Testing New Versions of the Wage Phillips Curve in the MeMo-It Model Used by Istat

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Abstract
The Phillips curve is a research object of interest from several years. The literature proposed a series of alternative formulations: the original Phillips curve, the expectations-augmented Phillips curve, the New Classical Phillips curve, the New Keynesian Phillips curve, the Hybrid Phillips curve.
In this work we test a new version of the wage Phillips curve evaluating its goodness of fit as well as its forecasting performance for the Italian context. This version includes an error correction term representing the theoretical cointegrating relationship between wage, prices and productivity. This new specification is also applied to the Italian data ranging from 1980 to 2019.
The proposed specification of the Phillips curve has been tested both in terms of its goodness of fit and in terms of forecasting ability inside the macro-econometric model for Italian economy (MeMo-It) developed by the Italian National Institute of Statistics. Our findings confirm a good fit of the model, highlighting a similar ability of the new specification of the Phillips curve equation in explaining wage growth. Nevertheless, the results in term of forecasting performance show a relevant improvement for all the considered measures, in comparison to what obtained with the original curve specification included in MeMo-It model.

Key Words: Phillips curve, error correction model, macroeconometric model

1. Introduction

1.1 Framework

Phillips (1958) empirically identified the presence of a negative relationship between wage inflation and unemployment, using U.K. data. Since those early years, the Phillips curve has been a widely studied topic, in the economic literature. In particular, it has been studied by introducing formulations alternative to the original one. One of the elements differentiating these Phillips curve specifications is attributable to the economic relationship object of interest. For instance, the Phillips curve could be expressed as the relationship between inflation and unemployment (Samuelson and Solow, 1960). Furthermore, after the introduction of the natural rate of unemployment concept (Friedman, 1977), the Phillips curve started to be proposed by replacing the

unemployment rate with the unemployment gap. This is measured as difference between unemployment and natural rate of unemployment, as difference between the unemployment rate and the non-accelerating inflation rate of unemployment (NAIRU) (Modigliani and Papademos, 1975), or as difference between the unemployment rate and the non-accelerating wage rate of unemployment (NAWRU) (Elmeskov and MacFarland, 1993 and Elmeskov, 1994).
Rather than the unemployment, in the Phillips curve equation we could introduce the output gap. The Okun's law (Okun, 1962) justifies this choice, because we expect a negative relationship between the unemployment and the output. When, instead of the unemployment, the output gap is introduced into the Phillips curve equation, the sign of the relationship becomes positive.

Furthermore, the Phillips curve formulations could differ according to the expectation-formation mechanism. The original specification did not include expectations. This aspect started to be included during the 70s, after the occurrence of the phenomenon known as stagflation (i.e. the coexistence of both high unemployment and high inflation). The reason is that the role of expectations could explain the apparent disappearance of the Phillips curve negative relationship between inflation and unemployment observed in that period. One of the first examples moving towards this direction is the expectations-augmented Phillips curve (Friedman, 1968) that includes adaptive expectations. The New Classical Phillips curve is derived by Lucas' surprise aggregate supply function (Lucas, 1973) and it includes rational expectations. According to adaptive expectations, individuals make decision for the future on the basis of past inflation. The forecasting error is gradually adjusted over time. The rational expectations (Muth, 1961, Lucas 1972 and 1976) assume that individuals take into account all information at their disposal, and, on average, they do not make errors.
Another possible formulation of the curve is the New Keynesian Phillips curve (Roberts, 1995), which includes forward-looking inflation expectations. As for the New Classical Phillips curve, these are rational expectations, but in this case the expectations are referred to the future rather than to the current inflation. The inclusion of backward-looking expectations to the New Keynesian Phillips curve specifications leads to the Hybrid Phillips curve (Galì and Gertler, 1999). The New Keynesian Wage Phillips curve was introduced by Galì (2011).

