From missing disinflation to missing inflation: Understanding the recent path of inflation in the US

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Abstract

- We study two recent episodes in which the evolution of inflation in the United States cannot be explained with a standard Phillips Curve framework. We refer to the first episode as missing disinflation (2009IV:2011IV), because observed inflation was higher than what the standard Phillips Curve predicts; and we call the second one missing inflation (2015I:2015II), because observed inflation was lower than predicted.
- We replicate the model from Ball and Mazumder (2011) to obtain predictions of inflation and empirically identify the timing of the episodes. Then we extend the baseline model in various dimensions to identify the drivers of inflation in these episodes.
- More specifically, we explore: the impact of shocks in energy prices by using inflation specifications that exclude this component, the role of inflation expectations, different measures of economic slack and the importance of structural factors that might be flattening the Phillips Curve, such as globalization.
- We find that shocks in energy prices and globalization have an important role in the episodes of missing disinflation and missing inflation. Besides, we also find that the short-term unemployment rate, instead of the total unemployment rate, better captures the slack of the US economy and, hence, the ability of the Philips Curve to explain the evolution of inflation during both episodes improves.

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1. Introduction

Inflation has experienced a significant moderation in advanced economies during the last few decades. For instance, in the United States, inflation has decreased from 5.3% on average in the preGreat Moderation era (1960-1983) to 2.7% in the postGreat Moderation era (1984-2016). During the last few decades, the volatility of inflation has also been lower. The coefficient of variation[1] has decreased from 0.7 to just 0.5. There are two main explanations in the literature for this phenomenon. The first one attributes it to *good luck*: a reduction of exogenous shocks that affect the prices of oil and other raw materials. These shocks were especially intense during the 70s. The second explanation points to the better conduct of monetary policy, coinciding with Chairman of the Federal Reserve Paul Volcker and his successor Alan Greenspan, who managed to reduce and stabilise inflation.

Moreover, the evolution of inflation has become less dependent on changes in the unemployment gap. Precisely, we are interested in the study of two recent periods when inflation has been inconsistent with the predictions of a standard Phillips Curve in the US economy. The first one was during the Great Recession, between 2009 and 2011, when inflation did not fall as much as the Phillips Curve predicts: while the unemployment gap increased, inflation remained at moderate levels. Thus, we refer to this episode as the *missing disinflation period*. The second episode occurred during 2015, when inflation remained below what the Phillips Curve suggests: the noticeable reduction in the unemployment gap was not accompanied by a rise in inflation. We refer to this episode as the *missing inflation period*.

The structure of the paper is organised as follows. First, we estimate a baseline Phillips Curve in order to formally identify the episodes in which the behaviour of inflation cannot be explained solely with the changes in the unemployment gap. Once these episodes have been identified, we modify the baseline Phillips Curve in four main ways. First, we use three alternative definitions of inflation. We use two measures of core inflation: the one excluding food and energy, and the one that also excludes the shelter component, and an alternative measure of inflation: the personal consumption expenditure (PCE). Second, we include household surveys as our measure of expected inflation. Third, we change the specification of the unemployment gap for other measures of slack in the economy. Fourth, we explore the hypothesis that globalization is making inflation less responsive to national slack by adding some of the traditional control variables from the literature. We conclude with a

[1] The coefficient of variation is defined as the ratio of the standard deviation to the mean.

discussion on whether these extensions have closed the gap between the observed and predicted inflation values during the two reference periods.

2. Baseline Phillips Curve

In an economy with nominal rigidities, the evolution of inflation is negatively related to the unemployment gap in the short run. The equation that formally captures this relationship is known as the Phillips Curve.

As first shown empirically by William Phillips for the case of the United Kingdom, and extended later by Samuelson and Solow, an economy with a high unemployment rate experiences lower inflation pressures. On the contrary, an economy with a low unemployment rate will experience higher inflationary pressures. Nowadays, this simple relationship has proved to be present in the short run, that is, when nominal rigidities still play a role. Friedman (1968) put forward the relevance of inflation expectations. He also noticed that there is a level of unemployment at which inflation remains constant, a concept later defined as the natural rate of unemployment (NAIRU) by Modigliani and Papademos (1975). Lastly, Clarida, Galí and Gertler (1999) and Blanchard and Galí (2007) prove that the Phillips Curve can be obtained from a dynamic general equilibrium model with nominal frictions.

After all the refinements, the standard Phillips Curve is still a simple equation that links the deviation of inflation from its expected value to the difference between the observed unemployment rate and the natural rate of unemployment (the unemployment gap):

$$\pi_t - E_t[\pi_{t+1}] = \beta \hat{u}_t + \epsilon_t \tag{1}$$

where π_t is the inflation rate year on year, $E_t[\pi_{t+1}]$ is the expected inflation for next year and $\hat{u}_t$ is defined as the difference between the observed unemployment rate and the natural unemployment rate.

Inflation in the United States has averaged 3.8% from 1960 to the present (2016)[2]. In Figure 1 we can appreciate that there have been two periods when inflation pressures were particularly high. From 1973 to 1975, inflation was above 10% and from 1978 to 1982 it was above 11% on average. These two episodes coincide with oil shortages stemming from wars in the Middle East. As we

[2] Inflation refers to the year-on-year variation in the Consumer Price Index in the United States provided by the Bureau of Labor Statistics.

discussed in the introduction, since 1984 inflation has been lower than in earlier decades and it has even reached negative figures.

The other main variable of the Phillips Curve, the unemployment gap, is defined as the difference between the observed unemployment rate and the natural rate of unemployment[3]. The average unemployment rate in the US between 1960 and 2016 is 6.1%. On the other hand, the average natural rate during the same period is 5.6%. We show the evolution of these variables in Figure 2.

Following Ball and Mazumder (2011) we estimate the Phillips Curve using Ordinary Least Squares (OLS) and robust standard errors.

$$\pi_t - \frac{1}{4}(\pi_{t-1} + \pi_{t-2} + \pi_{t-3} + \pi_{t-4}) = \beta \hat{u}_t + \epsilon_t \quad (2)$$

where $\hat{u}_t \equiv u_t - u_t^*$

This specification assumes that agents create their expectations of current inflation by looking at past inflation, especially at recent figures. This behaviour is captured with the average of observed inflation during the last four quarters. Thus, if inflation last year was 2% on average, then they expect it to be 2% for the next quarter too. We run this regression with data from 1960I to 2007IV in order to replicate the results from Ball and Mazumder (2011). Initially we exclude the period of the Great Recession, when unemployment gaps rose sharply, in order to obtain a comparable benchmark on which we then build up extensions and modifications. The results from the regression are presented in Table 1.

Table 1 1960-2007

	CPI Inflation			
Variable	β	SE(β)	t	95% confidence interval
Unemployment gap	-0.51**	0.05	-10.04	[-0.609 -0.408]
Observations	192			
Root MSE	1.00			
R-Squared	0.3050			

*p < .05. **p < .01.

[3] The Congressional Budget´s Office (CBO) estimate of the natural (or equilibrium) rate of unemployment is the non-accelerating inflation rate of unemployment (NAIRU), which is the rate of unemployment consistent with a stable rate of inflation. The CBO estimates the NAIRU using the historical relationship between the unemployment rate and changes in the rate of inflation. Other researchers use different estimates of the natural rate, such as the average historical rate of unemployment.

We find that the coefficient of the unemployment gap is negative and significant, -0.51, which means that for an increase of 1 percentage point in the unemployment gap, inflation falls 0.51 percentage points below the expected value. These results are in line with the Phillips Curve. As predicted, an increase of economic activity above its potential, that is, a negative unemployment gap, increases inflation.

Using equation (2) we define a threshold of $\pm$ one standard deviation of the average prediction errors. This allows us to formally identify the periods when inflation has evolved differently from what the standard Philips Curve predicts[4]. We consider only episodes when inflation was outside the threshold for at least two consecutive quarters. This has happened four times during the last decade. The first one from 2006IV to 2007I, when inflation averaged 2.2% but the Phillips Curve predicted 3.7%; the second one from 2008IV to 2009II, when inflation averaged 0.2% and the Phillips Curve predicted 2%; the third one from 2009IV to 2011IV, the longest episode and the only one with inflation above predicted (positive forecast error); and the fourth one from 2015I to 2015II. We show it graphically in Figure 3. We are interested in the study of the last two episodes. The third one because of its length has indeed attracted much attention in the academic literature; see, for instance, Ball and Mazumder (2014), Coibion and Gorodnichenko (2015), Gordon (2013). The last one because it is recent and it has been somewhat less examined; see, for instance, Abdih et al (2016) for a recent analysis of the determinants of US core inflation.

The episode of *missing disinflation*, from 2009IV to 2011IV, corresponds to a period when the unemployment gap reached a maximum level of 4.9% and stayed close to 4% until the end of 2011. Nonetheless, inflation remained above 2% on average during this period, whereas the Phillips Curve predicted a negative inflation of -1%. We also present results for a dynamic forecasting exercise, that is, from the beginning of the episode, the expectations variable is generated endogenously within the model without incorporating any new information about observed inflation. The dynamic prediction for inflation during this first episode falls to -6.2%.

Regarding the episode of missing inflation, in 2015 the unemployment gap in the United States fell to 0.10%, the same level as before the Great Recession. Yet inflation remained at low levels, 0% on average, whereas the Phillips Curve predicted 1.1% (1.3% with the dynamic forecasting exercise). In Figure 4 we can easily appreciate the difference in both episodes.

[4] We work with a forecast horizon of one quarter.

In the following sections we extend the model in four dimensions in order to better understand the determinants of inflation during these two episodes.

3. Inflation specifications

In this section we explore how the results change when we use different price indexes. This allows us to see whether temporary shocks to energy and food prices or the different indexation methods can help to solve the puzzles.

We run regression (2) using three alternative inflation variables. We use core inflation, which excludes the energy and food components, core inflation without rents and finally the Personal Consumption Expenditure inflation (PCE), the Fed´s preferred measure of inflation. The first two exclude some of the most volatile components of inflation while the PCE, as opposed to the CPI, captures how the composition of spending changes over time. As shown in Table 2, the coefficient of the unemployment gap is significant at the 1% level with each inflation measure.

Table 2	1960-2007								1969-2007				1961-2007			
	CPI Inflation				Core inflation				Core inflation without rents				PCE Inflation			
Variable	β	SE(β)	*t*	*95% confidence interval*	β	SE(β)	*t*	*95% confidence interval*	β	SE(β)	*t*	*95% confidence interval*	β	SE(β)	*t*	*95% confidence interval*
Unemployment gap	-0.51**	0.05	-10.04	[-0.609 -0.409]	-0.39**	0.06	-6.43	[-0.512 -0.271]	-0.27**	0.07	-4.06	[-0.397 -0.137]	-0.37**	0.05	-7.92	[-0.464 0.279]
Observations	192				192				156				188			
Root MSE	1.00				0.93				0.99				0.82			
R-Squared	0.31				0.23				0.11				0.26			

*p < .05. **p < .01.

