Introducing price-setting behaviour in the Phillips Curve: the role of nonlinearities

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Based on the theoretical literature on price setting behavior, we model three distinct forms of nonlinearity that can describe the reduced-form Phillips curve: reaction asymmetry, state dependence and a mix of both. Employing these models to the G5 for the 1985-2011 period, we find that: (i) the Phillips curve is unstable and nonlinear and (ii) there exist threshold levels of inflation and capacity utilization that erode price rigidity. Our results reinforce the existence of downward price rigidity in Japan, helping to explain the puzzle of gradual deflation. In opposition, downward price flexibility is verified for U.S.

JEL Classification: E31, C32, C51.

Keywords: Phillips Curve, deflation, rigidity, capacity constraint, non- linearity.

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Abstract

Based on the theoretical literature on price setting behavior, we model three distinct forms of nonlinearity that can describe the reduced-form Phillips curve: reaction asymmetry, state dependence and a mix of both. Employing these models to the G5 for the 1985-2011 period, we find that: (i) the Phillips curve is unstable and nonlinear and (ii) there exist threshold levels of inflation and capacity utilization that erode price rigidity. Our results reinforce the existence of downward price rigidity in Japan, helping to explain the puzzle of gradual deflation. In opposition, downward price flexibility is verified for U.S.

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1 Introduction

Over the past decades the dynamics of inflation seems to have changed substantially in most advanced countries. In fact, a large body of empirical and theoretical literature suggests a changing nature of the inflation-adjusted Phillips curve (see, for instance Roberts (2006), Kuttner and Robinson (2010) or Gordon (2011)). Concurrently, the rate of growth of prices appears to have become less responsive to fluctuations in output and unemployment.

More recently, a "puzzle of gradual deflation" has also appeared. As is well known, the traditional Phillips curve predicts falling inflation when the economy is depressed and the output gap is negative and rising inflation when the economy is overheating and the output gap is positive. This prediction has worked reasonably well in many advanced economies, explaining for example the disinflation of the Volcker recession of the 1980s in the US and the disinflation in recent years. The puzzle is, however, that the Phillips curve predicts not just deflation, but accelerating deflation in the face of a prolonged economic decline. Accordingly, the ongoing economic recession has left some economist and policy makers obsessed with the prospect of deflation.

However, increasing deflation has not taken place, and what we observe instead are long-lasting episodes of sustained gradual deflation. The most notorious case is the prolonged Japanese depression of the 90's, with its chronic deflation that has never turned into a rapid downward spiral. Rather than being deep and concentrated in a few years, the deflation has been surprisingly mild and prolonged[1].

A large body of literature offers interesting possible explanations for the flattening of the Phillips curve. For instance, Borio and Filardo (2007) or Razin and Binyamini (2007), among others, advance the notion that increasing globalization, which exposes domestic firms to fiercer international competition, severs the link between domestic demand and pricing. A more traditional explanation, with very different policy implications, focuses on the increase in the credibility of the monetary regime. According to this proposition, a low and stable rate of inflation implies an environment of greater predictability of monetary policy, leading to a very mild trade-off between inflation and real activity (e.g., Roberts (2006), Mishkin (2007), Carlstrom, et al. (2009), etc).

Alternatively, the theoretical literature based on price setting behavior proposes that the slope

[1] Consumer prices have been falling in Japan for 15 years, but never by more than 2% in any single year.

of the Phillips curve is flat under certain circumstances, becoming steeper, for instance, as the output gap approaches the capacity constraint. For example, in the capacity constraint model, firms find it difficult to increase their productive capacity in the short run, which implies that excess demand would increase inflation more than excess supply would reduce it. Alternatively, in Ball, Mankiw, and Romer (1988), trend inflation is among the determinants of the slope of the Phillips curve. In this model of costly price adjustment, the frequency of price correction depends on firms' optimizing decisions. A decrease in trend inflation causes firms to adjust prices less frequently, which in turns implies a flatter Phillips curve in a low inflation environment.

The dependence of the inflation-output trade-off on the state of demand, or on trend inflation, or both, implies nonlinearity in the Phillips curve. In this context, different types of nonlinearities are used to explain how sustained gradual deflation can persist or why excess demand may exert no significant impact on prices in an environment of low inflation. In general, the common argument is that there is some inflexibility in prices and wages, even after expectations have had time to fully adjust.

Remarkably, most of the theoretical and empirical works adhering to this view provide little information on the form that such asymmetries might take. Moreover, most extant studies do not attempt to test for non-linearity in a framework that considers more than one possibility at a time. For instance, non-linearities have been included to model inflation in state-space models where the slope varies over time as a random walk (see, Gordon (1997), Cogley and Sargent (2002), Primiceri (2005), etc.). This implies that the time-variation in the slope is largely systematic, rather than dependant on precise economic conditions. Other authors (e.g. Clark, Laxton, and Rose (1995) or Gordon (1997)) consider the significance of dummy variables capturing excess demand in standard Phillips curves as evidence of an asymmetry in the inflation-output relationship. More recently, Fuhrer et al. (2012) estimate a log-relationship that allows the trade-off between inflation and resource slack to vary at different levels of the output gap.

We consider that the recently cited literature includes only a limited analysis of possible instabilities and nonlinearities in the Phillips curve. In this paper we aim at filling this gap by developing a novel approach for asymmetric modeling. Our framework integrates the three forms of non-linearities that may characterize the Phillips curve according to the literature on price setting behaviour. The first one is based on the capacity constraint model and downward price rigidity and describes the different responses that may be elicited by heterogeneously positive or negative shocks to the output gap. A key feature of the second one, which finds support in the menu costs model, is that the impact of a change in slack is state-contingent. Finally, the third model nests the two cases: regime dependence and asymmetric reaction. Our approach formally tests these different nonlinearities. Moreover, we provide quantitative measures, in the form of thresholds levels of inflation and capacity utilization, that erode price rigidity.