The relevance of the Phillips curve is justified by its usefulness for policymakers. This is highlighted, for example, by the work of Eser et al. (2020). The authors focus on the relationship between the Phillips curve and monetary policy. The model consists of three equations: the IS curve, the Phillips curve and the monetary policy rule. The IS curve allows to take into account the effect of monetary policy on the economic slack. It shows that conventional monetary policies, by decreasing the interest rate, lead to an increase in consumption and to a reduction in economic slack. The impact of the reduction of the economic slack on inflation is then described by the Phillips curve equation. Inflation and wages increase due to the need of firms to increase labor, in order to produce the additional output.

1.2 Purpose

Our research topic consists in the estimation of the Phillips curve for Italian economy starting from the formulation contained in the macroeconometric model MeMo-It, i.e. the macro-econometric model used by Istat to provide forecasts for the Italian economy. This model has a block structure, as it is constituted by a series of blocks which are interacting together: supply, demand, prices, labor market. MeMo-It modelling approach is a mixture of the London School of Economics approach and of the Fair-updated Cowles Commission techniques. In order to merge theory and data, MeMo-It uses cointegration methods on dynamic sub-systems to estimate theory-interpretable and identified steady state relationships, imposed in the form of equilibrium-correction models (see Bacchini et al., 2013, for details; see Bacchini et al., 2018, for the description of the Investment block). The Phillips curve equation is included in the prices block.

With our work, we propose an alternative specification for the Phillips curve equation which is currently used in the MeMo-It model.

The introduction of this new version of the formula could lead to an improvement in the ability of the model to forecast wage growth as well as other labor market aggregates, in general. Furthermore, this could lead to an improvement in the formulation of policy scenarios. In particular, this work is focused on an initial evaluation of the new curve formulation we propose, starting by focusing on its performance.

The current formulation of the Phillips curve model presents wage growth as function of the lagged inflation, the lagged labor productivity, the unemployment gap and a dummy variable for the years 2010 and 2015. The new specification differs from the original one with respect to the inclusion of an error correction term, following what suggested by Blanchard and Katz (1999). This new term represents the cointegrating relationship between wages, price and productivity.
The original formulation and the alternative one are compared in terms of both goodness of fit and of forecasting performance. This is an additional element of novelty, as usually the focus is mainly on the goodness of fit. We expect the new specification to improve the original one according to both criteria.

The paper is structured as follows. Section 2 presents the literature review. In the following section 3 we describe the data used and the methodology of our research. Section 4 presents the results coming from model estimation and about the model evaluation. The final section provides our main conclusions as well as the main limits of our work, and suggestion of some ideas for future research.

2. Literature review

The literature on the Phillips curve is quite vast and heterogeneous with respect to the research questions that have been addressed.

Several formulations for the Phillips curve have been proposed: the original one (Phillips, 1958), the expectations-augmented Phillips curve (adaptive expectations, following Friedman, 1968), the New Classical Phillips curve (rational expectations, Lucas, 1973), the New Keynesian Phillips curve (Roberts, 1995), the Hybrid Phillips curve (Galì and Gertler, 1999) and so forth. Galì (2011) introduced the New Keynesian Wage Phillips curve equation, which provides a theoretical explanation to the original Phillips curve equation.

The Phillips curve can be analysed according to two levels: at a macroeconomic level, mainly with the times series analysis (e.g., Bulligan et al., 2017), and at microeconomic level, by means of the panel data analysis, mostly (Abdih and Danniger, 2018). It is also possible to consider both levels of analysis at the same time (as done by Bulligan and Viviano, 2017, or by Abdih and Danninger, 2018).