Observed inflation from the fourth quarter of 2009 to the fourth quarter of 2011 was always above predicted inflation regardless of the measure of inflation used. Prices went up by between 1.4% (core inflation) and 2.3% (CPI inflation), whereas predicted inflations were generally negative, between -0.3% (core inflation) and -1% (general inflation), except for a positive advance in core inflation without rents of only 0.9%. In all specifications, dynamic forecasting yields negative inflation figures. Hence, the missing disinflation period is not a direct result of a shock to energy or food prices or different indexation mechanisms. See Figure 5.

On the other hand, the episode of missing inflation changes dramatically with different inflation variables. The CPI and the PCE inflation rates were lower than the inflation predicted by the Phillips Curve. However, for the core inflation rate and the core inflation rate without rents, we observe quite the opposite: they were in line with the predictions of the Philips Curve. This phenomenon leads us to think of a particularity of this last episode: the fall in energy prices. Among all of the components of the CPI and PCE, the energy component was by far the one that experienced the largest fall and that explains why core inflations where higher. See Figure 6.

4. The role of inflation expectations

In this section we use a different measure of expectations in our regression. Instead of assuming that agents form their expectations about inflation on the basis of previous values of inflation, a behaviour that is also known as adaptive expectations, we use direct measures of agents' expectations taken from surveys.

The reason for using this alternative definition of expectations is as follows: adaptive expectations incorporate only past information, hence ruling out the possibility that agents also incorporate current information in the formation of their expectations. For instance, shocks to oil prices will be incorporated into agents' expectations who will alter their behaviour as a consequence of these shocks. Also, regime changes between periods will not be captured by simple backward looking expectations. A good example of this is when monetary authorities improve their commitment to rein in inflation.

There is also an econometric argument originally pointed out by Sargent and Wallace (1975) regarding the use of backward-looking inflation expectations: *"The usual method of modelling expectations in macroeconometric models - via a distributed lag on the own variable - leaves it impossible to sort out the scalar multiplying the public's expectations from the magnitude of the weights in the distributed lag on own lags by which expectations are assumed to be formed. Therefore, the coefficients on expectations are generally underidentified econometrically."* However, this point is not particularly relevant for our exercise. We discuss it in Appendix B.

We think it is appropriate to use inflation expectations that directly measure agents' expectations of inflation via surveys. Our Phillips Curve would be slightly different from (2):

$$\pi_t - E_t[\pi_{t+4}] = \beta \hat{u}_t + \epsilon_t \qquad (3)$$

where $\hat{u}_t \equiv u_t - u_t^*$

To estimate equation (3) we take the inflation expectations that agents have in period t about inflation one year ahead (t+4 since we are working with quarterly data). This means that expectations about inflation for the next year that agents have in the present affect current inflation. For instance, if an employer is negotiating a new contract with his/her employees, the latter might ask for a higher wage if they expect prices to be higher next year in order to maintain their purchasing power. Moreover, the employer will be more willing to accept this raise in wages because he/she expects prices to be higher too and thus to increase his/her revenues and maintain profits. In this example, the economy will experience a raise in current inflation because of the expectations that agents have of higher inflation in the future.

We use the household inflation expectations surveys from the University of Michigan. Ideally we would employ inflation expectations from firms, given that they govern price-setting in the economy. However, these are not available. There are several direct measures of inflation expectations available and also they can be inferred from financial instruments. However, as argued by Coibion and Gorodnichenko (2013), households' inflation expectations are likely to be the best proxy for firms' expectations on inflation.

In Figure 7 we can appreciate that households' inflation expectations did not only have a higher average value than the backward-looking measure of inflation expectations during the two episodes under study, but they also went up during the first period of missing disinflation.

We use the households' inflation expectations from the University of Michigan surveys to run the regression starting in 1984. As shown in Table 3, the coefficient of the unemployment gap becomes insignificant. However, this is partially explained by the shorter sample of the data compared to the baseline. We investigate the response of inflation to the unemployment gap during different time periods in more detail in Section 6.

Table 3

	1984-2007			
	CPI Inflation			
Variable	β	SE(β)	*t*	*95% confidence interval*
Unemployment gap	0.03	0.08	0.41	[-0.128 0.194]
Observations	96			
Root MSE	0.73			
R-Squared	0.0015			

*p < .05. **p < .01.

Nonetheless, it is remarkable that when inflation expectations are used, the missing disinflation episode is no longer a puzzle. The predicted values from the Philips curve are now in line with the observed data. On the other hand, during the missing inflation episode, including inflation expectations in the specification overpredicts inflation. See Figure 8 to have a better understanding of the role of expectations in both episodes.

Summing up, one could think that inflation expectations were an important factor during the missing disinflation episode. Even if positive and large unemployment gaps emerged due to the Great Recession, agents were still convinced that inflation was going to be positive and this indeed exerted lower downward pressure on prices. Coibion and Gorodnichenko (2013) argue that households' expectations grew during this period driven by the sharp increase in oil prices.

5. Measures of slack

In this section we explore whether introducing some alternative measures of economic slack can shed some light on these puzzling episodes. Slack is usually defined as the resource utilisation intensity of an economy. Economic theory predicts that costs rise when firms make use of labour and capital intensively. Increased costs are then passed on to prices. However, slack is not observable and either some proxy is used or it is estimated in order to gauge it. There are several readily available series usually used as proxies for slack, the standard one being the unemployment gap. We test their usefulness in predicting inflation during the episodes of missing disinflation and missing inflation. We also use alternative measures of slack and discuss whether these are better suited to explain inflation dynamics.

5.1. Short-term unemployment

A recent development in US labour markets post-financial crisis is the sharp increase in the rate of long-term unemployment, defined as those who are out of work for more than 27 weeks as a share of the labour force. In Figure 9 we show the evolution of the unemployment rate in the US as well as the long-term and short-term unemployment rate.

The literature has long-recognised the hysteresis-like effects of long-run unemployment; see for instance Blanchard et al (2015). This makes the long-term unemployed not to be considered viable applicants for jobs. This in turn causes them to either remain unemployed, further decreasing the chances of finding a job, or simply to make them stop searching for a job and move out of the labour force.

We present some evidence of the shift in the Beveridge Curve (BC) that has occurred since 2009. This curve derives from the canonical model of matching in labour markets by Pisarides (2000).

According to this framework, the number of job openings is negatively related to the unemployment rate. When demand conditions worsen, unemployment rises and incentives for firms to post vacancies diminish. This behaviour corresponds to a movement along the curve

On the other hand, shifts in the curve to the left are associated with a better matching efficiency as the vacancies are covered faster for any given unemployment rate.

Figure 10 depicts the BC for the US using monthly vacancy data from the Job Openings and Labor Turnover Survey (JOLTS), which is available since December 2000.

For the long-term unemployed there is a clear parallel shift to the right of the BC starting in 2009 which suggests that the Great Recession has had an effect on the matching efficiency of the labour market through the long-term unemployed. As acknowledged by Dickens (2009) "*If these changes [in the Beveridge Curve] do reflect changes in the efficiency of the functioning of the labor market then these should correspond to large changes in the natural rate*". However, it is difficult to translate these shifts into changes in the natural rate[5].

Gordon (2013) and more recently Ball and Mazumder (2014) have argued that detachment from the labour force makes the long-term unemployed exert less downward pressure on wages. Hence, a simple way to link shifts in the BC to changes in predicted inflation is to use short-term unemployment as an independent variable in our main regression, as in equation (4).

$$\pi_t - \frac{1}{4}(\pi_{t-1} + \pi_{t-2} + \pi_{t-3} + \pi_{t-4}) = \beta \hat{u}_t^{Short-term} + \epsilon_t \qquad (4)$$

where $\hat{u}_t^{Short-term} \equiv u_t^{Short-term} - u_t^*$

In Figure 11 we see that when we use the short-term unemployment rate instead of the total unemployment rate in the regression, the average predicted value of inflation for the first period is 1%, as opposed to -1% in the baseline regression. However, short-term unemployment does a worse job of explaining the missing inflation period than the baseline regression.

By construction, the short-term unemployment rate is always lower than the total unemployment rate. Therefore, one could think that if it does a better job at explaining the missing disinflation period it is due to the fact that short-term unemployment has a lower level than total unemployment and, hence, inflation pressures should be higher. We test this by running equation (5), which uses

[5] See for instance Dickens (2009) and Daly et al. (2011) for attempts to link changes in the Beverdige Curve to changes in the natural rate of unemployment.

long-term unemployment. In this case, the unemployment gap is not significant and the value of the coefficient is about 24 times smaller, as can be seen in table 4.

$$\pi_t - \frac{1}{4}(\pi_{t-1} + \pi_{t-2} + \pi_{t-3} + \pi_{t-4}) = \beta \hat{u}_t^{Long-term} + \epsilon_t \quad (5)$$

where $\hat{u}_t^{Long-term} \equiv u_t^{Long-term} - u_t^*$

This suggests that the detachment of the long-term unemployed from the labour force was a contributing factor to why inflation failed to recede during the missing disinflation period.

Table 4

1960-2007

Variable	CPI Inflation				CPI Inflation			
	β	SE(β)	*t*	*95% confidence interval*	β	SE(β)	*t*	*95% confidence interval*
Short-term unemployment gap	-0.48**	0.07	-7.21	[-0.61 -0.35]				
Long-term unemployment gap					-0.02	0.02	-0.94	[-0.05 0.02]
Observations	192				192			
Root MSE	1.07				1.20			
R-Squared	0.20				0.01			

*p < .05. **p < .01.

5.2. Labour force participation

In this section we analyse a factor that suggests that the unemployment gap might be larger, the opposite of what has been analysed in the previous section. The labour force participation rate went from 66% in 2006 to 62.6% in May 2016. This steep decline of the participation rate in the US labour markets after the financial crisis has been sizeable even when we take into account long run demographic trends.

As suggested by Aaronson et al. (2014) this could mean that the amount of slack present in the economy is not fully captured by the unemployment gap. Potentially, many workers have abandoned the labour force due to the economic downturn, which suggests a higher slack than what the unemployment rate implies. Although modelling the structural forces that drive the participation rate is beyond the scope of this paper, we provide some simple estimates which yield similar results to those of other studies and that suffice to illustrate the effect of decreased participation on inflation during the episodes in question.

Aaronson et al. (2014) find that between 0.24 and 1 percentage points of the decline of the participation rate are cyclical. Shierholz (2012) finds that between 2007 and 2011 two-thirds of the decline was due to the cyclical impact of the Great Recession. An analysis from the White House Council of Economic Advisers finds that 1.6 percentage points of the decline in participation between 2007 and the second quarter of 2014 are due to population aging.