To anticipate our results, we find support for the hypotheses of downward price rigidity, and of convexity of the Phillips curve in Japan and Germany; but we found no evidence of a convex relation between inflation and output in the environment characterized by low inflation. In these two countries, we also evidence a flattening of the Phillips curve in recent years. Finally, we provide evidence of a change in the shape of the Phillips curve -from convexity to concavity- in the United Kingdom and the United States, supporting the propositions of strategic pricing behavior of firms in monopolistically competitive markets. Being able to detect the actual form of the Phillips curve in the presence of nonlinearities has crucial monetary policy implications, which we also take up briefly in our work.

This paper is organized as follows. Section 2 reviews the existing theoretical literature on the asymmetric Phillips curve with its implications for monetary policy decision-making. Section 3 introduces the non-linear models and describes the data set. Section 4 presents the results and the discussion. Finally, section 5 concludes.

2 Price setting behaviour and the Phillips curve

The well known reduced form Phillips curve models the evolution of prices as follows:

$$\pi = E\pi_t + \gamma(y_t - y_t^*) + \phi s_t + \epsilon_t \tag{1}$$

where π_t is the inflation rate, $E\pi_t$ captures expected inflation, $(y_t - y_t^*)$ is the output gap that determines the effect of goods or labour demand on prices and wages, the s term represents supply shocks -such as relative price of energy or food products- which affect the productive potential of the economic activity, and ϵ_t captures shocks to the inflation process.

Underlying this framework is the assumption that the short run trade-off between output and inflation is constant over time. More precisely, Eq. 2 implies that the link between inflation and output does not depend on the macroeconomic environment, the initial level of inflation or the degree capacity utilization.

However, a growing body of literature suggests that inflation is becoming less sensitive to economic activity in recent years[2]. This flattening is often attributed to higher globalization or to a better monetary policy that has anchored inflation expectations more solidly (e.g. Boivin and Giannoni (2006), Roberts (2006), Mishkin (2009)). In this literature, a more credible monetary policy leads inflation to be less reactive to economic activity. Consequently, any permanent increase in inflation would tend to reestablish the Phillips curve. In this case, the perspective of economic policy differs from that associated with the globalization hypothesis.

More recently, several theoretical models of price-setting behavior suggest that the slope is a function of macroeconomic conditions, such as the state of the business cycle or the level of inflation leading also to non-linear Phillips curve. We can classify these theoretical models into three types of nonlinearities[3].

First, if inflation responds mainly to changes in demand than to changes in supply, as suggested by the capacity constraint model (Lipsey (1960)), the Phillips curve should distinguish between positive and negative output gaps, giving rise to a first type of nonlinearity that we can call asymmetric reaction. Moreover, distinguishing negative from positive output gaps allows us to test for downward price rigidity (i.e. when the negative output gap is not significant in the asymmetric Phillips curve or when it is weaker than the positive output gap coefficient in absolute value).

The second type of nonlinearity implies that the slope of the Phillips curve depends on the inflation environment. Chief among the reasons for this non-linearity is the existence of menu cost (see Ball, Mankiw, and Romer (1988) for instance). According to this theory, because there are costs linked to prices changes, in periods of low trend inflation, firms do not change their individual prices as frequently. This sluggishness in individual prices increases the degree of overall nominal rigidity in the economy, leading to a flatter Phillips curve. On the contrary, any sustainable increase in trend inflation tends to restore the Phillips curve. Consequently, the relevant output-inflation trade-off depends on the trend level of inflation[4].

[2]See Roberts (2006) and Ball and Mazumder (2011) for the US, Pain, Koske, and Sollie (2006) for a group of OECD countries and Veirman (2007) for Japan.

[3]Dupasquier and Ricketts (1998) provide a relevant graphic illustration of these different models.

[4]Another example of costly adjustment that affects prices indirectly through wages, is the existence of contracts between firms and workers and the duration of contracts. If the process of negotiating wages imposes some costs faced by agents, it would be optimal, in an environment characterized by low inflation, to negotiate longer contracts.

Alternatively, Lucas (1972) and Lucas (1973) proposes the misperception or signal extraction model, which establishes a relation between inflation and output, with agents being unable to distinguish between aggregate and relative price shocks. Since these shocks are not directly observable, their magnitude must be deduced from the behavior of individual prices. Therefore, agents base their output decisions on estimated relative price movements. The more (less) volatile the aggregate prices, the less (more) a given price change will be attributed to a change in relative prices and, consequently, the smaller (larger) will be the output response. The relationship between output and inflation in this model depends on the variance of inflation -itself conditioned by the level of inflation-.

Finally, the latter type of non-linearity implies that the slope of Phillips curve depends on both the inflation environment and the business cycle, implying either a convex or a concave Phillips curve. Indeed, the hypothesis of downward wage (and price) rigidity allows the existence of a convex relation between inflation and output in an environment characterized by low inflation (Stiglitz (1986)). The idea is as follows: if workers are more reluctant to accept a decrease in their nominal wages than a decrease in their real wages (because of money illusion, institutional, or behavioral factors) therefore, in an environment characterized by low inflation, real wage adjustment becomes more difficult. Consequently, in a context of low inflation and if the rigidity applies only to downward wage and price adjustment, then excess supply might have less effect on inflation than excess demand, leading to an asymmetry between the output gap and inflation.

Similarly, Akerlof, Dickens, and Perry (1996) and Akerlof, Dickens, and Perry (2000) develop a model in which downward nominal wage rigidity leads to a long-run trade-off between inflation and output when inflation is low or unemployment is high enough. These authors propose a stochastic general equilibrium model with downward nominal wage rigidity. They claim that the inflation-unemployment dilemma appears with low inflation levels. When the inflation is near zero, some firms (those suffering an adverse shock) face too high real wages[5]. As a result, they lower employment in a way that is not offset by the additional employment of firms benefiting from favorable shocks, leading to an increase in the equilibrium unemployment rate. Beyond some level of inflation (three percent in their calibration), inflation erodes mechanically real wages and downward nominal wage rigidity no longer constraints the evolution of real wages. Therefore, the long run unemployment rate compatible with stable inflation is increasing significantly when

[5]In their model, firms are heterogeneous because idiosyncratic shocks affect their demand and their individual productivity.

inflation falls to very low levels.