Looking with more detail at some specific studies, Del Boca *et al.* (2010) and Baffigi *et al.* (2015) analyzed the evolution of the Phillips curve over time for Italy. The period object of the study ranges from Italy's unification until the recent days. In particular, these authors analysed the period 1861 to 1998 and the period 1861 to 2012. The Phillips curve specification chosen consisted in a Hybrid Phillips curve. Del Boca *et al.* (2010) used OLS for model estimation. Baffigi *et al.* (2015) used the generalized method of moments (GMM), instead. The model estimated by Del Boca *et al.* (2010) pointed out that the coefficient for the output gap is not significant, whereas the scatterplots showed the presence of the expected relationship between inflation and the output gap only for the post-Second World War years (1950-1972) and for the years between 1985 and 1998. Baffigi *et al.* (2015) reached different results, as they identified the existence of the Phillips curve for all the period after the First World War.

Other studies were focused on the shape of the Phillis curve. With respect to this, Bulligan and Viviano (2017) tested the presence of non-linearities in a Hybrid Phillips curve specification. Four countries have been object of study: Italy, France, Germany and Spain. The analysis was performed from both a macroeconomic and a microeconomic point of view. As main conclusion, the presence of non-linearities in the Phillips curve was confirmed for the period following the crisis.

Several works extended the Phillips curve equation, by including some additional variables. The Phillips curve specification set by Conti and Gigante (2018), for example, included a set of control variables. Among them, it is interesting to highlight the presence of an indicator representing the financial conditions. This indicator has been constructed using principal component analysis on the basis of a set of variables capturing different aspects of financial markets conditions. Some of these variables were related to loans, prices, and bond yields. The other variables used to construct the indicator were the monetary policy rate, the CISS for euro area, and two measures of uncertainty, represented by financial uncertainty and economic policy uncertainty. Conti and Gigante (2018) also analyzed the forecasting performance by calculating the predicted values in two different ways. First, they used the observations ranging from 1999: Q1 to 2011: Q4 to estimate the model; these results were used to compute predictions for the period between 2012 and 2019. Then, they repeated the procedure by using the period from 1999: Q1 to 2014: Q4 in order to estimate the model and to compute predictions for the remaining period. In both cases, the graphical representation of actual and predicted values suggested that the inclusion of the new measures seemed to improve the forecasting performance.
In addition, they constructed a new variable to be used as replacement of the output gap and of the unemployment gap. This variable measured the gap between an indicator for the labor market conditions (LMCI) and the non-accelerating inflation rate of unemployment (NAIRU).

Recently, a new issue emerged in Phillips curve studies: the possibility of including new measures of the economic slack, rather than of the output gap or of the unemployment gap. This issue emerged from the hypothesis that the economic slack could be better captured by variables different from the ones more traditionally used. Bulligan et al. (2017) showed that this could explain the apparent weakness of the Phillips curve relationship during the recovery from the crisis period. These authors conducted an

analysis both at the euro area level and at the national level, focusing on five countries: Germany, France, Italy, Spain and Netherlands.
Two main categories of economic slack measures had been identified: supply side indicators and demand side indicators. The second category includes hours per worker, representing the intensive margin of labor. This variable was able to explain the flattening of the Phillips curve during the recovery from crisis: when the intensive margin is below its trend, the slope of the Phillips curve decreases.

Blanchard and Katz (1999) introduced an equation for wage dynamics which included an error correction term. This variable represents the cointegrating relationship between wages, prices and productivity. This term resulted to be significant for the European wage equation. Looking with more detail at the national level, for most European countries the coefficient of the error correction term was significant and negative. The opposite situation was observed for U.S., for which this component was not found to be significant.

What just presented constitutes some of the main results reached by the literature. All these works contributed to gain new insights into the study of the Phillips curve. In particular, our project aims at contributing to the existing literature by analyzing the Phillips curve in the specific framework of MeMo-It, the macro-econometric model developed by Istat. We extend the Phillips curve equation by introducing an error correction term, following what suggested by Blanchard and Katz (1999). We assess the validity of the new specification in terms of both goodness of fit and forecasting performance. This is important, as usually the focus is set on the forecasting performance only. An exception is the work by Conti and Gigante (2018), who also analyze the forecasting performance, as previously seen. However, the procedure that we adopt to assess the forecasting performance is different from their one, as we use a type of cross-validation defined forward-chaining. This consists in a sequential creation of training and test datasets, as will be shown with more details in the next section. Furthermore, in addition to the graphical comparison of observed and predicted values for the different models, we assess the forecasting performance by computing four measures: the Mean Absolute Error (MAE), the Mean Absolute Percentage Error (MAPE), the Mean Squared Error (MSE) and the Root Mean Squared Error (RMSE).