Although there is a high level of uncertainty surrounding the estimates, all of the evidence suggests that the amount of slack in the US labour market is actually higher than what is implied by the headline unemployment rate. Our estimates suggest that 1.6 percentage points, or about half of the decline in participation between 2007 and May 2016, is not due to demographic factors. In order to try to capture this extra slack we calculate a demographic-adjusted participation rate to measure to what extent the decline in the labour force has been due to demographic factors. We do so by fixing the participation rate of various sex and age groups prevalent in 2005III and letting the population distribution vary. We choose this period because participation was relatively flat before the Great Recession and hence cyclical factors are less likely to be important. Furthermore, it is the last time the economy was at full employment according to the Congressional Budget Office (CBO), so we can assume that this is the participation rate consistent with full employment. This is important because, as shown by Erceg et al. (2013), the participation rate varies with the business cycle, decreasing when unemployment is high.

We can estimate the size of the decline in participation due to the economic downturn as the difference between the actual decline and the decline due to demographic reasons. In Figure 12 we can see that approximately since the onset of the financial crisis, the participation rate has been below its demographic-implied trend.

What drives the results is the increase in the population share of those aged 55 and above, who tend to have the lowest participation rates, at the expense of prime-aged workers who have the highest participation rates.

To see how this extra slack affects inflation during our episodes in question we have to incorporate it into equation (2). One way to do this is to augment the unemployment rate by including those who are out of the labour force for cyclical (non-demographic) reasons. In other words, we consider those discouraged from the labour market as unemployed. However, some caution is warranted and the assumptions must be made clear. Some of those out of the labour force due to the economic downturn may never return to the labour force regardless of the economic situation if, for instance, they have reached retirement age. Furthermore, as mentioned before, there may be other structural forces driving the participation rate that we are not able to adjust for. For these reasons it is adequate to think of this augmented unemployment as an upper bound estimate of slack.

With the augmented unemployment as a right hand-side variable, we can compute the predicted inflation for both periods using the coefficients from the baseline regression. We opt not to re-run the regression because we do not think it is reasonable to assume that the baseline reference participation rates for the different demographic groups as of 2005III are representative of very distant periods as far as the 1960s. If this extra slack is present, then the low levels of inflation experienced during the missing inflation period are easier to understand. However, the results show that this model predicts an even lower inflation rate for the missing disinflation period as can be seen in Figure 13.

5.3. The natural rate of unemployment

In this section we investigate the consequences of demographic and participation rate changes on the natural rate of unemployment and how a different natural rate has implications for our measure of the unemployment gap and, in turn, inflation. A consequence of the changes in participation and in the population shares of different groups is that the composition of the aggregate labour force has evolved over time and should have an effect on the natural rate of unemployment.

It is an empirical regularity that the older age groups have a lower unemployment rate and that groups with higher education have lower unemployment rates. Using data from the Bureau of Labor statistics (BLS) on population disaggregated into sixteen sex and age groups and separately into four educational attainment groups, we compute two demographic-adjusted natural rates of unemployment.

The demographic-adjusted natural rates of unemployment are simply an unemployment rate weighted by the share of the labour force of each demographic group. The unemployment rate of each group is fixed to some reference value, again 2005III, and then the shares of each demographic group are allowed to change over time. A drawback of this method is that the labour force share of a demographic group is mechanically linked to that group´s unemployment rate. As noted by Barnichon and Mesters (2015), the flows from non-participants in the labour force to employment or unemployment affect both the labour force share and the rate of unemployment (and vice versa). However, we think this method provides good guidance insofar as the labour force share of a demographic group is predominantly determined by the age-structure of the labour force and hence we will place more emphasis on the sex-age-adjusted series than on the ones adjusted only for educational attainment.

A simple visual inspection of the series plotted against the CBO natural rate, see Figure 14, shows that up to the financial crisis the series are remarkably similar. However, after that, the CBO natural rate shows a hill shape, peaking by the end of 2011, while the demographically adjusted series continues its descent.

If we make the assumption that the natural rate is driven only by demographic factors, we can see how the results of our main regression would change with these alternative measures of the natural rate. To do so we plug the adjusted series by age and sex into the baseline regression and compute the predicted values of inflation[6]. Again, we deem this to be a better approach than running the regression again because the reference unemployment rate is more likely to be representative of the natural rate in years close to the reference period of 2005III but not for very distant periods.

In Figure 15 we see that, despite considerably different paths for the adjusted natural rate based purely on demographic factors, the predicted values of inflation are very similar to those of the main regression and do not help to explain either of the episodes. No improvement in the predictions is found when we perform the same exercise using household expectations as our expectations variable. These results suggest that changes in the natural rate due to demographic changes are not likely to be able to account for either the missing inflation or the missing disinflation.

However, some concerns need to be addressed before drawing conclusions from this exercise. First, both series show a downward trend and if we were to combine them, the decrease in the natural rate would be probably somewhat larger than what is implied by each of the series separately. This is indeed what Aaronson et al. (2014) find when they perform a similar exercise with data disaggregated by sex, age and education from the Current Population Survey (CPS). Second, the natural rate will change for reasons unrelated to demographics and it is likely to increase during and immediately after recessions, as we mentioned in the previous section. That leads us to believe that the natural rate did not fall as much as implied by demographic factors. These two concerns work in opposite directions and to some extent they will cancel each other out.

[6] We do not present the results for the series adjusted for education because the results are qualitatively similar.

Finally, estimates of the natural rate and its time variation are remarkably imprecise and are far from robust (Staiger, Stock and Watson 1997a, 2001; Stock 2001) and we do not claim that ours are any different.

For instance, using a conventional specification, Staiger, Stock and Watson (1997b) estimated a natural rate in 1990 of 6.2 percent, with a 95 percent confidence rate; the interval was between 5.1 and 7.7 percent. To give an example of how wide this margin is, if the natural rate was 1.1 p.p. lower (as in the example above) as of 2016I than the 4.9% that the CBO estimates, then our baseline regression would predict an inflation of -0.4% for the same quarter. This is far below the observed value of 1.06%. On the other hand, a natural rate 1.5 p.p. greater than the CBO estimate as of 2016I would predict, according to the baseline Phillips Curve we estimated, that inflation should be 0.9%.

That is not to say that any estimation of inflation incorporating the natural rate is doomed to fail but that measurement problems of the unobserved natural rate are likely to be present in most Phillips Curve regressions and should be taken into consideration.

5.4. Other measures

Finally, we report the results when we run the regression using some widely used measures of slack as an alternative to the unemployment gap in table 5.

Table 5	1967-2007				1984-2007			
	CPI Inflation				CPI Inflation			
Variable	β	SE(β)	*t*	*95% confidence interval*	β	SE(β)	*t*	*95% confidence interval*
Constant	-16.79**	1.88	*-8.91*	*[-20.571 -13.071]*				
Capacity utilisation rate	0.21**	0.02	8.92	[0.160 0.251]				
Output gap US					0.12*	0.05	2.30	[0.015 0.219]
Observations	164				96			
Root MSE	1.04				0.77			
R-Squared	0.35				0.06			

*p < .05. **p < .01.

The first alternative measure is the capacity utilisation rate estimated by the Federal Reserve. It is defined as the actual level of output over the greatest level of output a plant can maintain within the framework of a realistic work schedule, after factoring in normal downtime and assuming sufficient availability of inputs to operate the capital in place. When we run the baseline specification with the capacity utilisation rate as a measure of slack we observe, Figure 16, that it is a better predictor of inflation than the unemployment gap during both episodes. The coefficient on the capacity utilisation rate is 0.2 and significant at the 1% level of significance.

The second alternative measure is the output gap. That is the difference between the observed output and potential output. Here we use the series estimated by Oxford Economics. Due to the length of the output gap series, we have to run the regression starting in 1984. The coefficient is 0.12 and significant at the 5% confidence level. The predictions are somewhat better than the baseline, as can be seen in Figure 17, although not dramatically different.

6. Flattening and globalization

It has been argued that the slope of the Phillips Curve has decreased over the last few decades. Some papers even argue that in recent years it cannot be rejected that β=0.[7] This phenomenon is called the flattening of the Phillips Curve. We analyse this phenomenon, and we show the importance of adjusting for other variables, apart from the unemployment gap, to understand the dynamics of inflation in recent decades. An important factor that might explain the lower sensitivity of inflation with respect to the unemployment gap or other measures of slack is globalization . An economy that is more integrated into the international supply chains might have a lower β in equation (2): lower unemployment gap will exert lower pressure on inflation, and vice versa. We try to capture the effects of globalization on our baseline Phillips Curve in two different ways.

First, we introduce a measure of global output gap. As suggested by Fisher (2005), in a globalised world a country's inflation also depends on its trading partners' output gaps instead of just its own. If this were the case, we would expect US inflation also to react to changes in global slack.

Second, we adjust for the inflation of imported goods. This exercise, a part from adjusting for the potential growing importance of global economic conditions, also captures external shocks on energy prices. As we have seen, this is an important factor for understanding the missing inflation period.

6.1. Flattening

The main coefficient of the Phillips Curve, the β in equation (2), is highly dependent on the time horizon over which we run the regression. When we apply a time range from 1960 to 2007 in the baseline regression, like Ball and Mazumder (2011), the coefficient is both relevant and significant at

[7] IMF (2013), Kuttner and Robinson (2008), Coibion and Gorodnichenko (2015).

a 1% level. However, if we start at 1984, when the Great Moderation period starts in the US, this coefficient drops notably from -0.51 to -0.21. Hence, although still significant at the 5% level, the slope of the Phillips Curve is lower after the post-Great Moderation era. Moreover, this coefficient stops being significant when we run the regression from 1995. Lastly, if we also include the years 2008 to 2015 in the regression, the main coefficient drops for all the different time specifications. In Figure 18 we can easily see how the time horizon affects our main coefficient.

In order to show the flattening of the Phillips Curve, we run a rolling regression of the baseline model with a 10-year window, that is, 40 observations. We can appreciate that nowadays this coefficient is not different from 0 and that this evolution has been gradual since the 80s. For instance, in 2003, that is the window between 1994 and 2003, the coefficient stopped being significant at the 5% level, with the exception of the year 2009. We present the results of this rolling regression in Figure 19.

The previous findings suggest that, in recent decades, the importance of other variables besides the unemployment gap in determining the evolution of inflation is growing. In the following sections, we try to capture the effects of globalization.

Regarding the episode of missing disinflation, a less relevant coefficient of the Phillips curve would explain why inflation remained very high. Whereas for the episode of missing inflation, the different time range does not help at all to explain the low inflation experienced, mainly because during this period the unemployment gaps were very close to 0 and because the main reason why inflation was so low in this period is the drop in oil prices, as we have already shown. In Figure 20 we show the implications for our episodes in question.

6.2. Globalization

We now introduce two main approaches to adjusting for a well-discussed line of theory explaining the phenomenon of flattening in the Phillips Curve: globalization. One way is to use a global slack measure instead of the local one used so far and the other way is to incorporate the variable of imported inflation into the regression.