In addition, Stiglitz (1984) analyzes the strategic pricing behaviour of firms in monopolistically competitive or oligopolistic markets. In this case, firms will tend to rapidly reduce their prices and, in order to prevent new competitors to enter the market, they will be reluctant to increase them, even in an environment of general price rise. Under this scenario, the short -run Phillips curve will be concave. In this case, in periods of excess demand, monetary authorities have more time to react and get more information about the state of the economy. Note that the monopolistically competitive market model can also be test by an asymmetric reaction specification.

Finally, the capacity constraint model supposes that, in the situation of excess demand, some firms encounter difficulties to increase their capacity to produce in the short run. In this case, the incapability to increase produced quantities leads them to increase prices. Thus, in a period of strong aggregate demand, the effect of the output gap on inflation will be more important than excess supply because the number of constrained firms increases with demand. In this case, the short-run Phillips curve has a convex shape with the slope depending on the capacity utilization of the economy.

3 Methodology

In this section, we propose three econometric models to identify the general forms of non-linearity that may characterize the Phillips curve according to different theoretical models.

The first type of non-linearity implies that prices are generally considered to be more flexible when going up than when going down, in which case the asymmetry depends on the sign of the output gap. In this form of non-linearity which we call the asymmetric reaction, the elasticity depends on the sign of the output gap. This model is associated to the capacity constraint model (Lipsey (1960) and Clark, et al. (1995)) where the positive output gap has a stronger impact on inflation than the negative one. Furthermore, oligopolistic competitive market structures can also be inferred from an asymmetric reaction Phillips curve, where price increases are less important than price decreases (i.e. a concave Phillips curve).

Empirically, this asymmetric feature can be captured with a modified version of the following reduced form equation:

$$\pi = \alpha + \sum_{i=1}^{n} \beta \pi_{t-i} + \gamma(y_t - y_t^*) + \phi s_t + \epsilon_t \tag{2}$$

where π, y, y^*, $y - y^*$ and s_t are the inflation rate, the observed output, the potential output, the output gap and oil price inflation, respectively. In the previous equation, the current inflation expectations term of Equation (1) is replaced by lagged inflation (i.e it assumes backward-looking expectations) and the coefficients are not forced ex-ante to add up to one.

Equation (2) represents the standard reduced Phillips curve (i.e the linear form of the Phillips curve) which is based on the assumption that both excess demand and excess supply affect prices proportionally (but with different sign) and equal to γ.

The asymmetric reaction, suggested by the constraint capacity model, can be captured by defining two dummy variables, D_1 and D_2, that take the value of 1 when the output gap is positive or negative, respectively, and 0 otherwise. We then identify two asymmetric variables in the following way:

$$y_t^+ = (y_t - y_t^*) \times D_1$$

$$y_t^- = (y_t - y_t^*) \times D_2$$

In the previous setting, y_t^+ captures excess demand and y_t^- excess supply. Replacing $(y_t - y_t^*)$ in Equation (2) by its decomposition into positive and negative components, we get to the following asymmetric extension of the reduced form Phillips curve:

$$\pi = \alpha + \sum_{i=1}^{n} \beta \pi_{t-i} + \gamma^+ y_t^+ + \gamma^- y_t^- + \phi s_t + \epsilon_t \tag{3}$$

where all the variables were previously defined and $y_t^+ + y_t^- = y_t - y_t^*$ by definition. Note that y_t^+ (y_t^-) takes positive (negative) values when the output gap is positive (negative), and 0 otherwise. Hence, the estimated γ^+ coefficient in Equation (3) will be positive and significant if we expect prices to increase due to excess demand. Equally, the coefficient $\widehat{\gamma^-}$ will be also positive if excess supply reduces inflation.

In Equation (3), the estimated γ^+ and γ^- are not necessary equivalent. The reaction symmetry can then be verified with a Wald statistic testing the null hypothesis assumption that $\widehat{\gamma^+} = \widehat{\gamma^-}$. If $\widehat{\gamma^+}$ is statistically superior to $\widehat{\gamma^-}$, then there is an asymmetry where positive values of the output gaps (i.e excess demand) have higher impact on inflation than negative gaps, as stated by the capacity constraint model. In this case, this linear equation with a break point is an approximation of a convex function. On the other hand, if the estimated $\widehat{\gamma^+}$ is lower to $\widehat{\gamma^-}$, then the asymmetry implies that the positive output gap impacts inflation less than negative gaps, reflecting, in principle, monopolistic competition. In this case, the Phillips curve equation is an approximation of a concave function.

The second econometric model is called the state-dependant Phillips curve. This model allows us to test several forms of curve corresponding to different theoretical models: menu costs or misperception models. In this case, the Phillips curve is specified as follows:

$$\pi = \alpha + \sum_{i=1}^{n} \beta\pi_{t-i} + \gamma(y_t - y_t^*) + [\gamma^*(y_t - y_t^*) \times g(r_t; \xi, c)] + \epsilon_t \tag{4}$$

where $g(s; \xi, c)$ is the transition function, ξ is the speed of transition, r is the transition variable and c denotes the threshold that divides between regimes. The function $g(r; \xi, c)$ can be either a first-order logistic function, in which case the two regimes are associated with small and large values of the transition variable relative to the threshold or an exponential function which, contrary to the logistic model, is characterized by symmetric dynamics in the two extreme regimes.

Equation (4) allows the parameter measuring the output-inflation trade-off to vary with the size or the sign of a set of conditioning information set, contained in r_t. The variables entering this information set depend on the model that generates the non-linearity: for our purposes, we include the inflation environment (trend inflation and its volatility), which allows us to implicitly test the menu costs or misperception models.