3. Data and methodology

The Phillips curve equation currently used in the MeMo-It model is expressed as follows:

$$\Delta \log(WIPCP) = \beta_1 \Delta \log(PCH_{t-1}) + \beta_2 \Delta \log\left(\frac{YO_{t-1}}{ULA_{t-1}}\right) + \beta_3 \left(\frac{UR_t - NAWRU}{100}\right) + \beta_4(D2010 + D2015),$$

where the differenced, log-transformation of wage ($WIPCP$) is function of prices (PCH), of productivity (YO/ULA), of unemployment gap ($UR_t - NAWRU$) and of a dummy variable for the year 2010 and 2015. Excluding the unemployment gap, the other variables are log-transformed and expressed in terms of first difference. Prices and productivity are lagged.
In the MeMo-It model, wage is measured using private per capita income ($WIPCP$), expressed in thousands of Euro. Prices are proxied by means of the household consumption deflator (PCH), where 2015 is the base year. Labor productivity is the ratio between GDP in volume terms (YO) and the level of employment (ULA), in thousands of Euro. The unemployment gap is computed as difference between the unemployment rate

(UR_t) and the non-accelerating wage rate of unemployment ($NAWRU$). The dummy variable $(D2010 + D2015)$ is equal to 1 for years 2010 and 2015, whereas it is equal to zero otherwise. The year 2010 represents the starting point for the recovery from the 2008-2009 crisis; 2015 corresponds, instead, to the start of the recovery from the 2011 crisis (it is also the year when the Jobs Act was introduced).

For this research, we used annual data provided by Istat and referred to the period 1980 to 2019. The choice of annual data is justified by the fact that this is the data periodicity adopted in the MeMo-It model.
The alternative Phillips curve specification tested in our work includes an additional term, consisting in an error correction term, following what suggested by Blanchard and Katz (1999). Their equation for wage dynamics is the following:

$$(w_t - w_{t-1}) = \mu a + (p_t^e - p_{t-1}) - (1 - \mu\lambda)(w_{t-1} - p_{t-1} - y_{t-1}) + (1 - \mu\lambda)\Delta y_t - \beta u_t + \varepsilon_t,$$

where wage inflation $(w_t - w_{t-1})$ depends upon the difference between expected and lagged inflation $(p_t^e - p_{t-1})$, and upon an error correction term $(w_{t-1} - p_{t-1} - y_{t-1})$, as well as upon the labour productivity growth (Δy_t) and the unemployment rate (u_t).
The variables included in this equation are similar to the ones included in the Phillips curve equation currently used for the MeMo-It model. The main differences are that the equation by Blanchard and Katz (1999) takes into account expected prices rather than current prices; moreover, it uses the unemployment rate rather than the unemployment gap. Furthermore, they include a new element, i.e. an error correction term: $(w_{t-1} - p_{t-1} - y_{t-1})$.

Following this approach, it is interesting to analyse the MeMo-It Phillips curve equation with the inclusion of the error correction term, if a cointegrating relationship between wage, prices and productivity exists for our data.
Therefore, we tested for stationarity the following linear combination by using the Augmented Dickey-Fuller (ADF) test with a drift and one lag:

$$log(WIPCP_{t-1}) - log(PCH_{t-1}) - log\left(\frac{YO_{t-1}}{ULA_{t-1}}\right).$$