6.2.1. Global output gap

In this section we incorporate into the baseline regression the global output gap, which is the difference between the observed real output growth and the potential real output growth. The results are very similar to the ones obtained when we used the unemployment gap as a measure of slack. The sample in this case includes years 1984 to 2007 due to data availability. Of course, in this case the coefficient is positive because the higher the slack, the more positive the output gap is.

$$\pi_t - \frac{1}{4}(\pi_{t-1} + \pi_{t-2} + \pi_{t-3} + \pi_{t-4}) = \beta \hat{y}_t + \epsilon_t \qquad (6)$$

where $\hat{y}_t \equiv y_t - y_t^*$

$$\pi_t - \frac{1}{4}(\pi_{t-1} + \pi_{t-2} + \pi_{t-3} + \pi_{t-4}) = \beta \hat{y}_t^{OECD} + \epsilon_t \qquad (7)$$

where $\hat{y}_t^{OECD} \equiv y_t^{OECD} - y_t^{OECD*}$

We start substituting the local output gap of the US with the output gap of the OECD countries, which is representative of the main trading partners of the United States. When doing this, the main coefficient of the regression does not change much (0.118) but it has important implications for the predicted inflation, especially during the missing disinflation period. This is so because the output gap of the OECD economies did not fall as much as the US output gap did and therefore downward inflation pressures were lower using this specification. On the other hand, the missing inflation episode is very similar with both specifications because not only is the coefficient almost identical but the levels of output gap were similar too.

Table 6	1984-2007				1984-2007				1984-2007			
	CPI Inflation				CPI Inflation				CPI Inflation			
Variable	β	SE(β)	*t*	*95% confidence interval*	β	SE(β)	*t*	*95% confidence interval*	β	SE(β)	*t*	*95% confidence interval*
Unemployment gap	-0.21*	0.10	-2.16	[-0.397 -0.017]								
US Output Gap					0.12*	0.05	2.30	[0.015 0.219]				
OECD Output gap									0.12*	0.06	1.98	[-0.000 0.233]
Observations	96				96				96			
Root MSE	0.77				0.77				0.78			
R-Squared	0.05				0.06				0.03			

*p < .05. **p < .01.

We also use a specification that includes both output gaps but the explanatory power does not increase much (from 0.056 to 0.06) and the implications for the episodes in question remain equal.

In conclusion, like Ball (2006), we do not find any remarkable evidence suggesting that globalization has been more important now than in the last decades because of the similarity of both coefficients (local and OECD countries output gap) and the little increment in the R-Squared when comparing the regression with both output gaps and the one including only the local output gap. Nevertheless, it does make a difference for the missing disinflation period to take into account a more global output gap instead of the local one, but only due to the softer fall of this variable compared to the local one during the Great Recession, as seen in Figure 21.

6.2.2. *Imported inflation*

In this section we introduce a variable that adjusts for the effects of globalization as well as energy price shocks. The inflation of all imported goods obtained from the Bureau of Economic Analysis, especially driven by the energy component, rose significantly during the missing disinflation episode and dropped substantially during the missing inflation episode, as shown in Figure 22. Oil prices were directly responsible, through the effect on imported inflation, but also indirectly, through the impact on inflation expectations. In fact, households' inflation expectations are strongly correlated with oil prices and, as Coibion and Gordnichenko (2013) found, they remained at high levels during the first episode due to the rise in oil prices:

"The rise in inflationary expectations between 2009 and 2011—which can be ultimately explained by the large increase in oil prices of this period—can account for why inflation did not fall as much as one might have predicted"

In Figure 23 we show that once we adjust for imported inflation, predicted values move in the right direction but the effect is minor in both episodes. During the missing disinflation episode, although still negative (-0.4%), predicted inflation is slightly above the baseline prediction. Regarding the missing inflation episode, predicted inflation is slightly below the baseline prediction (0.7% instead of 1.1%) and thus closer to the actual value.

Table 7

	1960-2007			
	CPI Inflation			
Variable	β	SE(β)	t	95% confidence interval
Unemployment gap	-0.46**	0.047	-9.75	[-0.56 -0.37]
Imported Inflation	-0.064**	0.006	9.68	[0.051 0.077]
Observations	192			
Root MSE	0.81			
R-Squared	0.54			

*p < .05. **p < .01.

We also run rolling regressions for the imported inflation coefficient, presented in Figure 24, and we notice that it has gained relevance since the 1960s, when it was not even significantly different from 0. It is also worth pointing out that the coefficient has remained stable at 0.16 during the last 5 years.

7. The Phillips Curve that best fits US inflation

In this section we analyse the results obtained in the different sections of the paper in order to decide which modifications can improve the explanatory power of the Philips Curve. We present in Figure 25 a recap of all specifications; in green we highlight those that help us explain one of the puzzles and in red those which do not.

We present two selected Phillips Curve equations that do a good job of predicting inflation during both episodes. The results are presented in Table 8.

First, we choose to use the core inflation rate instead of the general inflation rate because, as we showed in section 3, it is useful for explaining the puzzle of missing inflation. Second, we choose to adjust for imported inflation because it has played an important role, especially through the energy component, during both periods and, as shown in section 6, it has been gradually gaining importance. We present two different measures of slack that predict our episodes in question well. The first one is the short-term unemployment rate when we construct the unemployment gap because, as shown in section 5, it can be a better proxy for the slack of the economy under certain circumstances and it also predicts the missing disinflation episode well. Second, we present the global output gap as a proxy for globalization and because of its better fit during the first episode, as shown in section 6. Finally, note that we choose not to use forward-looking inflation expectations despite their significant role during the missing disinflation episode (see section 4). The reason is their poor performance during the missing inflation episode, which makes them an unsuitable extension in a Phillips Curve aimed at providing a good fit for both episodes.

The first specification is constructed with the short-term unemployment gap as the slack measure. We also adjust for the inflation of imported goods. Both coefficients are significant at the 1% level for the whole sample from 1960 to 2007. Note that the coefficient of this new unemployment gap (-0.17) is smaller than the one used in the baseline specification (-0.51). The predicted core inflation for the missing disinflation period is very close to the observed core inflation, or even slightly higher, as seen in Figure 26. The prediction error for the missing inflation period is also much smaller than with the baseline specification. More specifically, the observed core inflation from 2009IV to

2011IV was 1.36% on average, and the predicted core inflation using equation (8) is 1.62% (2.3% if we run the dynamic prediction). Regarding the episode of missing inflation, the observed core inflation from 2015I to 2015II was 1.73% and the predicted value is 1.5%, with almost no changes with respect to the dynamic prediction. The R-Squared is 0.34, which is similar that of the baseline specification (0.31). When we use a sample from 1960I to 2015IV the R-Squared of equation (8) is 0.41 compared to 0.15 of the baseline specification.

$$\pi_t^{Core} - \frac{1}{4}\left(\pi_{t-1}^{Core} + \pi_{t-2}^{Core} + \pi_{t-3}^{Core} + \pi_{t-4}^{Core}\right) = \beta\hat{u}_t^{Short-term} + \pi_t^{Imported} + \epsilon_t \qquad (8)$$

where $\hat{u}_t^{Short-term} \equiv u_t^{Short-term} - u_t^*$

The second specification is constructed with the output gap of all OECD economies as the slack measure. In this specification we also adjust for the inflation of all imported goods. Both coefficients are significant at the 5% level for the whole sample from 1960 to 2007. This specification does a similar job than equation (4) regarding the episode of missing inflation, but it improves the prediction power for the episode of missing disinflation. The following results are presented in Figure 27. The predicted values are 1.3% with the static prediction and 1.6% with the dynamic prediction. The R-Squared is 0.13, lower than the baseline specification (0.31), although it not directly comparable as this specification has a shorter data sample. However, it is clearly superior to the baseline R-Squared when we use the same sample of 1984I-2007IV, which is just 0.05. When we extend the sample to 2016I, again the R-Squared of equation (9) is 0.13 compared to just 0.02 in the baseline specification.

$$\pi_t^{Core} - \frac{1}{4}\left(\pi_{t-1}^{Core} + \pi_{t-2}^{Core} + \pi_{t-3}^{Core} + \pi_{t-4}^{Core}\right) = \beta\hat{y}_t^{OECD} + \pi_t^{Imported} + \epsilon_t \qquad (9)$$

where $\hat{y}_t^{OECD} \equiv y_t^{OECD} - y_t^{OECD*}$

Table 8

	1960-2007								1984-2007							
	CPI Inflation (eq. (2))				Core Inflation (eq. (8))				CPI Inflation (eq. (2))				*Core Inflation* (eq. (9))			
Variable	β	SE(β)	*t*	*95% confidence interval*	β	SE(β)	*t*	*95% confidence interval*	β	SE(β)	*t*	*95% confidence interval*	β	SE(β)	*t*	*95% confidence interval*
Unemployment gap	-0.51**	0.05	-10.04	[-0.609 -0.408]					-0.2*	0.095	-2.16	[-0.397 -0.017]				
Short-term unemployment gap					-0.17	0.06	-2.75	[-0.292 -0.048]								
OECD Output gap													0.07	0.03	2.12	[0.0043 0.134]
Imported Inflation					0.06**	0.01	5.88	[0.038 0.077]					0.02	0.01	2.39	[0.003 0.041]
Observations		192				192				96				96		
Root MSE		1.00				0.86				0.73				0.78		
R-Squared		0.31				0.34				0.0015				0.14		

*p < .05. **p < .01.

We presented two specifications, (8) and (9) that do a good job of predicting inflation during very particular periods. Nevertheless, the performance of these specifications, as shown by the R-Squared, is also superior to the baseline specification during all time periods on which the regressions are run.

8. Summary and conclusions

The recent path of inflation in the US has sparked a discussion about the validity of the Phillips Curve as a tool to model the behaviour of inflation. Very different explanations have been put forward to describe the recent behaviour of inflation in the US. Some articles point to the more muted response of inflation to excess demand (IMF, 2013), the famous flattening of the Phillips Curve. Some others, such as Coibion and Gorodnichenko (2013), put more emphasis on the role of expectations and oil price shocks. Finally, Ball and Mazumder (2011) also add to the discussion the role of longer unemployment duration.

When we test these, and some of our own explanations, we find that while some of them suggest that the Phillips Curve was not a good predictor of inflation during our episodes in question, other explanations keep the Phillips Curve alive.

Although the recent path of inflation has surprised with its inconsistency with a baseline Phillips Curve framework, we think this framework can be used for building upon. We find that for two specific periods, the role of inflation expectations and oil price shocks has been highly relevant and could be so again in the future. Due to the harsh and volatile oil price movements during the last decade, core inflation might be a better reflection of economic activity.

We also find that inflation still responds to slack, but we point out that the unemployment gap is not always the best way to measure it. For instance, the short-term unemployment rate improves the prediction, especially during our periods in question.