Given that the function $g(r_t; \xi, c)$ is continuous and bounded between 0 and 1, depending on the realization of the transition variable, the slope of the Phillips curve will be specified by a continuum of parameters. In the two extremes -when the transition variable reaches its lower and upper values- the estimated slope is $\widehat{\gamma}$ (first regime, when $g = 0$), and $\widehat{\gamma + \gamma^*}$ (second regime, when $g = 1$)[6]. Indeed, whereas the elasticity in a linear model is constant and equal to $\widehat{\gamma}$ in equation (2), in Eq.(4) model the elasticity varies in time according to the value of the transition function. In particular, the elasticity at time t is defined as a weighted average of the estimated parameters $\widehat{\gamma}$ and $\widehat{\gamma^*}$ as follow:

[6] For more details, see Terasvirta and Anderson (1992) and van Dijk, Terasvirta, and Franses (2002).

$$\frac{\partial \pi_t}{\partial (y_t - y_t^*)} = \widehat{\gamma} + \widehat{\gamma^*} \times g(r_t; \xi, c) \tag{5}$$

That is, if the transition variable r_t is trend inflation, the two regimes can be associated with low and high inflation environments, as in the menu costs theory. In addition, if $\widehat{\gamma}$ is non significant but $\widehat{\gamma} + \widehat{\gamma^*}$ is positive and significant, Eq. (4) allows us to estimate the mean inflation that erodes price stickiness.

The third type of non-linearity nests reaction asymmetry with the state-dependance, taking into account both capacity constraints and menu costs models. Indeed, according to downward nominal wage rigidity model, in a context of low inflation, disinflation in case of excess supply is less important than inflation in case of excess demand. If the rigidity applies only to downward price adjustment, then at low rates of inflation excess supply might have less effect on inflation than excess demand.

By combining Equations (3) and (4) we get the fully non-linear Phillips curve:

$$\pi = \alpha + \sum_{i=1}^{n} \beta \pi_{t-i} + \gamma^+ y^+ + \gamma^- y^- + \left[(\gamma^{*+} y^{*+} + \gamma^{*-} y^{*-}) \times g(r; \xi, c) \right] + \epsilon_t \tag{6}$$

If excess supply has less effect on inflation than excess demand at low levels of inflation, then $\widehat{\gamma^+} > \widehat{\gamma^-}$ in Equation (6). In addition, if prices are more flexible downward than upward in a high inflation environment, $\widehat{\gamma^+} + \widehat{\gamma^{*+}} > \widehat{\gamma^-} + \widehat{\gamma^{*-}}$. Equally, we can estimate the elasticity at each point in time and when the output gap takes positive or negative values:

$$\frac{\partial \pi_t}{\partial (y_t^+)} = \widehat{\gamma^+} + \widehat{\gamma^{*+}} \times g(r_t; \xi, c); \quad \frac{\partial \pi_t}{\partial (y_t^-)} = \widehat{\gamma^-} + \widehat{\gamma^{*-}} \times g(r_t; \xi, c) \tag{7}$$

Finally, according to the capacity constraint model, if firms are operating near the capacity constraint, increases in aggregate demand cannot be met with increased production. In this setting, the increase in demand translates almost uniquely into higher inflation, even in the short run. Hence, the Phillips curve is nearly vertical near the capacity constraint.

Note that in the capacity constraint model, convexity is not present at negative output gaps. This implies setting $\gamma^{*-} y^{*-} = 0$ in Eq. (6) such that the functional form becomes:

$$\pi = \alpha + \sum_{i=1}^{n} \beta \pi_{t-i} + \gamma^+ y^+ + \gamma^- y^- + \left[(\gamma^{*+} y^{*+} \times g(r; \xi, c) \right] + \epsilon_t \tag{8}$$

A Wald test for $\hat{\gamma}^{+} = 0$ and $\hat{\gamma}^{*+} > 0$ would imply a vertical asymptote in the Phillips curve at the capacity constraint. In this case, the estimated threshold level, $\hat{c}$, can be interpreted as the capacity constraint level (i.e the level of demand that cannot be met by increased production).

To summarize, the previous econometric models allow us to test the following 6 hypothesis:

(i) if $\widehat{\gamma^{+}} > \widehat{\gamma^{-}}$ in Eq.(3): convex Phillips curve, captures the capacity constraint model;

(ii) if $\widehat{\gamma^{+}} < \widehat{\gamma^{-}}$ in Eq. Eq.(3): refers to a concave Phillips curve and a strategic pricing behaviour in oligopolistic competitive markets;

(iii) if $\widehat{\gamma} = 0$ and $\widehat{\gamma} + \widehat{\gamma^{*}} > 0$ in Eq. (6): there is a threshold level of trend inflation that erodes price rigidity. Corresponds to the menu costs or the misperception models;

(iv) if $\widehat{\gamma^{+}} > \widehat{\gamma^{-}}$ with trend inflation as the transition variable in Eq. (6): downward nominal wage rigidity model;

(v) if $\widehat{\gamma^{+}} + \widehat{\gamma}^{+} < \widehat{\gamma^{-}} + \widehat{\gamma}^{-}$ with trend inflation as the transition variable in Eq. (6): strategic pricing behaviour;

(vi) if $\widehat{\gamma}^{+} = 0$ and $\widehat{\gamma}^{+} + \widehat{\gamma}^{*+} > 0$ with the capacity utilization as transition variables in Eq. (8): capacity constraint model. The estimated threshold correspond to the capacity constraint level which provides the maximum possible level of output that firms can supply in the short run.

3.1 Data description

Quarterly data were collected for France, Germany, Japan, the United Kingdom and the United States for the 1985:1-2011:4 period (except for Germany, in which case the sample covers the 1992:1-2011:4 period).

All data were obtained from the OECD's economic Outlook. The inflation rate is the seasonally adjusted annual rate of growth of the consumer price index. In the case of Japan and the United States, we also computed core inflation with the core price index. Regarding the potential output, it was calculated using the Hodrick-Prescott filter. The output gap corresponds to the difference, in percentage points, between the real GDP and the potential GDP[7]. We control for supply shocks by including the annual rate of growth of oil prices (source IMF).