The number of lags for the ADF test is chosen according to the Bayesian information criterion (BIC). The null hypothesis of unit root is rejected at a significance level of 5%. Therefore, the error correction term has been included into the Phillips curve. The new equation of the curve is expressed as follows:

$$\Delta\log(WIPCP) = \beta_1\Delta\log(PCH_{t-1}) + \beta_2\Delta\log\left(\frac{YO_{t-1}}{ULA_{t-1}}\right) + \beta_3\left(\frac{UR_t - NAWRU}{100}\right) + \beta_4(D2010 + D2015) + \beta_5(EC_{t-1}),$$

where:

$$EC_{t-1} = log(WIPCP_{t-1}) - log(PCH_{t-1}) - log\left(\frac{YO_{t-1}}{ULA_{t-1}}\right).$$

The new term, (EC_{t-1}), represents the theoretical cointegrating relationship between wage, prices and productivity.

Our research is conducted according to the following steps. First, both models are estimated using Ordinary Least Squares (OLS). Then, in order to detect which model should be preferred, two criteria are considered: the goodness of fit and the forecasting performance. The goodness of fit is assessed by comparing the adjusted *R*-squared for the two models. The forecasting performance is assessed by calculating the forthcoming four measures (computed according to the following formulas):

- the Mean Absolute Error (MAE):
  $MAE = \frac{1}{n}\sum_{i=1}^{n}|y_i - \hat{y}_i|$;
- the Mean Absolute Percentage Error (MAPE):
  $MAPE = \frac{1}{n}\sum_{i=1}^{n}\frac{|y_i - \hat{y}_i|}{y_i}$;
- the Mean Squared Error (MSE):
  $SE = \frac{1}{n}\sum_{i=1}^{n}(y_i - \hat{y}_i)^2$;
- the Root Mean Squared Error (RMSE):
  $RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}$.

In these formulas, y_i is the value of the response variable observed for time i (i = 1, …, n), while $\hat{y}_i$ is the predicted value of the response variable for the time i.

The predicted values used to compute these four measures are estimated by performing a type of cross-validation method called forward-chaining, which allows to account for the temporal dependencies among data. The procedure consists in sequentially estimating the model on a series of training datasets and in using each time the results coming from the model estimation, in order to predict the response variable for the test observation, given by the first observation following the training data. The size of the training data, initially set equal to the number of observations available until 2012, is then increased gradually by one. The iterative loop repeats until it reaches the end of the dataset. The final result is a vector of predictions for the test data that can be compared to the values actually observed, leading to the four performance measures previously listed.

4. Results

4.1 Model estimation

The estimated models are reported in *Table 1*. *Column 1* shows the results from the estimation of the original formulation included in MeMo-It model (*Mod1*), whereas *Column 2* contains the results obtained using the new alternative curve specification (*Mod2*) (note: standard errors are reported within parentheses).
The adjusted *R*-squared of the new model (0.959) is very good, but just slightly higher (+0.31%) than the one observed for the original model (0.959). Thus, the new model does not show a relevant improvement, in terms of goodness of fit, in explaining the wage growth. Even in terms of *R*-squared the two specifications show excellent, but very close results (0.961 vs 0.964).

For both models, most coefficients are significantly different from zero at a significance level of 5%:

- *lag(DlogPCH)*: p < 2e-16;
- *UR_T_NAWRU*: p =.0439, p = .0206;
- *lag(DlogYO_ULA)*: p = .006, p = .034;
- *dummy*: p = 0.0005, p = .006.

An exception is the coefficient of the error correction term, which is significantly different from zero at a significance level of 10% (-0.006; p = .088).