We show that the responsiveness of inflation to slack has diminished over time, partly due to globalization. When we adjust for the inflation of imported goods and a measure of global slack, the prediction of inflation improves during the episodes studied.

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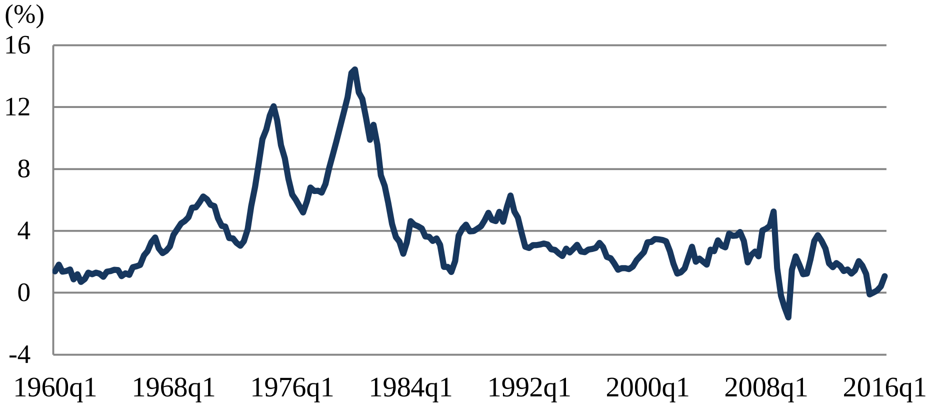
Appendix A

Figure 1 [Return]

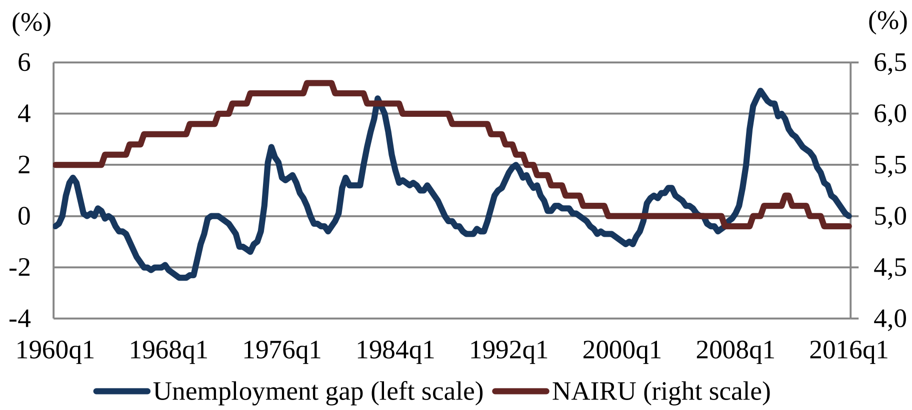
Evolution of inflation in the US



Source: Bureau of Labor Statistics.

Figure 2 [Return]

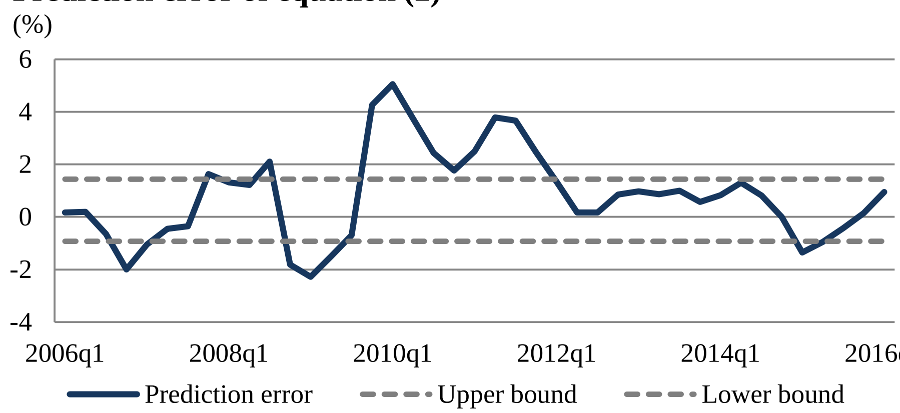
Evolution of the unemployment gap and the NAIRU in the US



Source: Bureau of Labor Statistics and Congressional Budget Office.

Figure 3 [Return]

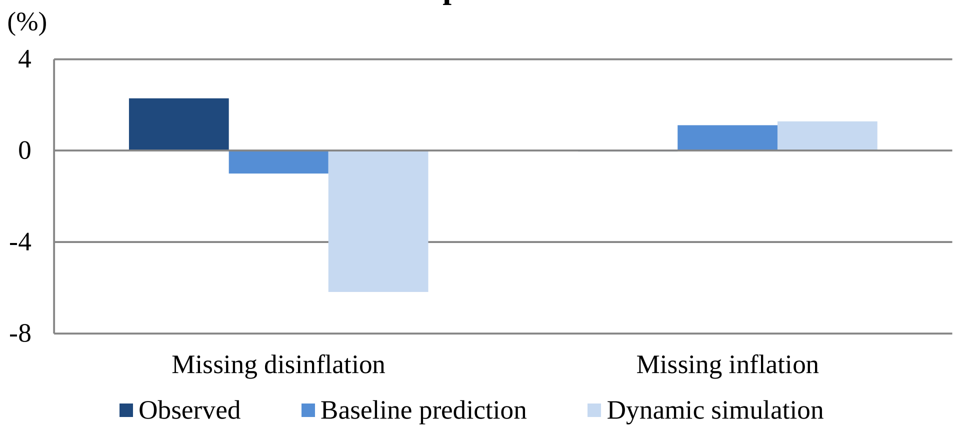
Prediction error of equation (2)



Source: Bureau of Labor Statistics and Congressional Budget Office.

Figure 4 Return

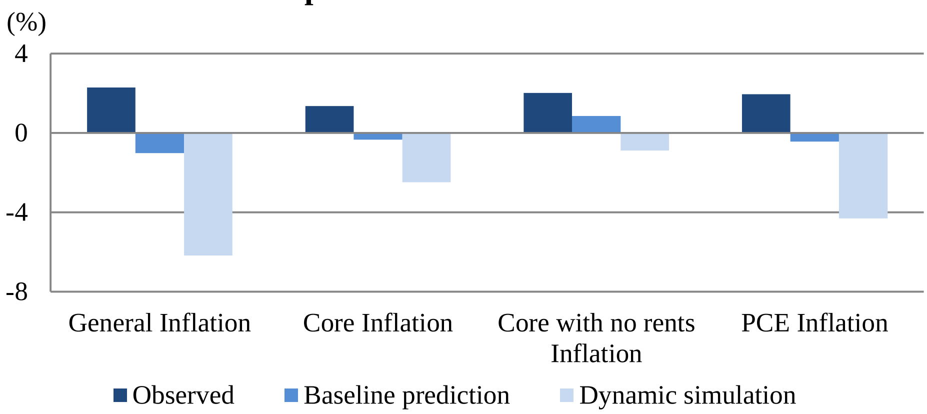
Inflation: Observed vs Baseline prediction



Source: CaixaBank Research, based on Bureau of Labor Statistics and Congressional Budget Office data.

Figure 5 Return

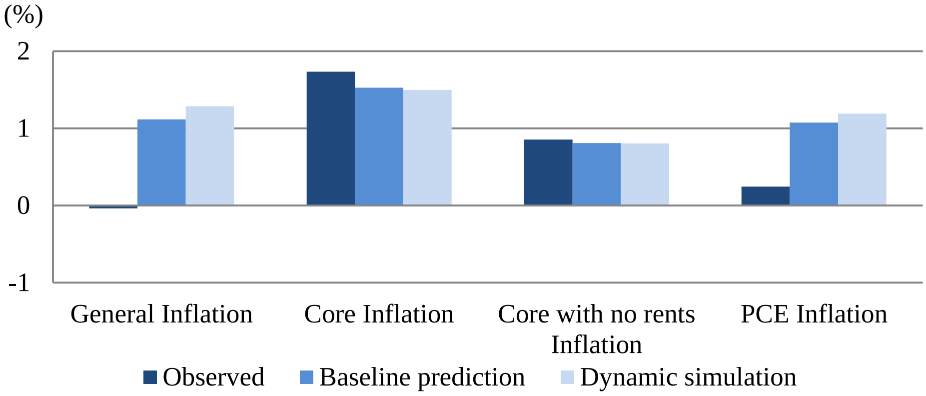
Episode of missing disinflation 2009IV:2011IV
Observed vs Baseline prediction



Source: CaixaBank Research, based on Bureau of Labor Statistics and Congressional Budget Office data.

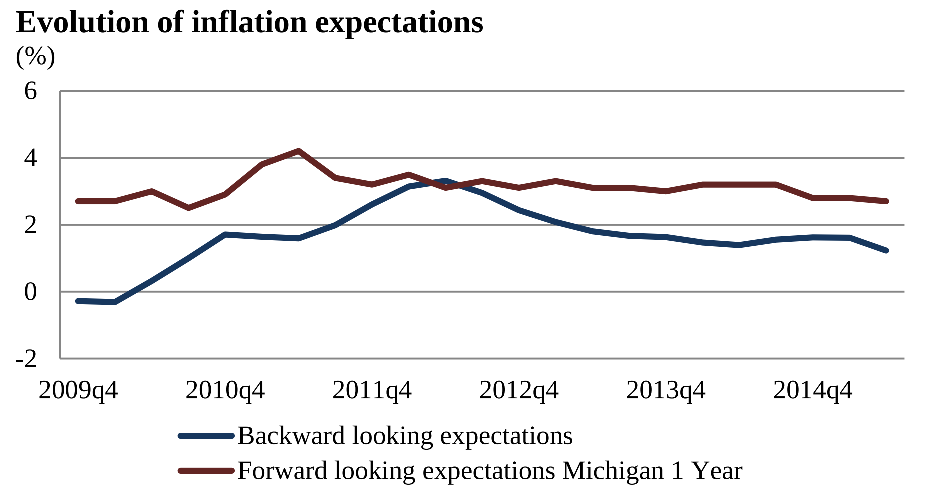
Figure 6 Return

Episode of missing inflation 2015I:2015II
Observed vs Baseline prediction



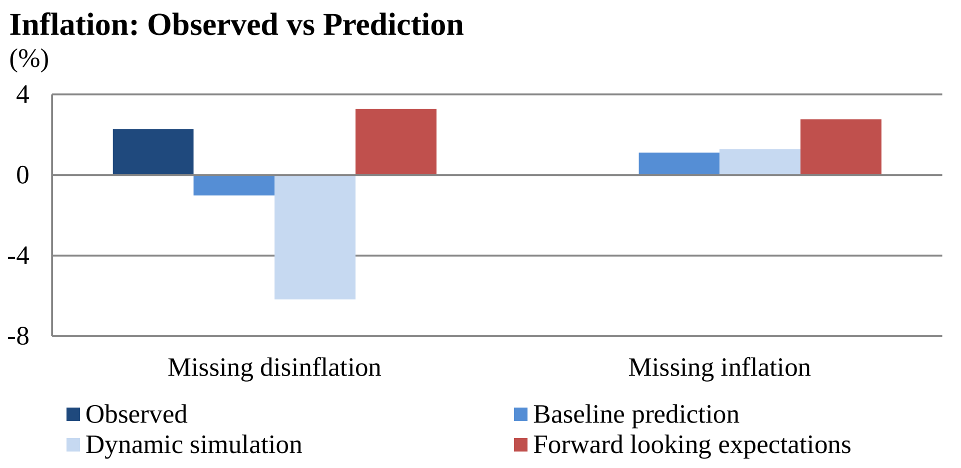
Source: CaixaBank Research, based on Bureau of Labor Statistics and Congressional Budget Office data.