[7]For robustness checks, we compared our results with the output gap provided by the OECD. Results are qualitatively similar.

For the transition variables in Eqs. (4), (6) and (8), we use trend inflation computed as the yearly (fourth-quarter) moving average of the inflation rate. We also generate the variance of inflation as a geometrically weighted average of past squared deviations of inflation from its trend. Finally, the capacity utilization of the industry was obtained from the Board of Governors of the Federal Reserve System in the case of the US, the OECD for France, Germany and the UK. For Japan, it corresponds to the operating ratio provided by the Ministry of Economy[8].

4 Estimation Results

To provide a first glimpse of the capacity constraint model in a simplified version, we first estimate Equations (2)- the reduced form equation- and (3) -the asymmetric reaction Phillips curve-. In this simplified version, we suppose that the threshold of the output gap coefficient is equal to zero[9]. Table 1 presents the estimated slope for both equations. The second column of the table shows the symmetric slope as a benchmark against which to judge any asymmetry. The third and fourth columns present the asymmetric coefficients where $\widehat{\gamma^+}$ denotes the estimated elasticity of prices to excess demand and $\widehat{\gamma^-}$ the corresponding elasticity to excess supply.

TABLE 1 ABOUT HERE

As seen, the estimated symmetric coefficient of the linear reduced form equation ($\hat{\gamma}$) is positive and significant at the 5% level in all the countries, with the exception of France and Japan. In Germany, the reaction of inflation is symmetric to both positive and negative output gaps, though it is low in both directions.

On the contrary, in the United Kingdom and the United States, the symmetry restrictions with respect to the output gap cannot be accepted. Indeed, in these two countries, the results indicate that inflation reacts mainly to negative output gaps[10]. In other words, when the overall level of demand is weak relative to supply, prices would fall. Surprisingly, when the economy in these two countries is in a position of excess demand, no upward pressure on prices takes place and inflation does not rise as expected, at least in the short-run. Striking though these results may appear at first sight, they are consistent with monopolistically competitive models.

[8]Note that whereas this indicator is between 0 and 100, with 100 representing full utilization in France, Germany, the UK and the US, the operating ratio in Japan exceeds 100. See descriptive statistics in the Appendix.

[9]In this case, we interpret values above (below) zero as excess demand (excess supply).

[10]The Phillips curve for core inflation (table 6 in the Appendix) is symmetric with respect to positive and negative output gaps.

According to the latter, firms operating under monopolistic competition may exhibit greater willingness to reduce prices under weak demand to avoid being undercut by rivals[11].

Given that, at first glance, the capacity constraint model is not validated, we turn our attention to the second type of nonlinearity. In this case, we allow the slope of the Phillips curve to depend on the inflation environment, captured by trend inflation and its volatility. The estimated slopes in the low and high inflation environments, relative to a threshold level, are presented in table 2.

As seen, excluding France whose Phillips curve is resolutely flat, supply or demand pressures do not have a noticeable effect on inflation for moderate levels of trend inflation or its volatility. In effect, prices are rigid for low levels of inflation. However, when the mean inflation is relatively higher than 1.3%, 2.8% and 3.7% in Germany, the UK and the USA, respectively, our results indicate that the response of the inflation rate is considerably more aggressive than below these thresholds[12].

TABLE 2 ABOUT HERE

An important remark should be made in the case of Japan. In this country, as the estimated threshold level for trend inflation is found to be zero, we confirm that any positive mean inflation level implies a positive and significant slope of the Phillips curve. On the contrary, in periods of negative inflation (between the year 2000 and 2007 and latter at the end of 2009 until 2011), the output-inflation trade-off becomes flat (i.e. the Phillips curve disappears). Note that for Germany the threshold level of inflation that erodes price rigidity is also very low (1.5 percent). In both countries, the general inflation environment, captured by the trend level and volatility of inflation, seems to be a significant determinant of the Phillips curve slope, as suggested by the menu costs and the misperception models.

Now, with the third type of nonlinearity we test for the existence of convex relation between inflation and output, in the environment characterized by low inflation. According to our results, presented in table 3, we cannot validate the downward nominal wage rigidity model, as the

[11]Existing empirical studies for the Phillips curve in the US are contradictory. For instance, Laxton, Rose, and Tambakis (1999) suggest that monetary authorities should assume the traditional convex form. Akerlof, Dickens, and Perry (1996) and Laxton and Debelle (1996), also argue in favor of a convex Phillips curve. On the contrary, Gordon (1997) concludes that the Phillips curve is resolutely linear. Furthermore, Stiglitz (1997) conclude in favor of concave curve and Filardo (1998) argues that the Phillips curve is convex when the output gap is positive and concave when the gap is negative.

[12]Note that in these countries, the estimated slope in a sizable inflation environment is considerably larger than the symmetric elasticity in table 1. The same applies to core inflation. See table 7 in the Appendix.

inflation-output trade off is flat for low trend inflation in all the countries. We recall that this model proposes that in a context of low inflation, if rigidity applies only to downward nominal wage, then excess supply might have less effect on inflation than excess demand, leading an asymmetry between the output gap and inflation.

The previous result is not surprising in the case of Japan. Effectively, downward nominal wage flexibility is very important in this country, at least when compared to some other advanced countries such as France. The USA, in turn, is in an intermediate situation, with nominal wages being more downward rigid than in Japan, but more flexible than in some European countries (see Lopez-Villavicencio and Saglio (2012)). It is important to note that this result does not imply that nominal wages are not downward rigid.

Furthermore, there is another way of seeing the third econometric model insofar it integrates both the menu costs and the capacity constraint models. This makes it difficult to distinguish among the possible propositions. What is clear from our results is that the inflation environment determines the slope of the Phillips curve, regardless of the sign of the output gap.