Table 1: OLS estimates for the original Phillips equation (*Mod1*) and the alternative Phillips curve specification (*Mod2*)

Coefficients	*Mod1*	*Mod2*
lag(DlogPCH)	0.875***	0.833***
	(0.040)	(0.046)
UR_T_NAWRU	-0.003**	-0.004**
	(0.002)	(0.002)
dummy	0.034***	0.027***
	(0.009)	(0.009)
lag(DlogYO_ULA)	0.460***	0.361**
	(0.158)	(0.163)
lag(EC)		-0.006*
		(0.003)
Observations	38	38
R^2	0.961	0.964
Adjusted R^2	0.956	0.959
Residual Std. Error	0.012(df=34)	0.011(df=33)
F Statistic	207.414***(df=4;34)	176.760***(df=5;33)
Note:	*p<0.1;**p<0.05;***p<0.01	

All coefficients' signs correspond to the initial (and to literature's) expectations. However, we highlight the presence of a positive relationship between wage growth and inflation and between wage growth and productivity growth. The sign of the coefficient for the unemployment gap is negative. Therefore, within this version of the Phillips curve, the negative relationship between wage growth and unemployment gap is confirmed. The sign of the coefficient for the error correction term is negative, as expected. According to these results, the validity of the extended Phillips curve equation suggested by Blanchard and Katz (1999) is confirmed also for Italy, with the data we have available and for the time frame analyzed.

4.2 Forecasting performance

Figure 1 shows the observed values for the whole period (1980 to 2019) and the predicted values for the last years (2013 to 2019). In particular, with *Mod1* we mean the predicted values obtained using the original model, whereas with *Mod2* we refer to the predicted values provided by using the new version of the model. We can compare with more detail the two models by focusing on the more recent period ranging from 2013 to 2019 (directly shown in *Figure 2*).

The predicted values for both models are quite close to the actual ones, but the new model (*Mod2*) seems to provide better results: the blue line is closer to the actual values line. In 2015 we notice that both models lead to an overestimation of the wage growth. This could be due to the fact that 2015 corresponds to the beginning of recovery from 2011 crisis, i.e. to an unexpected change in the trend of the series, when past data are considered.

After the initial graphical comparison between observed and predicted values, the forecasting performance is more precisely evaluated by computing the four measures previously introduced (see sect. 3): MAE, MAPE, MSE and RMSE. The results are reported in *Table 2*. The lower the value for these measures, the better is the model, as all

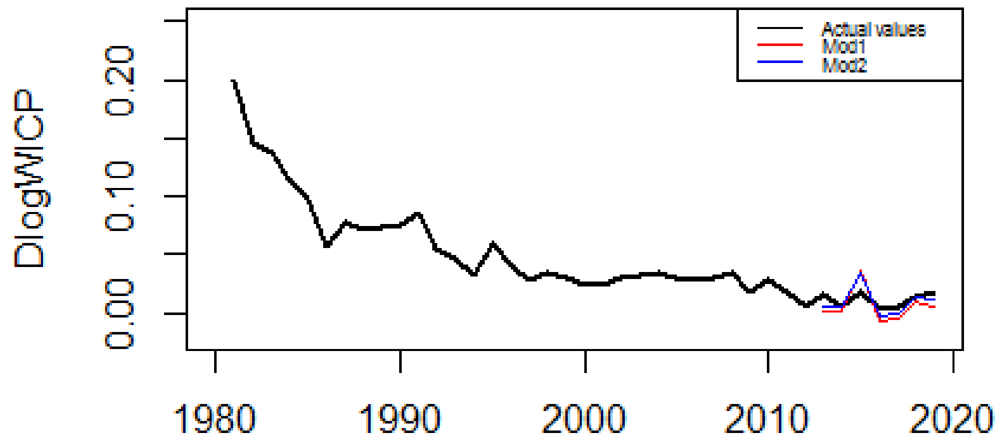

Figure 1: Actual values (1980-2019) and predicted values (2013-2019) for *Mod1* and *Mod2*. Predictions are computed for the test data, using the forward-chaining method