Figure 7 [Return](#)



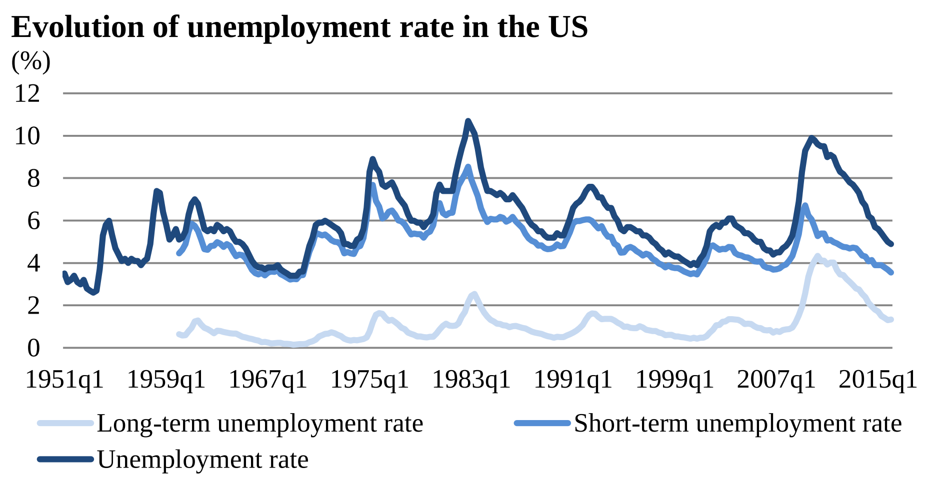
Source: Bureau of Labor Statistics and University of Michigan surveys.

Figure 8 [Return](#)



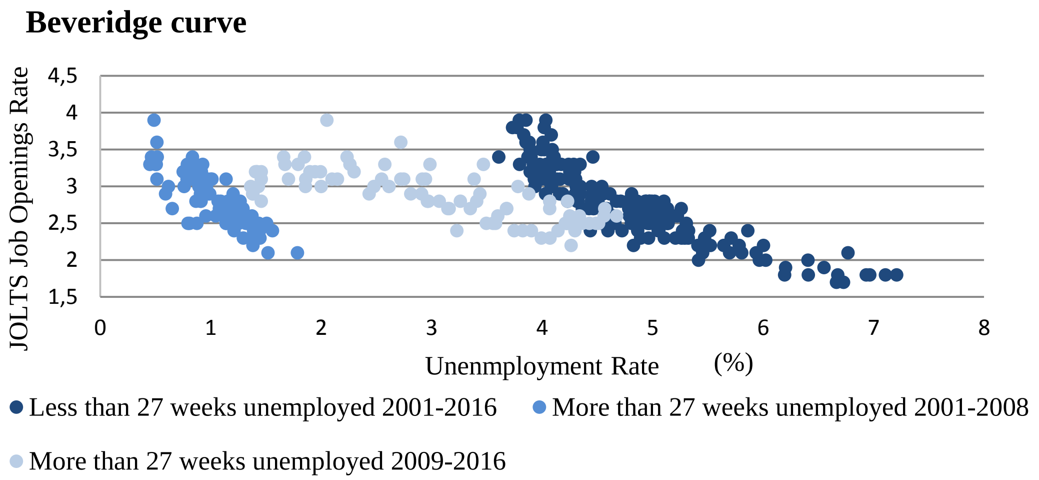
Source: CaixaBank Research, based on Bureau of Labor Statistics ,Congressional Budget Office and University of Michigan surveys data.

Figure 9 [Return](#)



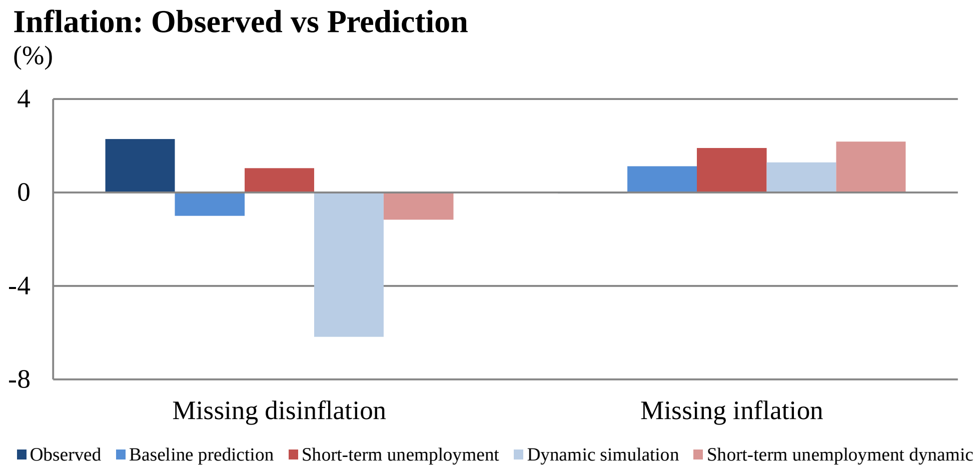
Source: Bureau of Labor Statistics.

Figure 10 Return



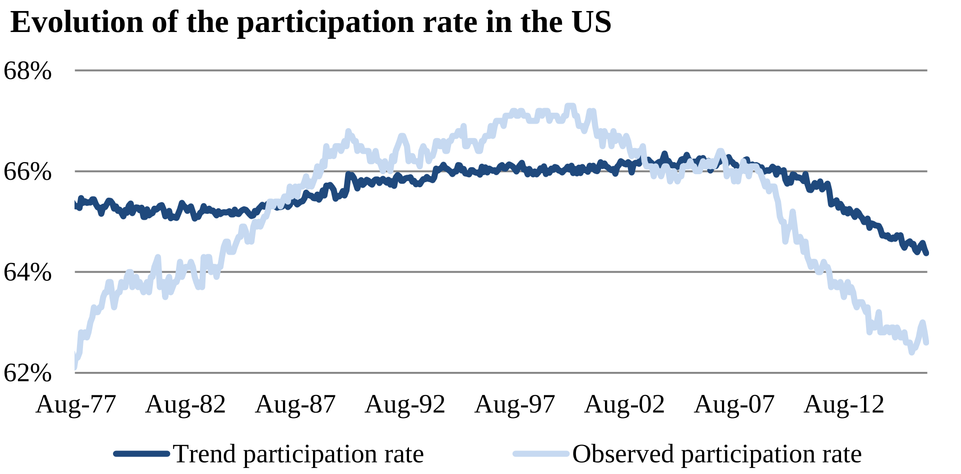
Source: Bureau of Labor Statistics.

Figure 11 Return



Source: CaixaBank Research, based on Bureau of Labor Statistics and Congressional Budget Office data.

Figure 12 Return

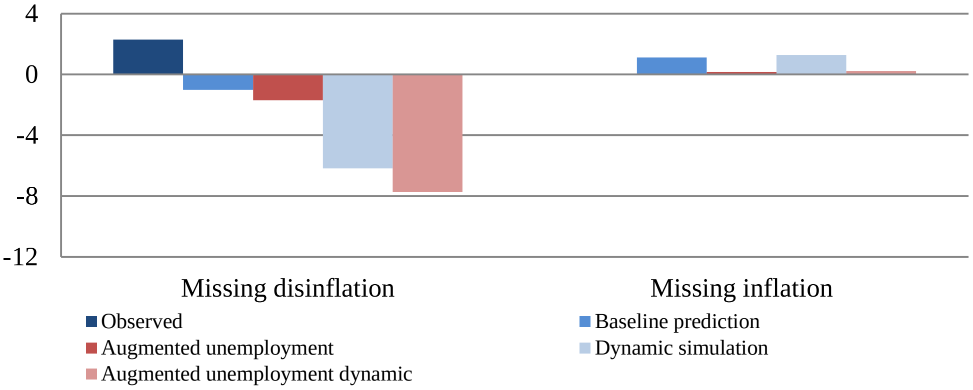


Source: Bureau of Labor Statistics.

Figure 13 [Return]

Inflation: Observed vs Prediction

(%)

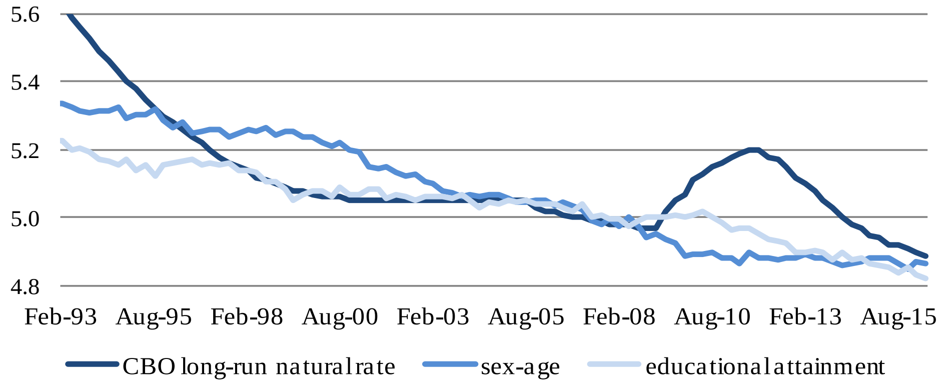


Source: CaixaBank Research, based on Bureau of Labor Statistics and Congressional Budget Office data.

Figure 14 [Return]

CBO NAIRU and demographic-adjusted unemployment rates

(%)

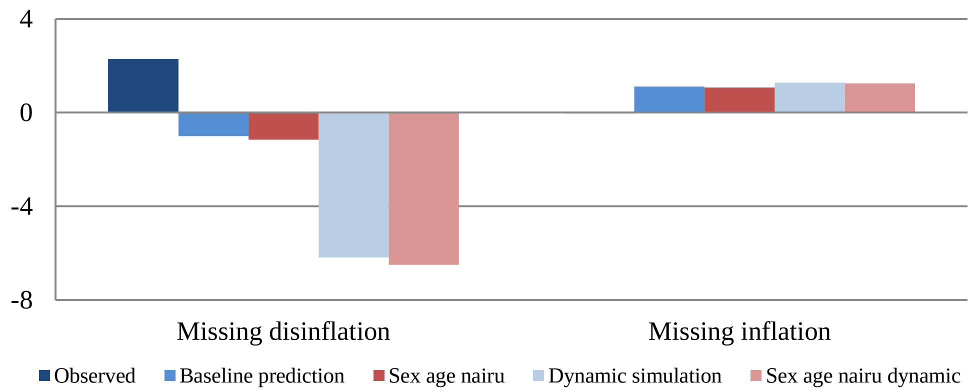


Source: CaixaBank Research, based on Congressional Budget Office data.