On the contrary, when the inflation is above the estimated threshold in the UK and the USA, decreases in prices are more important than increases. More precisely, when inflation is below 3.6 percent in the US, excess supply is not significant. This downward rigidity could explain why the low or even negative inflation rate during 2009 never turned into a deflationary spiral.

TABLE 3 ABOUT HERE

Finally, the results of a more complicated version of the capacity constraint model derived from the third econometric model are presented in table 4. As seen, when the existing capacities are used above approximately 82%, the increase in demand translates into an increase in inflation in the UK and the US. Hence, the slope becomes gradually steeper as the economy moves towards the capacity constraint. Note, however, that below the capacity constraint level, firms are more likely to decrease prices in case of excess supply and less likely to increase them under excess demand in the later country. In the cases of France, Japan and Germany, the inflation-output trade-off is independent of the production capacity in the short run.

4.1 Discussion and policy implications

Our results confirm that in periods of low and stable inflation, the Phillips curve can flatten or even disappear. A flatten Phillips curve implies that it is easier to control inflation, since adjustments to excess demand are slower. Likewise, when inflation is below the estimated thresholds, monetary authorities could stimulate economic activity without creating inflationary pressures. However, if the slope is nonexistent or weak, as it is the case in France, the cost of reducing inflation, once established, would increase (i.e. in this case the sacrifice ratio is higher). Furthermore, if the Phillips curve is relatively flat in periods of low inflation, deflationary spirals can be avoided.

We have shown that there is an inflation-output trade-off in Japan only in periods of positive inflation and for positive output gap (excess demand). This result is important to understand why, even though Japan looked like a candidate for a deflationary spiral, it experienced instead stable but moderate deflation during a long period. Indeed, in this country standard estimates suggest that the output gap was negative for most of the period 2000-2007 and latter at the end of 2009 until 2011. Inflation remained fairly stable at moderately negative levels. As argued by Veirman (2007), the fact that deflation remained surprisingly mild notwithstanding a relatively long period of negative output gap presents a puzzle to anyone who takes a standard linear Phillips curve literally.

By showing that there is no trade-off between inflation and real activity for negative inflation rates in Japan, we provide evidence that downward price rigidity at relatively low levels of inflation is important to understand this puzzle. In addition, the standard adjustment mechanism of prices falling in case of excess supply is no longer valid if the slope of the Phillips curve is flat. In this case, if the output gap is negative, a country can experience stable but prolonged deflation. This is exactly what we observed in Japan: at low or negative inflation, falling prices are blocked by downward rigidity. However, when inflation is positive, excess demand has a significant (and positive) effect on prices in this country.

On the contrary, in the UK and the USA, when inflation is above the inflation threshold, excess supply has a significant negative impact on prices (for inflation above 3.6% and 2.7% respectively). Moreover, in these two countries there is evidence of a strategic pricing behavior at the aggregate level since firms seem reluctant to increase prices, even in an environment of general price rise. However, when inflation is below this threshold, the Phillips curve becomes flat, even in the periods of excess supply. This situation, in accordance with theories of costly price adjustment, prevents drastic falls in the inflation rate and avoids deflation. In this sense, our results confirm those of Ball and Mazumder (2011) for the USA. However, the slope of the

Phillips curve alone cannot explain the current rise in prices in the USA.

Our results have a number of important implications for the conduct of monetary policy. Indeed, the simple linear form of Phillips curve suggests that policymakers can directly trade higher economic activity against higher inflation and vice-versa, independently of the inflation environment.

However, things are different with a non-linear Phillips curve. For instance, if the Phillips curve is flat under certain circumstances, a decline in the output gap inflation trade-off can be seen as a benefit, since high levels of the output gap would be less inflationary. In other words, in periods of low inflation, inflationary consequences of demand pressures take longer to occur, allowing more time for monetary authorities to react. This means that controlling inflation is easier when inflation is low.

Nonetheless, if price adjustment is costly and the Phillips curve is flat for low trend inflation, a disinflation will require more efforts in terms of output when the current inflation is low than when it is relatively high (in this case the sacrifice ratio is higher). However, note that if the Phillips curve is flat when inflation is negative, then it can be consider as a good think since a flat curve prevents a fall into deflation.

By the same token, if the short-run Phillips curve has a convex shape, excess demand increases inflation more than excess supply reduces it. In this case, the stabilization of output becomes more important than in a linear world, where policy mistakes affect the variability of output but not its average level (DeLong and Summers (1988)). More precisely, the convexity of the Phillips curve implies an active policy by monetary authorities. However, if the Phillips curve is concave, in periods of demand pressures monetary authorities have more time to react.

In this sense, our results suggest that at least for the UK, the USA and France, monetary authorities could raise their inflation targets and stimulate economic activity without inflationary consequences[13].

In relationship with the current debate on the risk of deflation, our evidence in favor of a flat Phillips curve in periods of low inflation implies that the forecasted fall in inflation will be reduced. In this setting, an accelerating deflation can be avoided[14].

[13]Recently, Blanchard, Dell'Ariccia, and Mauro (2010) propose to raise inflation targets to 4-5% in advanced countries, mainly to avoid problems of zero-bound interest rate. The aim is to increase the leeway of monetary policy in the event of a major shock.

[14]Veirman (2007) and Ball and Mazumder (2011) support this prediction for the Japanese and the US experiences, respectively.

5 Concluding Remarks

Recent empirical studies show a flattening in the Phillips curve. This implies that inflation is becoming less sensitive to economic activity in a world of low and stable inflation. Moreover, the Japanese experience with gradual deflation reinforces the view that is some cases, the Phillips curve is inoperative or nonexistent.

In this paper, we challenge this view by proposing that, rather than nonexistent, the Phillips curve is non-linear. Provided that there are non-linearities in the relationship between inflation and economic activity, monetary policies based on a linear view of the world are likely to be both inefficient and incorrect.

