\chi^2_{(7)}$ at the 5% level of significance is 14.07. The p-value is within brackets.

4.3 Identification and calibration

As a result from the theoretical definitions given by equation (12), the estimated coefficients A_1 and A_2 are subject to restrictions. The first one is that $0.5 \le A_1 \le 1$, because $A_1 = \dfrac{1}{1+\beta}$ and $0 \le \beta \le 1$. The estimated value of $A_1 = 0.59$ is perfectly according to this restriction. The second one comes from $A_2 = \dfrac{\beta}{1+\beta}$, imposing the restriction that $0 \le A_2 \le 0.5$. The estimated value of $A_2 = 0.41$ is also consistent with that theoretical restriction. The third, and

[4] The critical value of $\chi^2_{(7)}$ at 5% of significance is 14.07. The p-value is within brackets.

[5] Both the *F* and χ^2 versions of the test yielded p-values of 0.4.

final, restriction is that $A_1 + A_2 = 1$, which was already tested and not rejected by the Wald test.

The other two coefficients, A_3 and A_4, are functions of structural parameters, which can not be individually identified. The parameters of price rigidity, λ, and wage rigidity, γ, are of special interest. Let's, first, examine the compound coefficient $A_4 = \frac{\alpha \cdot \lambda}{1+\beta}$, defined in equation (12).

By using the estimated value of $A_4 = 0.07$ from Table 2 and the discount factor β computed from A_1 (or A_2), one can find the product $\alpha\lambda \cong 0.12$, where α is the share of the non-produced input, *M,* in the Cobb-Douglas production function. One can, then, analyze the wage rigidity appearing in the coefficient $A_3 = -\frac{\lambda\phi(1-\alpha)(1-\gamma)}{\gamma(1+\beta)}$, which can be rewritten as:

$$\gamma = \frac{-\lambda\phi(1-\alpha)}{A_3(1+\beta)-\lambda\phi(1-\alpha)} \tag{21}$$

Assuming a labor supply slope of $\phi = 1$, as Blanchard and Galí (2007), and that the fraction of firms that do not change prices in the current period is 0.25, i.e. $\theta = 0.25$, obtained from micro-data[6], one gets $\lambda \equiv \theta^{-1}(1-\theta)(1-\beta\theta) = 2.48$. This implies that the real wage rigidity in the Brazilian economy is $\gamma = 0.92$. From equation (8), this means that about 92% of the current wage is explained by previous wage and only 8% is due to changes in the marginal rate of substitution. This result reveals the presence of high real wage rigidity in the Brazilian economy.

4.4 Analysis of the Trade-off

In the occurrence of a supply shock, the monetary authority faces a trade-off between stabilizing inflation or stabilizing the gap between actual output and efficient output. Supposing that the goal of the monetary authority is to keep inflation constant when faced with a supply shock, the gap between actual output and efficient output shall suffer a higher decrease the higher is the real wage rigidity. This effect is shown by[7]:

$$\frac{\partial(y-y_1)}{\partial\upsilon} = \frac{d(y-y_1)/d\varepsilon_m}{d\upsilon/d\varepsilon_m} = -\frac{(1-\alpha)\Theta}{(1-\alpha)(1-\Theta)} = -\frac{\alpha\gamma}{(1-\gamma)(1+\phi)} \tag{22}$$

Substituting values for $\gamma = 0.92$, the corresponding $\lambda = 2.48$, and using $\alpha\lambda = 0.12$ to estimate $\alpha \cong 0.05$, one gets:

$$\frac{\partial(y-y_1)}{\partial\upsilon} = -\frac{0.05(0.92)}{0.08(1+1)} = -0.29$$

Thus, after a 1% increase in non-produced input prices, as long as the inflation is kept constant, the gap between actual output and efficient output shall experience a negative

[6] This value of $\theta = 0.25$ implies a price duration of 4 months, which is consistent with the 3.8 months found by Gouvea (2007) and 4.2 months estimated by Barros and Matos (2008).

[7] The solution of the differential equations that yielded (22) and (23) were taken from Blanchard and Gali (2007). It was assumed $\xi = 0$ and a random walk for *M*, such that $\Delta m = \varepsilon_m$ is a white noise.

variation of 0.29% on the first quarter, implying that the actual output will depart from y_1 [8]. The persistence of this effect is measured by the auto-regressive parameter $\Theta = 0.13$, given by equation (9).

On the other hand, if the objective is to keep the gap between actual output and efficient output constant, then the inflation shall rise, as indicated below:

$$\frac{d\pi_t}{d\upsilon} = \frac{d\pi / d\varepsilon_m}{d\upsilon / d\varepsilon_m} = \frac{\lambda\alpha\gamma}{(1-\beta\gamma)[\alpha\gamma + (1-\alpha)]} \tag{23}$$

Substituting the estimated values:

$$\frac{d\pi_t}{d\upsilon} = \frac{(2.48)(0.05)(0.92)}{[1-0.69(0.92)][(0.05)(0.92)+(1-0.05)]} = 0.31$$

A rise of 1% in the non-produced input prices leads to 0.31% increase in next period inflation. Therefore, the monetary authority might decide between allowing 0.31% increase in next period inflation, a negative variation of 0.29% in the gap between actual output and efficient output, or any combination of these two results.

5. Concluding remarks

The standard version of new Keynesian Phillips curve has been criticized for not being able to explain the trade-off between stabilizing inflation versus stabilizing the gap between actual output and natural output. Blanchard and Galí (2007) proposed a new approach to deal with this issue, showing that when real wage rigidity is incorporated into the new Keynesian framework, stabilizing the gap between actual and natural output is not the same as stabilizing the gap between actual and efficient output. From their model, it emerges a new analytical version of the Phillips curve, according to which there is a short run trade-off between stabilizing inflation and stabilizing the gap between actual and efficient output. The later is defined as the optimal level of output for an economy working in perfect competition in the goods and labor markets.

This new Phillips curve was confronted with Brazilian data to estimate the short run trade-off between inflation and output gap, analyze wage rigidity, and test restriction on the estimated coefficients imposed by the theoretical model. It was estimated by GMM due the rational expectations nature of the model. The instrument list was composed by lagged variables of the regression. The Hansen test was applied to verify the validity of the excess of instruments and did not reject the over-identifying restrictions.

The empirical results revealed that the new Phillips curve fitted very well the Brazilian data. The estimated coefficients presented expected signs and were all statistically significant. In addition, they satisfied all theoretical restrictions imposed by the model. Thus, the estimated coefficient for lagged inflation and expected future inflation were found in the intervals $[0.5,\ 1]$ and $[0,\ 0.5]$, respectively. Yet, the sum of those coefficients was statistically equal to 1 by the Wald test.

The short run trade-off faced by the monetary authority, using two calibrated parameters due to the under-identified structure of the model, was estimated. Assume that there is a 1% rise in the price of non-produced input. The monetary authority will face a decision of fighting inflation versus stabilizing the output gap. The cost of keeping constant

[8] The output gap rises in absolute value, given that $y < y_1$.

the gap between actual and efficient output is a 0.31% increase in inflation. Alternatively, by choosing to stabilize inflation, the cost in terms of output gap will be 0.29% decrease. Needless to say that intermediate choices will also be possible.

Interestingly, the lower the wage rigidity parameter, γ, the less persistent will be the short run trade-off. For the special case of $\gamma = 0$, which corresponds to fully flexible wages, the real wage is given by the marginal rate of substitution and there is no short run trade-off. In this case, the *divine coincidence* identified by Blanchard and Galí (2007) is still observed.

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