Figure 15 [Return]

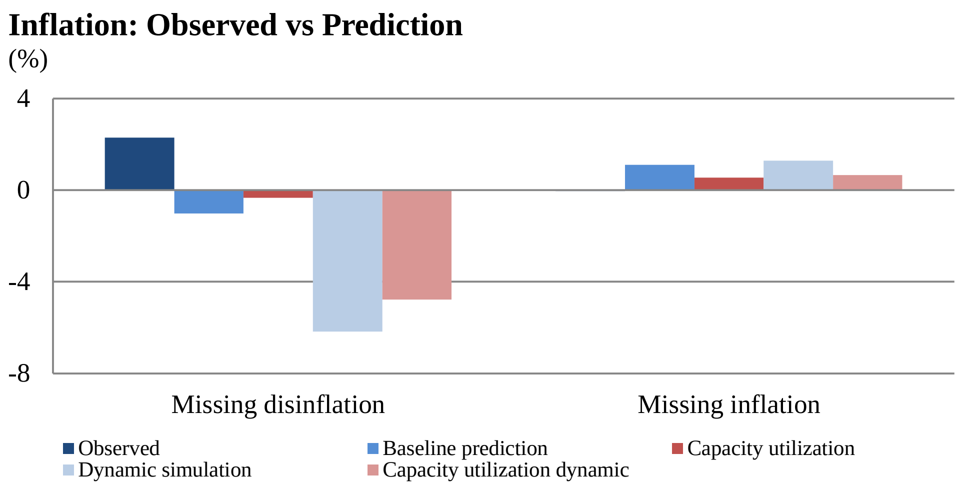
Inflation: Observed vs Prediction

(%)



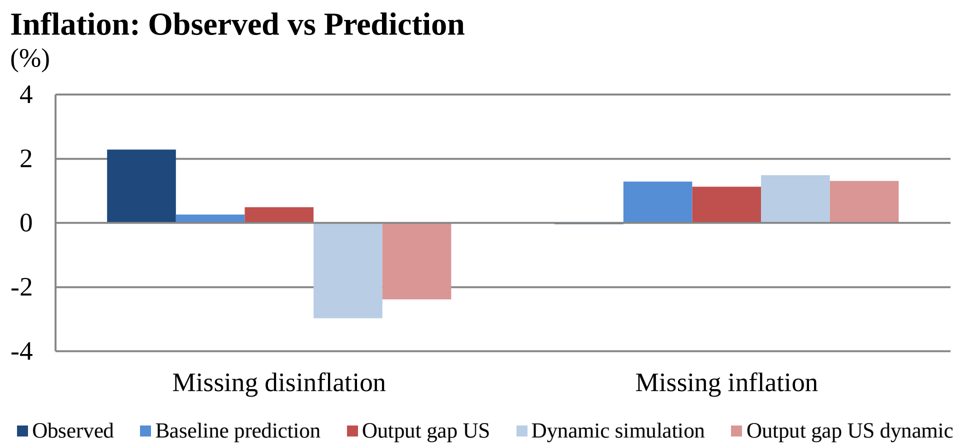
Source: CaixaBank Research, based on Bureau of Labor Statistics and Congressional Budget Office data.

Figure 16 [Return]



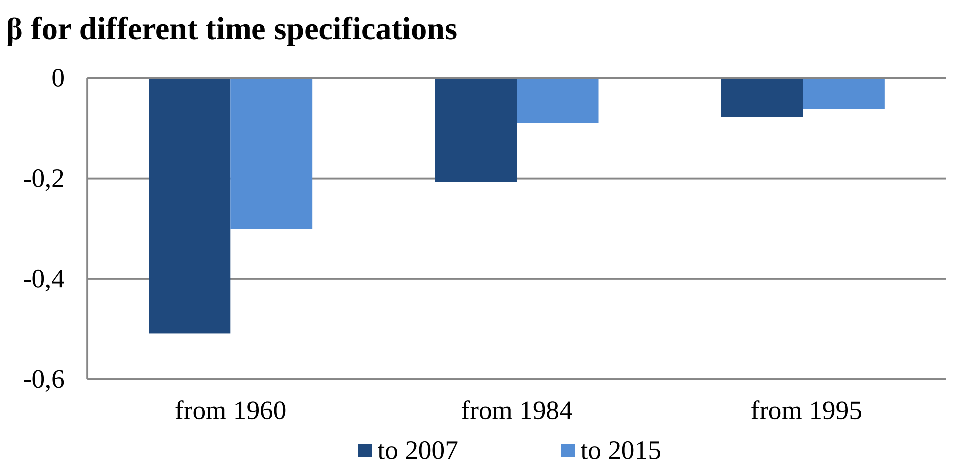
Source: CaixaBank Research, based on Bureau of Labor Statistics and Congressional Budget Office data.

Figure 17 [Return]



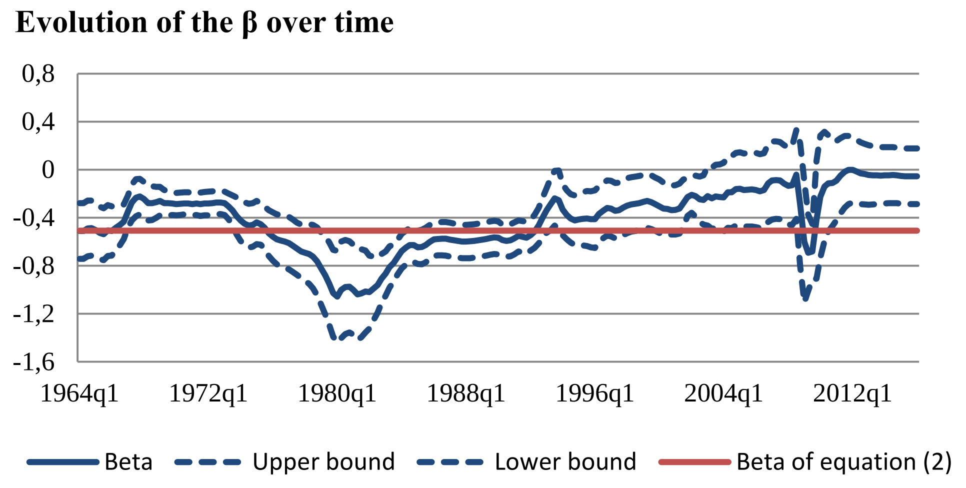
Source: CaixaBank Research, based on Bureau of Labor Statistics, Congressional Budget Office and Oxford Economics data.

Figure 18 [Return]



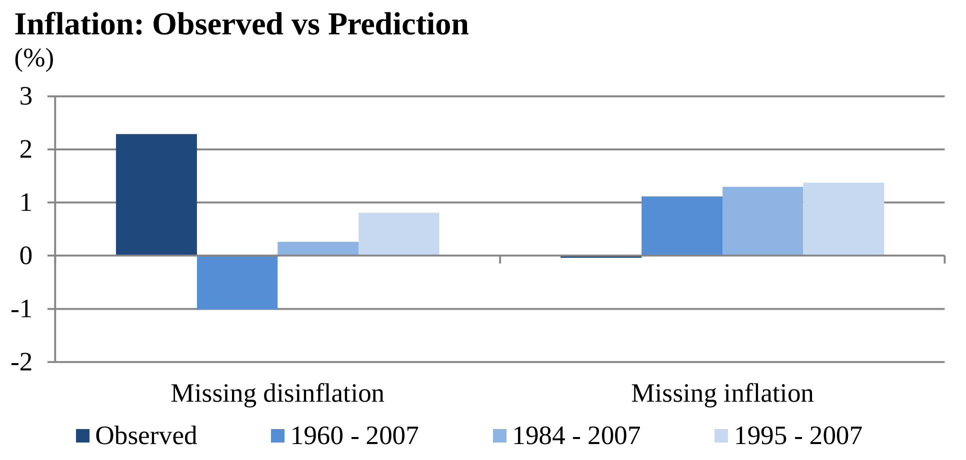
Source: CaixaBank Research, based on Bureau of Labor Statistics and Congressional Budget Office data.

Figure 19 Return



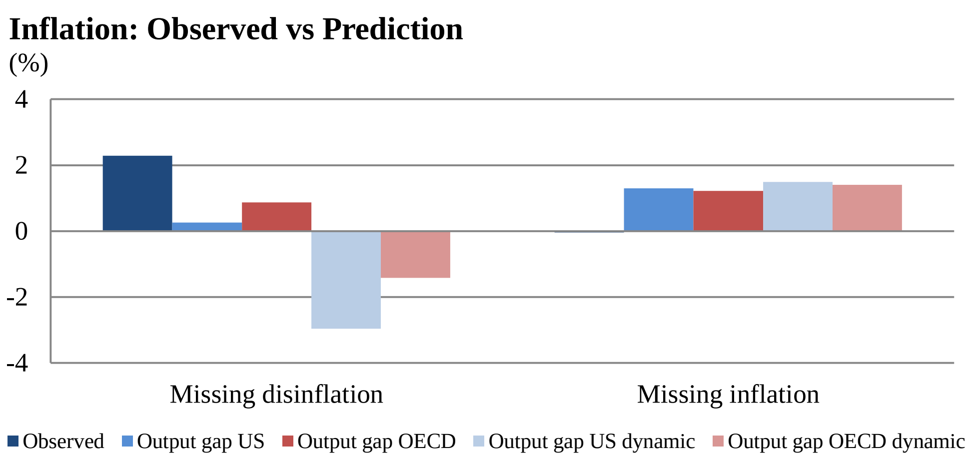
Source: CaixaBank Research, based on Bureau of Labor Statistics and Congressional Budget Office data.