We study the shape of the traditional Phillips curve for Germany, Japan, France, the UK and the US for the period 1985q1-2011q4. We develop a novel framework for modelling three forms of non-linearity characterizing the inflation-output relationship as proposed by the price setting theoretical literature. These models allow: i) an asymmetric response of inflation according to the sign of the output gap, ii) the possibility that the response of the inflation rate is state dependent and iii) a non linearity that nests an asymmetric response with an inflation environment or capacity utilization dependency, taking into account both capacity constraint and menu costs models.

First, we show evidence that the slope of the Phillips curve is a function of the inflation environment, as suggested by the costly adjustment model. This model suggests that a decline in trend inflation increases the degree of overall nominal rigidity in the economy, leading to a flatter Phillips curve. Our results actually show that the Phillips curve disappears in all our countries in periods of low inflation.

On the contrary, any sustainable increase in inflation tends to reestablish the relationship. This is the case only for excess demand in Japan and Germany and for excess supply for the UK and the USA.

In the case of Japan, there is an inflation-output gap trade-off only in periods of positive inflation and for excess demand, explaining why in this country inflation did not spiral downward. On the contrary, in the US there is no overwhelming evidence of downward price rigidity. Rather, the concavity of the curve in this country seems to support the propositions of strategic pricing behavior of firms in monopolistically competitive markets, with firms showing increasingly willingness to reduce prices to avoid being undercut by rivals. The implication of this concavity is that the output gain from an inflationary episode is likely to outweigh the output loss associated with a given disinflation, at least until the inflation threshold. Hence, a risk averse policymaker will act less conservatively than in the case of convexity.

At the same time, in the US the Phillips curve becomes flat when inflation is below 3.6%. This is an important argument to explain why in this country the risk of deflation is very limited. It has been suggested that the absence of deflation in the U.S. after the Great Recession is due to downward nominal wage rigidity (e.g. Fuhrer, Olivei, and Tootell (2012)). Two important things can be said at this respect. First, our results do not support this proposition. Rather, we validate the presence of menu costs. Second, previous empirical evidence show that nominal wages are rather flexible in Japan and not so rigid in the US, at least when compared to other advanced countries (see Lopez-Villavicencio and Saglio (2012)).

Regarding countries belonging to the Monetary Union, our results are mixed. Indeed, there is no trade-off between inflation and the output gap in France. In contrast, the elasticity of the output gap is significant in Germany when trend inflation is above 1.3% and for the periods of excess demand. Note that France and Germany follow the same monetary policy, established by the European Central Bank. A Phillips curve that is considerably different among the member countries of the Monetary Union would be an additional source of asymmetry in the euro zone.

Second, we provide evidence that the level of capacity to produce that erodes price rigidity is considerably high and operate only in the UK and the USA. In this setting, monetary authorities could raise their inflation targets to about 3-4% and stimulate economic activity without having inflationary pressures, at least for the UK, the USA and France. This is less clear for Japan and Germany.

Finally, we conclude by remarking that it is critical for policymakers to consider that the nonlinear relationship between slack and price inflation is an important feature of the data. Consequently, derivations of optimal rules for the conduct of monetary policy should not be based assuming linearity of economic relation.

Table 1: **Capacity constraint and monopolistically competitive models: Estimated output gap elasticities in the linear symmetric and asymmetric reaction models**

	Symmetric	Asymmetric		Symmetry
	$\widehat{\gamma}$	$\widehat{\gamma^+}$	$\widehat{\gamma^-}$	test
France	0.035 (1.03)	0.072 (1.08)	−0.006 (−0.09)	0.513
Germany	0.070 (2.17)	0.068 (1.09)	0.073 (1.23)	0.966
Japan	0.067 (1.83)	0.066 (1.19)	0.068 (1.47)	0.984
UK	0.103 (2.57)	0.053 (0.86)	0.177 (2.24)	0.027
US	0.129 (2.57)	−0.037 (−0.39)	0.307 (3.44)	0.023

Notes: (1) $\widehat{\gamma}$ denotes the estimated coefficient in Equation (2); (2) $\widehat{\gamma^+}$ and γ^- are the coefficients associated with positive and negative output gaps; (3) The symmetry test is the p-value of the Wald test of the equality of the coefficients associated with y^+ and y^- in Eq. (3).

Table 2: **Costly adjustment model: Estimated elasticity at lower and higher trend and volatility inflation**

	At lower trend inflation $\widehat{\gamma}$	At higher trend inflation $\widehat{\gamma}+\widehat{\gamma^*}$	Threshold $\widehat{c}$	At lower volatility inflation $\widehat{\gamma}$	At higher volatility inflation $\widehat{\gamma}+\widehat{\gamma^*}$	Threshold $\widehat{c}$
France	*Linear*			*Linear*		
Germany	−0.073 (−1.14)	0.096 3.18	1.3	0.020 0.43	0.154 3.64	0.20
Japan	0.029 (0.61)	0.126 (2.30)	0.0	0.033 0.67	0.166 3.20	0.39
UK	−0.085 (−1.18)	0.168 (3.51)	3.8	−0.086 −0.91	0.357 3.91	0.36
US	0.070 (1.24)	0.360 (3.72)	3.7	0.051 (0.76)	0.348 (3.84)	0.88

Notes: (1) $\widehat{\gamma}$ is the estimated elasticity in the lower regime (when trend inflation or its volatility are below the threshold level $\widehat{c}$) in Eq. (4); (2) $\widehat{\gamma}+\widehat{\gamma^*}$ is the estimated elasticity when $g = 1$ in Eq. (4).