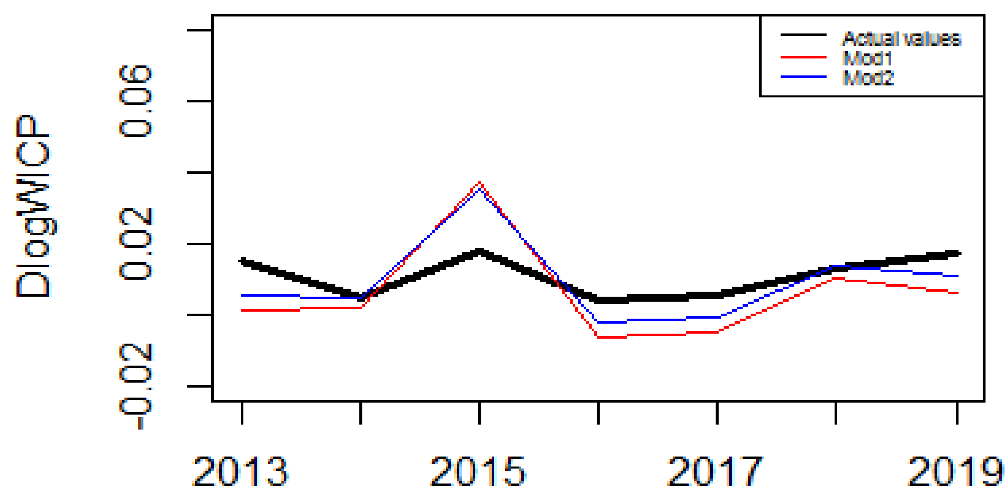

Figure 2: Zoom of Figure 1 on the actual and predicted values (2013-2019)

Table 2: Measures of prediction accuracy: *MAE*, *MAPE*, *MSE, RMSE*

Model	MAE	MAPE	MSE	RMSE
Mod1	0.00993	1.12964	0.00013	0.01129
Mod2	0.00652	0.66666	0.00007	0.00833
% change (Mod2 vs Mod1)	-34.30	-40.98	-45.48	-26.16

indexes measure the prediction error. For all the indexes, the *Mod2* reports lower values than *Mod1*. According to this result, the new model is better able to forecast wage growth: the average cut in the percentage error is equal to 36.73%, that is a relevant reduction.

5. Conclusions

Our work presents an estimation of the Phillips curve to the Italian economy exploring its impact in the framework of the Istat macroeconometric MeMo-It model. In particular, we assess the validity of an alternative Phillips curve specification of the curve including an error correction term, following the suggestion by Blanchard and Katz (1999). The linear combination between wages, prices and productivity resulted to be stationary, according to ADF test. These findings confirm the possibility of including this variable into the equation.

The new Phillips curve specification performs similarly, in terms of goodness of fit, if compared to the original model, as highlighted by a very slight increase in the adjusted R-Squared. Moreover, the coefficient for the error correction term has the expected negative sign and it is significantly different from zero (α = 0,1). Therefore, the validity of the inclusion of the error correction term following Blanchard and Katz (1999) is confirmed according to the data we used.

Looking at the evaluation of the forecasting ability, the graphical representation suggests that the predicted values for the new model are closer to the observed values, compared to the original model. Furthermore, all the measures computed to assess the accuracy of the predictions (MAE, MAPE, MSE and RMSE) present lower values for the new specification, with an average reduction of errors around 36%. This represents a remarkable performance for the new model, that is able to relevantly improve the original one in terms of forecasting ability, since it is better able to predict wage growth.
Therefore, the new model specification is able to reach better results, taking into account the considered criteria as a whole.

This work is affected by some limitations, that could be interpreted as starting points for further research development paths. One of these limits is related to the fact that the new variable is significant only at the 10% significance level: this could be due to the reduced number of data analyzed or to the wide periodicity of the observations. The study of a longer time lag or an increase of the observations periodicity could lead to an higher significance level. Thus, we suggest this option for a further development of our research. Furthermore, the impact of the inclusion of the new specification on the performance of the overall MeMo-It model has not been assessed yet. This is another possible idea to further develop in future research. For the future, we can also suggest to test and study the effects of some alternative curve specifications, different from the one we provided in our work and/or the assessment of the validity of our results with new data that will become available in the future.

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