Figure 20 Return



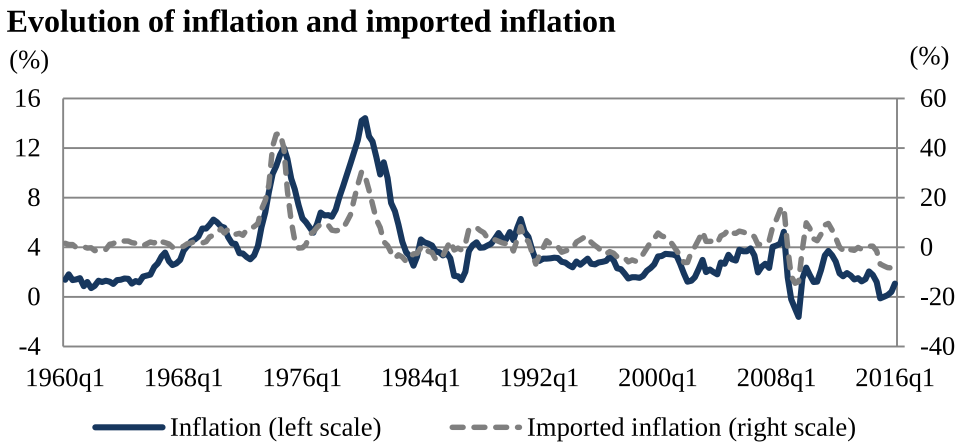
Source: CaixaBank Research, based on Bureau of Labor Statistics and Congressional Budget Office data.

Figure 21 Return



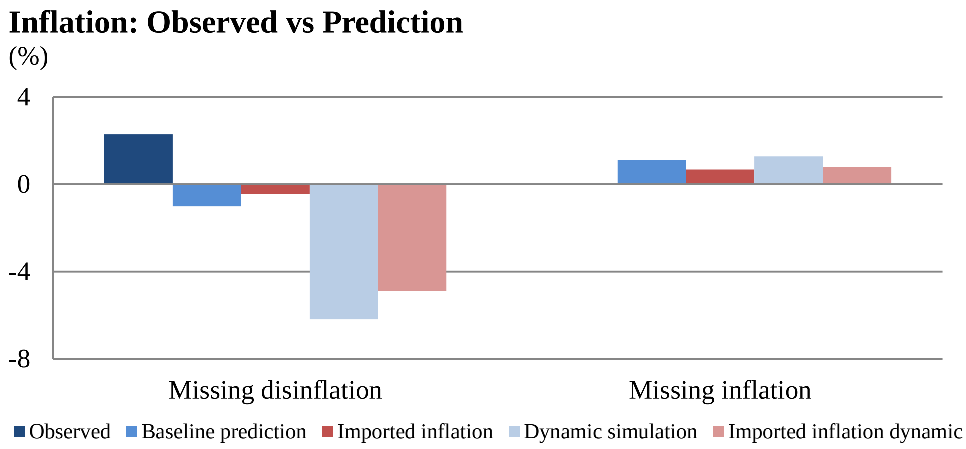
Source: CaixaBank Research, based on Bureau of Labor Statistics, Congressional Budget Office and Oxford Economics data.

Figure 22 [Return](#)



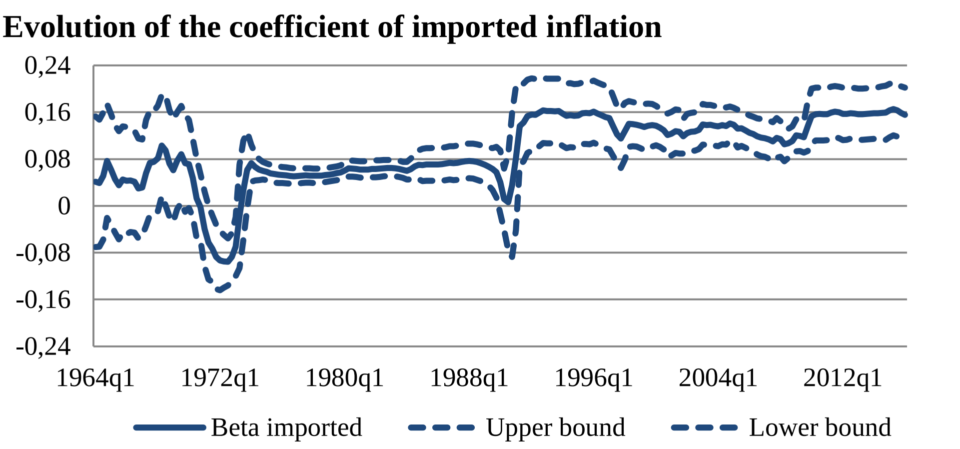
Source: Bureau of Labor Statistics and Bureau of Economic Analysis.

Figure 23 [Return](#)



Source: CaixaBank Research, based on Bureau of Labor Statistics and Congressional Budget Office data.

Figure 24 [Return](#)

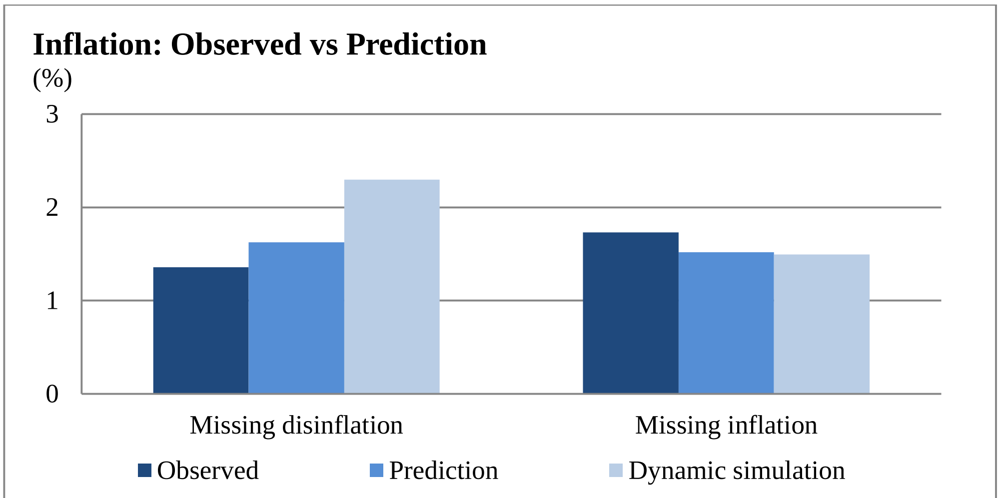


Source: CaixaBank Research, based on Bureau of Labor Statistics and Bureau of Economic Analysis data.

Figure 25 [Return]

Specification	Missing disinflation	Missing inflation
Baseline		
Core inflation		
Core inflation without rents		
Personal consumption expenditure		
Forward-looking expectations		
Short-term unemployment		
Augmented unemployment		
Demographic adjusted natural rate		
Capacity utilisation rate		
Local output gap		
Different time horizon		
Global output gap		
Imported inflation		

Figure 26 [Return]

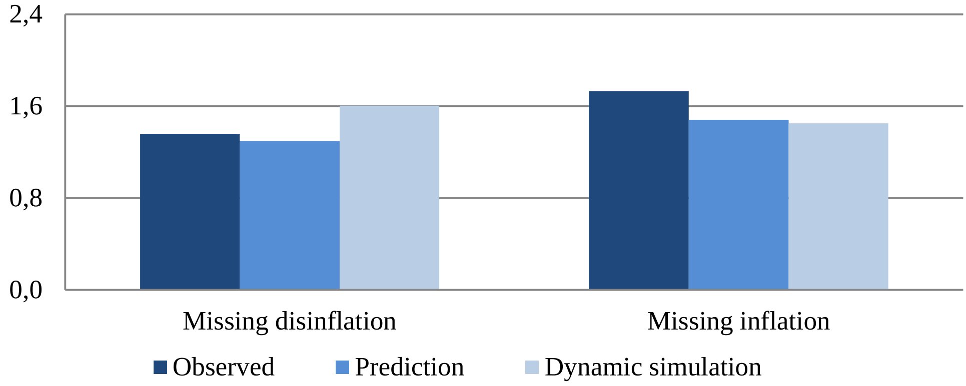


Source: CaixaBank Research, based on Bureau of Labor Statistics, Bureau of Economic Analysis and Congressional Budget Office data.

Figure 27 [Return](#)

Inflation: Observed vs Prediction

(%)



Source: CaixaBank Research, based on Bureau of Labor Statistics, Bureau of Economic Analysis and Congressional Budget Office data.

Appendix B

Without loss of generality, and in order to simplify the exposition, we can express the relationship between lagged variables and inflation expectations, given that the general distributed lag representation would be $E_t[\pi_{t+1}] = \sum_{i=1}^{n} \alpha_i \pi_{t-i}$ where n stands for the number of significant lags, as follows:

$$E_t[\pi_{t+1}] = \alpha \frac{1}{4}(\pi_{t-1} + \pi_{t-2} + \pi_{t-3} + \pi_{t-4})$$

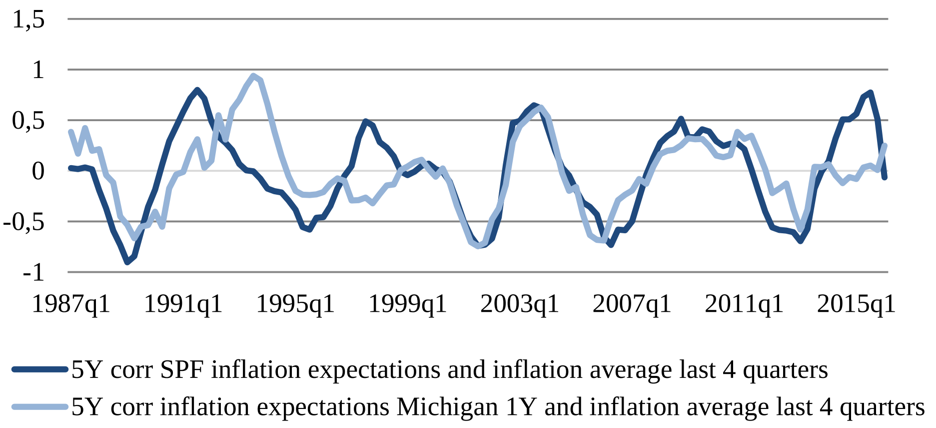
Therefore, when we estimate the regression below, the product $\beta_1 \alpha$ is estimated jointly with the consequent identification problem raised by Sargent and Wallace (1975). In other words, we are unable to distinguish the effect of past inflation on expectations from the effect of expectations on actual inflation.

$$\pi_t = \beta_1 \alpha \frac{1}{4}(\pi_{t-1} + \pi_{t-2} + \pi_{t-3} + \pi_{t-4}) + \beta \hat{u}_t + \epsilon_t$$

where $\hat{u}_t \equiv u_t - u_t^*$

In order to overcome this problem, the identification restriction that the product $\beta_1 \alpha$ (or more generally the sum of the coefficients on the distributed lag) is equal to one is usually applied. So far we have imposed this restriction in our baseline regression; however, there is no economic reason behind it. In the graph below we plot five year rolling correlations of inflation expectations and past values of inflation. It is clear that the relationship is far from stable and jumps frequently between positive and negative values. Therefore, even though we test the identification restriction of $\beta_1 \alpha$ =1 and it holds, we do not know the sign and magnitude of β_1 and α separately.

Correlation between past inflation and inflation expectations



Source: Survey Professional Forecasters and University of Michigan surveys.