Table 3: **Downward nominal wage rigidity model: Estimated elasticity of the positive and negative output gaps at lower and higher trend inflation**

	Pos. elast. at lower inflation γ^+	Neg. elast. at lower inflation γ^-	Symmetry test	Threshold $\hat{c}$	Pos. elast. at higher inflation $\gamma^+ + \gamma^{+*}$	Neg. elast. at higher inflation $\gamma^- + \gamma^{-*}$	Symmetry test
France	*Linear*						
Germany	−0.256 (−1.70)	−0.018 (−0.23)	0.067	1.5	0.106 (2.25)	0.079 (1.57)	0.007
Japan	−0.098 (−1.04)	0.271 (1.47)	0.065	0.0	0.306 (2.18)	0.084 (1.13)	0.032
UK	−0.239 (−1.62)	0.032 (0.33)	0.078	2.7	0.102 (1.51)	0.334 (2.77)	0.039
US	−0.019 (−0.16)	0.106 (1.18)	0.078	3.6	−0.235 (−1.21)	0.774 (3.33)	0.039

Notes: (1) γ^+ (γ^-) is the estimated elasticity due to positive (negative) output gaps in the lower regime (when inflation is below the threshold level $\widehat{c}$ in Eq. (6); (2) $\gamma^+ + \gamma^{+*}$ ($\gamma^- + \gamma^{-*}$) is the estimated elasticity due to positive (negative) output gaps when inflation is above the threshold level $\widehat{c}$ in Eq. (6).

Table 4: **Capacity constraint model: Estimated elasticity of the positive and negative output gaps at lower and higher capacity utilization**

	Pos. elast. at lower capacity utilization γ^+	Neg. elast. at lower capacity utilization γ^-	Symmetry test	Threshold utilization $\hat{c}$	Pos. elast. at higher capacity $\gamma^+ + \gamma^{+*}$
France	*Linear*				
Japan	*Linear*				
Germany	*Linear*				
UK	−0.119 (−1.21)	0.131 (1.52)	0.078	82.18	0.148 (2.00)
US	−0.118 (−1.25)	0.289 (3.30)	0.006	82.71	0.437 (2.02)

Notes: (1) γ^+ (γ^-) is the estimated elasticity of the positive (negative) output gap in the lower regime (when the capacities are used below the threshold level $\widehat{c}$ in Eq. (6); (2) $\gamma^+ + \gamma^{+*}$ is the estimated elasticity of the positive output gap when the capacities are used above the threshold level $\widehat{c}$ in Eq. (6). This threshold can be interpreted as the capacity constraint level; (3) n.d means that no data is available for this period.

6 Appendix

Table 5: **Descriptive statistics**

		Mean	Median	Maximum	Minimum	Std. Dev.
France	CPI Inflation	2.10	1.89	6.26	-0.44	1.12
	Trend inflation	2.29	1.89	7.89	0.59	1.36
	Volatility inflation	0.46	0.13	3.29	0.02	0.72
	Output gap	-0.04	-0.22	2.23	-2.16	1.06
	Capacity utilization	85.15	85.75	90.90	71.30	3.60
Japan	CPI Inflation	0.51	0.14	3.54	-2.26	1.30
	Core inflation	0.61	0.28	3.22	-1.51	1.26
	Trend inflation	0.59	0.30	2.99	-1.09	1.12
	Volatility inflation	0.56	0.31	2.87	0.02	0.61
	Output gap	-0.01	-0.02	3.83	-6.12	1.64
	Capacity utilization	97.59	98.22	113.60	63.10	8.40
UK	CPI Inflation	2.98	2.44	8.06	0.61	1.78
	Trend inflation	2.98	2.48	7.14	0.97	1.63
	Volatility inflation	0.61	0.18	5.44	0.01	0.97
	Output gap	0.03	-0.09	3.88	-3.35	1.37
	Capacity utilization	80.75	81.40	85.80	70.00	3.02
USA	CPI Inflation	2.86	2.87	6.09	-1.61	1.22
	Core inflation	2.46	2.15	4.55	0.95	0.97
	Trend inflation	2.86	2.80	5.05	0.66	0.91
	Volatility inflation	0.78	0.37	7.08	0.01	1.25
	Output gap	0.06	-0.01	2.47	-3.46	1.18
	Capacity utilization	79.80	80.35	84.93	67.20	3.81

Table 6: **Phillips curve: Estimated output gap elasticities in the linear symmetric and asymmetric models for Core inflation**

	Symmetric	Asymmetric		Symmetry
	γ	γ^+	γ^-	Test
Japan	0.032 (1.58)	0.034 (1.11)	0.029 (1.08)	0.778
United States	0.033 (2.20)	0.045 (1.58)	0.023 (0.90)	0.630

Notes: IDEM table 2

Table 7: **Nonlinear models: Estimated elasticity at lower and higher inflation environments for core inflation.**

	Lower inflation γ	Higher inflation $\gamma+\gamma^*$	Threshold
Japan	-0.079 (-1.10)	0.050 (2.16)	0.0
US	0.001 0.65	0.060 2.75	2.4

Notes: IDEM table 3

Table 8: **Estimated elasticity of the positive and negative output gaps at lower and higher trend inflation for core inflation**

	Pos. elast. at lower inflation γ^+	Neg. elast. at lower inflation γ^-	Symmetry test	Threshold $\hat{c}$	Pos. elast. at higher inflation $\gamma^+ + \gamma^{+*}$	Neg. elast. at higher inflation $\gamma^- + \gamma^{-*}$	Symmetry test
Japan	-0.017 (-0.47)	0.067 (2.06)	0.042	0.0	0.178 (2.38)	-0.004 (-0.05)	0.002
US	-0.112 (-0.80)	0.013 (0.36)	0.766	2.2	0.92 (0.029)	0.099 (2.34)	0.021

Notes: IDEM table 3

Table 9: **Capacity constraint model for core inflation: Estimated elasticity of the positive and negative output gaps at lower and higher capacity utilization**

	Pos. elast. at lower capacity utilization γ^+	Neg. elast. at lower capacity utilization γ^-	Symmetry test	Threshold utilization $\hat{c}$	Pos. elast. at higher capacity $\gamma^+ + \gamma^{+*}$
Japan	0.033 (1.32)	0.021 (0.72)	0.741	108.2	-0.326 (-3.29)
US	*Linear*				

Notes: IDEM table 4

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